111th Congress, 2d Session – – – – – – – – – – – – – House Document 111–98

TOPEKA, KANSAS, FLOOD RISK MANAGEMENT PROJECT

COMMUNICATION

FROM

THE ASSISTANT SECRETARY OF THE ARMY, CIVIL WORKS, THE DEPARTMENT OF THE ARMY

TRANSMITTING

RECOMMENDING THE AUTHORIZATION OF THE PROPOSED TOPEKA, KANSAS, FLOOD RISK MANAGEMENT PROJECT

MARCH 23, 2010.—Referred to the Committee on Transportation and Infrastructure and ordered to be printed

U.S. GOVERNMENT PRINTING OFFICE
55–567 WASHINGTON : 2010

DEPARTMENT OF THE ARMY
OFFICE OF THE ASSISTANT SECRETARY
CIVIL WORKS
108 ARMY PENTAGON
WASHINGTON DC 20310-0108

MAR 05 2010

Honorable Nancy Pelosi
Speaker of the House
of Representatives
U.S. Capitol Building, Room H-232
Washington, D.C. 20515-0001

Dear Madam Speaker:

Section 216 of the 1970 Flood Control Act provides authority to the Secretary of the Army, acting through the Chief of Engineers, to review projects constructed by the Corps of Engineers and to report back to Congress with recommendations on the advisability of modifying these projects in the overall public interest. In response to this authority, and direction provided in the conference report of the Energy and Water Development Appropriations Act of 1994 (P.L. 103-126), the Secretary of the Army recommends authorization of the proposed Topeka, Kansas, Flood Risk Management project. The proposed project is described in the report of the Chief of Engineers, dated August 24, 2009, which includes other pertinent reports and documents. The views of the Department of Agriculture, Department of the Interior, and Department of Transportation, as well as those of the State of Kansas and City of Topeka, are set forth in the enclosed feasibility report and communications.

Federal involvement in Topeka levees was established by the Flood Control Act of 1936 and the first Federal units of the system were constructed in 1938-1939. Following the flood of 1951, work to expand the existing units along with construction of additional units was authorized by the Flood Control Act of 1954. Construction of the expanded system started in the mid 1960's and was completed in 1974. In 1992, hydraulic studies prepared by a consultant working for the Kansas Department of Transportation as part of a new highway bridge design questioned the capacity of the levees to provide the expected level of flood risk management. The City acted upon those concerns by requesting a study of the levees by the Corps of Engineers.

The levee system was analyzed for hydraulic (overtopping), structural, and geotechnical adequacy using the latest available data and modeling methods. The study found multiple structural and geotechnical features that do not meet currently acceptable levels of reliability to pass the design flood. The recommended improvements were reviewed as possible design deficiency corrections, but it was determined that they did not meet the applicable criteria. The need for reconstruction is based on the age of the project along with improvements to state of the art engineering practices since the project was originally constructed. The study area contains a population greater than 16,000;

significant residential, commercial, and industrial development valued at over $2.7 billion; and regionally and nationally significant utility and transportation infrastructure. Failure to implement reliability improvements will subject this area to a continued high risk of flooding in future years.

The recommended flood risk management project would modify the existing project to address levee under-seepage and improve the reliability of the system to provide increased flood risk management benefits to the City of Topeka, Kansas. The plan includes recommendations for modifications to four existing levee units within the Topeka Flood Risk management Project: the South Topeka Unit, the Oakland Unit, the North Topeka Unit and the Waterworks Unit. The construction features of the project include: addressing levee under-seepage concerns at the South Topeka Unit by installation of a control berm; modification of the Kansas Avenue Pump Station and three manholes; removal and replacement of approximately 2,000 linear feet of existing concrete floodwall on timber-pile foundations, and removal of 7.5 acres of woodland habitat and appropriate mitigation measures; control of an area of under-seepage at the Oakland Unit by installing a berm and a stability berm to improve the stability factor of safety of the existing floodwall, and structural modification of the East Oakland Pump Station to address uplift failure concerns; improvement of two areas of low under-seepage reliability at the North Topeka Unit by installing an under-seepage control berm and a series of pumped relief wells, and removal of a pump station that is no longer required and currently poses an uplift failure risk; and increases the reliability of an existing concrete floodwall at the Waterworks Unit by installing landside stability berms to protect the primary water source for the City of Topeka and surrounding communities. The levee improvements would provide greater than 90% reliability against damages from the base flood, which has a 1 percent chance of occurrence in any given year.

Based on October 2009 price levels, the total first cost for construction of these four measures as part of the recommended plan is estimated at $21,446,000, all for flood risk management. Under cost sharing specified by Section 103 of the Water Resources Development Act (WRDA) of 1986, Public Law 99-662, as amended by Section 202 of WRDA 1996, each measure would be cost shared 65 percent Federal and 35 percent non-Federal, resulting in an estimated Federal share of $13,940,000 and an estimated non-Federal share of $7,506,000, which includes a 5 percent cash contribution of $1,072,300, a credit toward lands, easements, rights-of-way, relocations and disposal areas (LERRD) of $1,305,000, and an additional cash contribution of $5,128,700. The total expected annual costs, based on a discount rate of 4.375 percent and a 50-year period of analysis, are $1,135,000, including operation, maintenance, repair, replacement, and rehabilitation. The expected annual benefits are estimated to be $15,109,000 with net annual benefits of $13,974,000. The benefit-cost ratio is approximately 13.3 to 1 for the new work. The proposed plan is the National Economic Development plan. The City of Topeka is legally capable of fulfilling the requirements for being the non-Federal sponsor.

The Office of Management and Budget (OMB) advises that there is no objection to the submission of the report to Congress and concludes that the report recommendation is consistent with the policy and programs of the President. A copy of its letter is enclosed. I am providing a copy of this transmittal and the OMB letter dated February 18, 2010 to the House Committee on Appropriations' Subcommittee on Energy and Water Development and the House Committee on Transportation and Infrastructure's Subcommittee on Water Resources and Environment.

Very truly yours,

Jo-Ellen Darcy
Assistant Secretary of the Army
(Civil Works)

Enclosures

9 Enclosures

1. Report of the Chief of Engineers, Aug 24, 2009
2. USDA letter, dated Mar 31, 2009
3. DOI letter, dated Apr 22, 2009
4. Kansas Dept. of Health and the Environment letter, dated Apr 13, 2009
5. City of Topeka letter, dated Dec 11, 2008
6. Finding of No Significant Impact, dated Dec 22, 2008
7. OMB Clearance letter, dated February 18, 2010
8. Supplemental Design Deficiency Decision Paper
9. Feasibility Report, Dec 2008

DEPARTMENT OF THE ARMY
OFFICE OF THE CHIEF OF ENGINEERS
WASHINGTON, D.C. 20314-1000

REPLY TO
ATTENTION OF:

CECW-PC (1105-2-10a) AUG 24 2009

SUBJECT: Topeka Flood Risk Management Project, Topeka, Kansas

THE SECRETARY OF THE ARMY

1. I submit for transmission to Congress my report on flood risk management improvements on the Kansas River in the vicinity of Topeka, Kansas. It is accompanied by the report of the district and division engineer. These reports are submitted pursuant to Section 216 of the Flood Control Act of 1970, authorizing me to determine whether any modifications to the local flood risk management projects are advisable in order to improve the reliability and performance of the existing levee system. The existing units were originally authorized by the Flood Control Acts of 1936 and 1954. Project construction of the levee system was completed in 1974. The study was requested by the local sponsors and the Congress of the United States. Preconstruction engineering and design activities, if funded, would be continued under the authority provided by the act cited above.

2. The reporting officers recommend authorizing a plan to reduce flood damages by construction of modifications to significantly improve reliability and performance of the levee system in the vicinity of Topeka, Kansas. The recommendation is supported by the non-Federal Sponsors, the City of Topeka, Kansas, and the North Topeka Drainage District. The recommended plan is the National Economic Development (NED) plan. All features are located in the State of Kansas. The plan includes recommendations for modifications to four existing levee units within the Topeka Flood Risk Management Project: the South Topeka Unit, the Oakland Unit, the North Topeka Unit, and the Waterworks Unit.

a. South Topeka Unit. Levee under-seepage concerns will be addressed by installation of a control berm. Structural strength and uplift concerns will be improved by modifications of the Kansas Avenue Pump Station and three manholes. Approximately 2,000 linear feet of existing concrete floodwall on timber-pile foundations will be removed and replaced with a new floodwall on concrete piles following the same alignment and to the same height as the existing floodwall. The work in this unit will result in the removal of 7.5 acres of woodland habitat and appropriate mitigation measures are included in the Recommended Plan.

b. Oakland Unit. An area of under-seepage concern will be controlled with a berm and a stability berm will be installed to improve the stability factor of safety of the existing floodwall. Structural modification of the East Oakland Pump Station will be implemented to address uplift failure concerns.

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c. North Topeka Unit: Two areas of low under-seepage reliability will be improved by installation of an under-seepage control berm and a series of pumped relief wells, respectively. One pump station that is no longer required, and currently poses an uplift failure risk, will be removed.

d. Waterworks Unit: Landside stability berms will be installed to increase the reliability of an existing concrete floodwall protecting the primary water source for the City of Topeka and surrounding communities.

3. Project costs are allocated to the Flood Risk Management purpose. Based on the October 2008 price levels, the estimated first cost to the plan is $21,157,000. In accordance with the cost sharing provisions of Section 103 of the Water Resources Development Act (WRDA) of 1986, as amended by Section 202 of WRDA 1996, the Federal share of the total project cost would be $13,752,000 (65 percent) and the non-Federal share would be $7,405,000. The non-Federal costs include the costs of lands, easements, rights-of-way, relocations, and dredged (LERRD) or excavated material disposal areas, estimated at $1,279,000.

4. Based on a 4.625 percent discount rate and a 50-year period of analysis, the total equivalent average annual costs of the project, including operation, maintenance, repair, replacement, and rehabilitation (OMRR&R), are estimated to be $1,168,000. The selected plan is estimated to be approximately 95 percent reliable in protecting the study area from the flood with a one percent chance of occurrence in any year (formerly referred to as the "100-year flood"). The selected plan would reduce average annual flood damages by about 67 percent and would leave average annual residual damages estimated at $7,438,000. Annual average economic benefits are estimated to be $15,428,000; net average annual benefits are $14,260,000. The system-wide benefit-to-cost ratio is 13.2 to 1. The selected plan is composed of three separable elements: South Topeka/Oakland, North Topeka, and Waterworks Units. Although South Topeka and Oakland are separate units, they are linked hydrologically and therefore combine to form a single, separable element. The South Topeka/Oakland Units would provide $4,014,000 in annual benefits with an annual cost of $996,000 for a benefit-to-cost ratio of 4.0. The North Topeka Unit would provide $11,408,000 in annual benefits with an annual cost of $169,000 for a benefit-to-cost ratio of 67.4. The Waterworks Unit would provide $6,000 in annual benefits with an annual cost of $3,000 for a benefit-to-cost ratio of 2.0.

5. The goals and objectives included in the Campaign Plan of the U.S. Army Corps of Engineers have been full integrated into the study process. The project effectively implements a comprehensive systems approach with full stakeholder participation. The project study has undergone rigorous quality control reviews in accordance with recent USACE guidance. These reviews included technical review of the engineering, economic, and environmental analyses by another USACE district. These reviews strengthened the recommendations of the reporting officers. The study report describes existing risks to the community, risks that will be reduced by the Recommended Plan, and residual risks that will remain from large, infrequent, flood events. In accordance with EC 1105-2-410, Appendix D, and future guidance that may be developed, a Safety Assurance Review (SAR) will be conducted prior to initiation of physical construction and periodically thereafter until construction activities are completed. The SAR

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will be conducted by an independent (outside of the Corps of Engineers) panel. Establishment of the panel will be in accordance with applicable guidance at the time of project construction.

6. The levee system consist of six separately authorized units and is a component of a larger system of levees and reservoirs that provides flood damage reduction benefits to the Kansas River basin. There are no significant direct or cumulative environmental impacts associated with the recommended plan, primarily because it sustains the existing levee rather than encumbering additional resources for a "new" project. The long-term environmental and cultural consequences of plan implementation are positive as the increased reliability of the units act to guard the social and environmental fabric that has developed within the study area. The plan also contributes to regional economic development.

7. Washington level review indicates that the project recommended by the reporting officers is technically sound, environmentally and socially acceptable, and economically justified. The plan complies with all essential elements of the U.S. Water Resources Council's Economic and Environmental Principles and Guidelines for Water and Land Related Resources Implementation Studies and complies with other administration and legislative policies and guidelines. Also, the views of interested parties, including Federal, State, and local agencies have been considered. Agency Technical Review was conducted for the study and all issues were satisfactorily resolved. This study was not required to conduct an Independent External Peer Review (IEPR). A safety assurance review (TYPE II IEPR) will be conducted during the design phase of the project.

8. I generally concur in the findings, conclusions, and recommendations of the reporting officers. Accordingly, I recommend that the plan to reduce flood damages for Topeka, Kansas, is authorized in accordance with the reporting officers' recommended plan at an estimated cost of $21,157,000 with such modifications as in the discretion of the Chief of Engineers may be advisable. My recommendation is subject to cost sharing, financing, and other applicable requirements of Federal and State laws and policies, including Section 103 of WRDA 1986, as amended, and in accordance with the following required items of cooperation that the non-Federal sponsor shall, prior to project implementation, agree to perform:

a. Provide a minimum of 35 percent, but not to exceed 50 percent of total project costs as further specified below:

    1. Provide 25 percent of design costs in accordance with the terms of a design agreement entered into prior to commencement of design work for the project;

    2. Provide, during the first year of construction, any additional funds necessary to pay the full non-Federal share of design costs;

    3. Provide, during construction, a contribution of funds equal to 5 percent of total project costs;

4. Provide all lands, easements, and rights-of-way, including those required for relocations, the borrowing of material, and the disposal of dredged or excavated material; perform or ensure the performance of all relocations; and construct all improvements required on lands, easements, and rights-of-way to enable the disposal of dredged or excavated material all as determined by the Government to be required or to be necessary for the construction, operation, and maintenance of the project;

5. Provide, during construction, any additional funds necessary to make its total contribution equal to at least 35 percent of total project costs;

b. Shall not use funds from other Federal programs, including any non-Federal contribution required as a matching share therefore, to meet any of the non-Federal obligations for the project unless the Federal agency providing the Federal portion of such funds verifies in writing that expenditure of such funds for such purpose is authorized;

c. Not less than once each year, inform affected interests of the extent of protection afforded by the project;

d. Agree to participate in and comply with applicable Federal floodplain management and flood insurance programs;

e. Comply with Section 402 of the Water Resources Development Act of 1986, as amended (33 U.S.C. 701b-12), which requires a non-Federal interest to prepare a floodplain management plan within one year after the date of signing a project cooperation agreement, and to implement such plan not later than one year after completion of construction of the project;

f. Publicize floodplain information in the area concerned and provide this information to zoning and other regulatory agencies for their use in adopting regulations, or taking other actions, to prevent unwise future development and to ensure compatibility with protection levels provided by the project;

g. Prevent obstructions or encroachments on the project (including prescribing and enforcing regulations to prevent such obstructions or encroachments) such as any new developments on project lands, easements, and rights-of-way or the addition of facilities which might reduce the level of protection the project affords, hinder operation and maintenance of the project, or interfere with the project's proper function;

h. Comply with all applicable provisions of the Uniform Relocation Assistance and Real Property Acquisition Policies Act of 1970, Public Law 91-646, as amended (42 U.S.C. 4601-4655), and the Uniform Regulations contained in 49 CFR Part 24, in acquiring lands, easements, and rights-of-way required for construction, operation, and maintenance of the project, including those necessary for relocations, the borrowing of materials, or the disposal of dredged or excavated material; and inform all affected

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SUBJECT: Topeka Flood Risk Management Project, Topeka, Kansas

persons of applicable benefits, policies, and procedures in connection with said Act;

i. For so long as the project remains authorized, operate, maintain, repair, rehabilitate, and replace the project, or functional portions of the project, including any mitigation features, at no cost to the Federal Government, in a manner compatible with the project's authorized purposes and in accordance with applicable Federal and State laws and regulations and any specific directions prescribed by the Federal Government;

j. Give the Federal Government a right to enter, at reasonable times and in a reasonable manner, upon property that the non-Federal sponsor owns or controls for access to the project for the purpose of completing, inspecting, operating, maintaining, repairing, rehabilitating, or replacing the project;

k. Hold and save the United States free from all damages arising from the construction, operation, maintenance, repair, rehabilitation, and replacement of the project and any betterments, except for damages due to the fault or negligence of the United States or its contractors;

l. Keep and maintain books, records, documents, or other evidence pertaining to costs and expenses incurred pursuant to the project, for a minimum of 3 years after completion of the accounting for which such books, records, documents, or other evidence are required, to the extent and in such detail as will properly reflect total project costs, and in accordance with the standards for financial management systems set forth in the Uniform Administrative Requirements for Grants and Cooperative Agreements to State and Local Governments at 32 Code of Federal Regulations (CFR) Section 33.20;

m. Comply with all applicable Federal and State laws and regulations, including, but not limited to: Section 601 of the Civil Rights Act of 1964, Public Law 88-352 (42 U.S.C. 2000d) and Department of Defense Directive 5500.11 issued pursuant thereto; Army Regulation 600-7, entitled "Nondiscrimination on the Basis of Handicap in Programs and Activities Assisted or Conducted by the Department of the Army"; and all applicable Federal labor standards requirements including, but not limited to, 40 U.S.C. 3141- 3148 and 40 U.S.C. 3701 – 3708 (revising, codifying and enacting without substantial change the provisions of the Davis-Bacon Act (formerly 40 U.S.C. 276a *et seq.*), the Contract Work Hours and Safety Standards Act (formerly 40 U.S.C. 327 *et seq.*) and the Copeland Anti-Kickback Act (formerly 40 U.S.C. 276c *et seq.*);

n. Perform, or ensure performance of, any investigations for hazardous substances that are determined necessary to identify the existence and extent of any hazardous substances regulated under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), Public Law 96-510, as amended (42 U.S.C. 9601-9675), that may exist in, on, or under lands, easements, or rights-of-way that the Federal Government determines to be required for construction, operation, and maintenance of the project. However, for lands that the Federal Government determines to be subject to the navigation servitude, only the Federal Government shall perform such investigations

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SUBJECT: Topeka Flood Risk Management Project, Topeka, Kansas

unless the Federal Government provides the non-Federal sponsor with prior specific written direction, in which case the non-Federal sponsor shall perform such investigations in accordance with such written direction;

o. Assume, as between the Federal Government and the non-Federal sponsor, complete financial responsibility for all necessary cleanup and response costs of any hazardous substances regulated under CERCLA that are located in, on, or under lands, easements, or rights-of-way that the Federal Government determines to be required for construction, operation, and maintenance of the project;

p. Agree, as between the Federal Government and the non-Federal sponsor, that the non-Federal sponsor shall be considered the operator of the project for the purpose of CERCLA liability, and to the maximum extent practicable, operate, maintain, repair, rehabilitate, and replace the project in a manner that will not cause liability to arise under CERCLA; and

q. Comply with Section 221 of Public Law 91-611, Flood Control Act of 1970, as amended (42 U.S.C. 1962d-5b), and Section 103(j) of the Water Resources Development Act of 1986, Public Law 99-662, as amended (33 U.S.C. 2213(j)), which provides that the Secretary of the Army shall not commence the construction of any water resources project or separable element thereof, until each non-Federal interest has entered into a written agreement to furnish its required cooperation for the project or separable element.

9. The recommendation contained herein reflects the information available at this time and current Departmental policies governing formulation of individual projects. It does not reflect program and budgeting priorities inherent in the formulation of a national civil works construction program or the perspective of higher review levels within the executive branch. Consequently, the recommendation may be modified before they are transmitted to the Congress as proposals for authorization and implementation funding. However, prior to transmittal to the Congress, the sponsors, the State, interested Federal agencies, and other parties will be advised of any significant modifications and will be afforded an opportunity to comment further.

R. L. VAN ANTWERP
Lieutenant General, US Army
Chief of Engineers

United States Department of Agriculture

NRCS

Natural Resources Conservation Service
760 South Broadway
Salina, Kansas 67401-4604

Phone: 785-823-4500
FAX: 785-823-4540
www.ks.nrcs.usda.gov

March 31, 2009

Mr. Theodore A. Brown
Headquarters, U.S. Army Corps of Engineers
CECW-P (SA)
7701 Telegraph Road
Alexandria, Virginia 22315-3860

Dear Mr. Brown:

As requested and in accordance with established coordination procedures on water resources reports, the Kansas Natural Resources Conservation Service (NRCS) has reviewed the Topeka Kansas Flood Risk Management Project Feasibility Study Report and Environmental Assessment (EA) as requested.

In past reviews, NRCS has provided comments related to Food Security Act compliance and Form AD-1006, Farmland Conversion Impact Rating. These assessments and documents are included in your December 2008 document as part of EA Appendix B and Public Involvement Appendix B.

The Kansas NRCS has no changes or amendments to offer and I concur with the U. S. Army Corps of Engineers proposed project report and EA.

If you have any questions, please contact Terry M. Conway, State Resource Conservationist, at 785-823-4547 or by e-mail at terry.conway@ks.usda.gov.

Sincerely,

James J. Krueger ACTING FOR
ERIC B. BANKS
State Conservationist

cc:
Terry M. Conway, State Resource Conservationist, NRCS, Salina, Kansas
Kenneth A. Kuiper, State Biologist, NRCS, Salina, Kansas
Jeffrey L. Gross, Assistant State Conservationist, NRCS, Salina, Kansas

United States Department of the Interior

OFFICE OF THE SECRETARY
Washington, D.C. 20240

9043.1
PEP/NRM

APR 22 2009

ER 09/337

Mr. Theodore A. Brown, P.E.
Chief, Planning and Policy Division
Directorate of Civil Works
Headquarters
U.S. Army Corps of Engineers
CECW-P (SA)
7701 Telegraph Road
Alexandria, VA 22315-3860

RE: Thirty–Day Review of Chief of Engineers Proposed Report, Topeka Flood Risk Management Project, Topeka, Kansas

Dear Mr. Brown:

The U. S. Department of the Interior (Department) has reviewed the U. S. Army Corps of Engineers (USACE), Chief of Engineers Proposed Report on the Topeka Flood Risk Management Project, Topeka, Kansas.

The Department does not object to the proposed project. Our U.S. Fish and Wildlife Service (USFWS), Kansas Ecological Services Field Office, previously prepared a Fish and Wildlife Coordination Act (FWCA) report for the subject project and it appears that all of their concerns and recommendations have been addressed or are being implemented. If you have any questions in regards to the FWCA report, please contact Mr. Michael J. LeValley, USFWS, Kansas Ecological Services Field Office at 785-539-3474, Ext. 105.

We appreciate the opportunity to review the Chief's Proposed Report and supporting documents.

Sincerely,

Willie R. Taylor

Willie R. Taylor, Director
Office of Environmental Policy
and Compliance

KANSAS

DEPARTMENT OF HEALTH
AND ENVIRONMENT
Division of Environment

Kathleen Sebelius, Governor
Roderick L. Bremby, Secretary

www.kdheks.gov

April 13, 2009

Theodore A. Brown, P.E.
Headquarters, U.S. Army Corps
CECW-P (SA)
7701 Telegraph Road
Alexandria, VA 22315-3860

Re: Topeka Flood Risk Management Project, Topeka, KS

Dear Mr. Brown:

Mr. Donald Carlson, Bureau of Water has offered the following comments. I have no objection to the proposal but offer the following comment for review and consideration:

Any construction activity which disturbs one acre or more is required to file a National Pollutant Discharge Elimination System (NPDES) permit application for stormwater runoff resulting from construction activities. The project owner (party responsible for the project) must obtain authorization from KDHE to discharge stormwater runoff associated with construction activities prior to commencing construction. The Kansas construction stormwater general permit, a Notice of Intent (application form), a frequently asked questions file and supplemental materials are on-line on the KDHE Stormwater Program webpage at www.kdhe.state.ks.us/stormwater.
Answers to questions regarding or additional information concerning construction stormwater permitting requirements can be obtained by calling (785) 296-5549.

Sincerely,

Donna Fisher
Division of Environment
Director's Office

DC/df

CURTIS STATE OFFICE BUILDING, 1000 SW JACKSON ST., STE. 400, TOPEKA, KS 66612-1367
Voice 785-296-1535 Fax 785-296-8464

KANSAS

Kathleen Sebelius, Governor
Roderick L. Bremby, Secretary

DEPARTMENT OF HEALTH
AND ENVIRONMENT

www.kdheks.gov

Division of Environment

Comments by: KDHE

Transmittal Date: April 15, 2009

This form provides notification and the opportunity for your agency to review and comments on this proposed project as required by Executive Order 12372. Review Agency, please complete Parts II and III as appropriate and return to contact person listed below. Your prompt response will be appreciated.

RETURN TO: Theodore A. Brown, P.E.
Headquarters, U.S. Army Corps of Engineers
CECW-P (SA)
7701 Telegraph Road
Alexandria, VA 22315-3860

PART I **REVIEW AGENCIES/COMMISSION**

___Aging	___Education	___State Forester
___Agriculture	___Geological Survey, KS	___Transportation
___Biological Survey	_X_Health & Environment	___Water Office, KS
___Conservation Commission	___Historical Society	___Wildlife & Parks
___Corporation Commission	___Social & Rehabilitation	___Commerce

PART II **AGENCY REVIEW COMMENTS**

COMMENTS: (Attach additional sheet if necessary: Topeka Flood Risk Management Project, Topeka, KS
Please see the enclosed comments submitted by Glenna Drake and Don Carlson.

PART III
RECOMMENDED ACTION COMMENTS

_X_Clearance of the project should be granted.

___Clearance of the project should not be granted.

___Clearance of the project should be delayed until the issues or questions above have been clarified.

___Request a State Process Recommendation in concurrence with the above comments.

___ Clearance of the project should not be delayed but the Applicant should (in the final application) address and clarify the question or concerns indicated above.

___Request the opportunity to review final application prior to submission to the federal funding agency.

DIVISIONS/ AGENCY/ COMMISSION

Reviewer's Name: John W. Mitchell Date: April 15, 2009

Organization: John W. Mitchell, Director, Division of Environment
Kansas Department of Health & Environment

CURTIS STATE OFFICE BUILDING, 1000 SW JACKSON ST., STE. 400, TOPEKA, KS 66612-1367
Voice 785-296-1535 Fax 785-296-8464

MEMORANDUM

To: Donna Fisher

From: Glenna Drake
BER/Remedial Section

CC: Rick Bean, BER

Date: April 3, 2009

Re: Agency Review - Topeka Flood Risk Management Project

Approved: Yes

Comments: Note that groundwater in the area may be contaminated with volatile organic compounds from area sites. The following Identified Sites are located within one mile of the river near the project areas.

Project Code	Site Name	Status	Contamination Type
C408970885	SALISBURY SUPPLY COMPANY	Resolved	VOC
C408900065	CROCO ROAD SITE(SEWARD,KINCAID ROAD)	Active	VOC
C408970154	SCOTCH CLEANERS - TOPEKA	Active	VOC, Other (see Site Narrative)
C408971337	TOPEKA PARK PROJECT -- BTA	Resolved	Heavy Metal
C408971643	ONEOK FMGP - TOPEKA	Active	
C408971297	1ST & MONROE, TOPEKA	Active	VOC
C408970776	DG'S RADIATOR	Active	Heavy Metal
C408900026	HYDRO-FLEX CORP., INC.	Resolved	Heavy Metal
C408970728	ELT TOPEKA, LLC	Active	VOC
C408971976	TOPEKA RIVERFRONT DEVELOPMENT -- BTA	Active	
C408970230	BNSF - MAGNUS METALS SITE	Resolved with Restrictions	Heavy Metal
C408900058	MIDWEST MACHINE WORKS	Resolved with Restrictions	VOC
C408900027	INDUSTRIAL CHROME, INC.	Active	Heavy Metal
C408971651	JEFFERSON STREET DRUMS	Resolved	Refined Petroleum, SVOC, VOC
C408903035	ARMCO - TOPEKA	Active	Heavy Metal, Refined Petroleum, VOC
C408971975	EBA BUILDING -- BTA	Active	
C408971557	DEGGINGER'S FOUNDRY	Active	Heavy Metal
C408970958	BNSF - TOPEKA SHOPS	Active	Heavy Metal, Refined Petroleum
C408903009	SEWARD & GOLDEN, TOPEKA	Active	Heavy Metal, Refined Petroleum, SVOC

More information about these sites can be viewed on our Identified Sites List website at http://kensas.kdhe.state.ks.us/pls/certop/ISearch.

CITY OF TOPEKA

Norton N. Bonaparte, Jr.
City Manager and CEO
215 S.E. 7th St.
Topeka, KS 66603
(785) 368-3725
(785) 368-3909 fax

December 11, 2008

Department of the Army
US Army Corps of Engineers
Kansas City District

Re: Topeka, Kansas Local Flood Protection Project

As the local sponsor for the Topeka Levee Project. the City of Topeka recognizes and affirms its continued support of the US Army Corps of Engineers' project as it moves forward to the design and construction phase. The City of Topeka has been involved with the project since the Feasibility Cost Sharing Agreement was signed in 1998. As the project progresses the City of Topeka will continue to partner with the non-Federal sponsors; the North Topeka Drainage District and Shawnee County.

The City of Topeka is aware of the requirements for participation in the project, including the financial commitment for design and construction. As the local sponsor, the City of Topeka and its partners will provide 35% of the projects cost, to include land, easements and right-of-ways. Additional local sponsor responsibilities have been discussed and are acceptable to the City of Topeka for participation in the project based on the Feasibility Study and Environmental Assessment.

Upon acceptance by the Civil Works Review Board, the City of Topeka requests the project be submitted for funding in the next Water Resources Development Act.

Sincerely,

Norton N. Bonaparte, Jr.
City Manager and CEO

NON-FEDERAL SPONSOR'S SELF-CERTIFICATION OF FINANCIAL CAPABILITY FOR THE TOPEKA, KANSAS LOCAL FLOOD PROTECTION PROJECT

I, Jim Langford, do hereby certify that I am the Director of Budget and Financial Services of the City of Topeka, Kansas; that I am aware of the financial obligations of the Non-Federal Sponsor for the Topeka, Kansas Local Flood Protection Project; and that the Non-Federal Sponsor will have the financial capability to satisfy the Non-Federal Sponsor's obligations for that project. I understand that the Federal Government's acceptance of this self-certification shall not be construed as obligating either the Federal Government or the Non-Federal Sponsor to implement a project.

IN WITNESS WHEREOF, I have made and executed this certification this 25th day of November, 2008.

BY: [signature]

TITLE: Director of Budget and Financial Services

DATE: 11-25-08

NOTARY PUBLIC, State of Kansas
KIMBERLY FULGHUM
My Appt. Exp. 9-22-12

[signature]

DEPARTMENT OF THE ARMY
KANSAS CITY DISTRICT, CORPS OF ENGINEERS
700 FEDERAL BUILDING
KANSAS CITY, MISSOURI 64106-2896

Finding of No Significant Impact

CITY OF TOPEKA
FLOOD RISK MANAGEMENT PROJECT
TOPEKA, KANSAS

SUMMARY

The U.S. Army Corps of Engineers, Kansas City District (USACE), at the request and with the cooperation of the City of Topeka (local sponsor), proposes to provide flood risk management for the City of Topeka, Kansas. Specifically, this project will correct the existing geotechnical and structural weaknesses and increase the reliability of the flood risk management system for the City of Topeka. The Topeka flood risk management levee system is located in Shawnee County, Topeka, Kansas at the confluence of Soldier Creek and the Kansas River, and is a unit of the Kansas River Basin System. The levee units in Topeka that are proposed for modifications in this plan are: South Topeka Unit, Waterworks Unit, Oakland Unit, and North Topeka Unit. Proposed improvements include the installation of landside underseepage berms, heel extensions, fill behind floodwalls, new pressure relief wells, a wall stiffener on Kansas Avenue Pump Station, stability berms, removal of the Fairchild Pump Station, replacement of a section of the floodwall, and replacement of floodwall gatewells and sluice gates. The Auburndale and Soldier Creek units were studied for deficiencies in the early phase of the project. However, there were no deficiencies found; therefore, no work has been proposed for the Auburndale and Soldier Creek units. The authority for the study of this project is provided by Section 216 of the 1970 Flood Control Act.

PUBLIC INVOLVEMENT

A public meeting was held on 14 November 1996 at the Garfield Community Center in Topeka, Kansas. The purpose was to inform the public of the proposed study and to get feedback on the alternatives proposed in the study. Comments were addressed by USACE representatives and a record of these comments was included in the 1997 Reconnaissance Report. A second public meeting was conducted October 22, 2008 during the 30-day public review period of the Draft EA and Feasibility Report. The Draft Report was mailed to Federal and state agencies, local media, residents within the affected community and other interested parties. All comments received during the public review period were addressed. Comments were received during the public review period from the following entities: City of Topeka, Friends of the Kaw, North Topeka Drainage District, U.S. Fish & Wildlife Service, Kansas State Historical Society, Natural Resources Conservation Service, and Federal Aviation Administration. There were no comments that required reevaluation of the alternatives, identification of a new recommended plan, or a critical change to impact analysis. Copies of the comment letters and USACE responses can be found in the Appendix B of the Main Feasibility Report.

ALTERNATIVES

A total of four alternatives were evaluated in terms of individual and cumulative effects for the proposed project, which are Alternative 1-Recommended Plan, Alternative 2-Pressure Relief Wells, Alternative 3- Commercial Fill, Alternative 4- No-Action. These are addressed below.

Alternative 1- Recommended Plan: The Recommended Plan consists of the preferred alternatives for each levee unit and these are listed below. In addition, the Recommended Plan will require fill from two borrow areas. Fill will be obtained from two agricultural areas within the Oakland and South Topeka units. Approximately 19.3 acres will be excavated at the Oakland borrow site and 27.3 acres at the South Topeka borrow site.

Oakland Unit: A new earthen underseepage berm will be installed landward of the levee behind the water treatment plant. The berm will be placed along the toe of the levee for about 1,600 linear feet at a height of 6.5 feet, sloping to three feet thick at a distance of about 240 feet outward from the levee. At stations 75+50 and 220+00, heel extensions will be added to the manholes and to the East Oakland Pump Station to mitigate uplift pressures. Two feet of additional fill will be required behind the Shunganunga Creek floodwall to meet sliding stability requirements. About 388 cubic yards of fill will be used and will extend about five feet from the floodwall centerline and taper at a 1:3 slope.

North Topeka Unit: A new earthen underseepage berm will be installed landward of the levee from station 165+00 to 189+00. The berm will be placed along the levee toe for 2,400 linear feet. About 122,250 cubic yards of fill will be used for construction of the berm. New pressure relief wells will be installed along the levee for about 400 linear feet between stations 246+00 and 250+00. Six wells will be placed 75 feet apart and 75 feet deep. The existing Fairchild Pump Station will be removed. However, the below ground level structures will be left in place, filled with concrete-like material, and then covered with soil.

South Topeka Unit: A new earthen underseepage berm will be installed landward of the levee from station 22+00 to 48+00. The berm will be installed at the toe of the levee for about 2,200 linear feet. About 48,150 cubic yards of fill will be used for the construction of the berm. At station 74+41 to 93+86, the existing South Topeka floodwall will be removed and replaced. The new floodwall will be concrete and built along the existing wall alignment to the same length and height. Also, a working platform will be constructed on the bank of the river. This platform is not likely to extend into or impact the river itself. Access to this area will be from the landside through the first removed section of the existing wall. The existing gate wells and sluice gates will be replaced as part of the floodwall replacement. Three existing manholes will require heel extensions to mitigate uplift pressures. In addition, a wall stiffener at Kansas Avenue Pump Station will be installed to meet the required strength factor for safety.

Waterworks Unit: Approximately two feet of additional fill will be placed behind the floodwall to meet sliding stability requirements. About 1,272 linear feet of fill will be placed along the tow of the wall to five feet out from the floodwall centerline and tapered on a 1 to 3 slope. At stations 13+07 and 15+95, two feet of backfill will be placed behind the stop-log gap sidewalls to address sliding stability. A total of 958 cubic yards of fill will be used to meet sliding stability requirements.

Alternative 2 - Pressure Relief Wells: Under this alternative, the proposed actions will be the same as those described in the Recommended Plan, except pressure relief wells will be installed in place of the proposed underseepage berms on the North Topeka, South Topeka and Oakland Units. The relief wells will be placed landward and within the maintained right-of-way of the levee. The relief well system provides the reliability required with minor, negligible environmental impacts. With the use of pressure relief wells, the amount of borrow material required will be reduced. Both the Waterworks and the Oakland stability berms will be supplied by a single borrow cell. However, this alternative will be more expensive than the recommended plan due to its associated annual operation and maintenance costs.

Alternative 3 - Commercial Fill: Under this alternative, the proposed actions will be the same as those described in the Recommended Plan except under this alternative, borrow fill will obtained from a commercial source. Commercially obtained fill will likely come from permitted dredging operations in the Kansas River. The estimated amount of commercial fill needed is about 281,000 cubic yards. Several large dump trucks will be used to haul the fill from the commercial dredge site to the project area. This option was not selected as part of the recommended plan because there is a risk that this option may not be available at the time of construction. However, if the total amount of fill needed cannot be obtained from the proposed borrow sites at the time of project construction; then commercial fill will be obtained if available.

Alternative 4 - No-Action Alternative: Under the No-Action Alternative, the proposed project will not be constructed by the USACE. Existing weaknesses in the levees system would be allowed to continue and the risks to public safety and community infrastructure from potential flooding would remain.

SUMMARY OF ENVIRONMENTAL IMPACTS

The recommended plan has relatively minor impacts to the natural environment with overall positive benefits to the socio-economic environment. Impacts to the natural environment are minor because the project is located within a previously disturbed environment that is highly industrial and urbanized. The recommended plan would not result in any impacts to Federally-listed threatened or endangered species or their habitat. The proposed action would have no impact to sites listed on or eligible for inclusion on the National Register of Historic Places. Temporary, short-term construction impacts to natural and human environment would be related to noise, visual disturbance. The adverse impacts to the natural environment are minor and include the loss of about seven and one-half acres of woodland from the proposed construction of the underseepage berm at South Topeka unit. These impacts will be compensated through replanting and establishment of a natural area within a designated mitigation site. In addition, for borrow excavations from the two agricultural areas, appropriate measures will be taken to allow these areas to return to agricultural use after borrow and construction operations. For borrow operations, the top one foot of soil will be removed, stockpiled, and returned to the site after completion of excavation. In addition, excavation depths in agricultural areas will be kept to a minimum (four feet or less) to reduce impacts to field drainage and to allow farming operations to resume after construction is complete. Also, borrow cells will be excavated after the crops are harvested to avoid crop loss.

MITIGATION

Compensatory mitigation will include establishing a 15-acre planting regime within the South Topeka and North Topeka unit areas. Native tree and grass plantings will be implemented concurrently and/or following project construction. Additional mitigation measures will include the avoidance of construction activities in woodland areas during the migratory bird nesting season of April 1 to July 15. In addition, to minimize risk associated with HTRW contamination from proposed activities, any soil removed from a site associated with the levee work or borrow areas will be analyzed to ensure proper disposal.

CONCLUSION

Based on the environmental assessment, it has been determined that the Recommended Plan will not have any substantial adverse impacts on the natural and human environment. All practicable means to avoid and/or minimize adverse environmental effects have been incorporated into the Recommended Plan. Therefore, the Recommended Plan is the environmentally preferable alternative. Further, the USACE has determined that construction of the proposed project would not significantly impact the human environment and, therefore, an Environmental Impact Statement will not be prepared.

Date: 22 DEC 08

Roger A. Wilson, Jr.
Colonel, Corps of Engineers
District Commander

02/19/2010 12:18 FAX 202 395 4817 OMB WATER & POWER BRANCH 002

EXECUTIVE OFFICE OF THE PRESIDENT
OFFICE OF MANAGEMENT AND BUDGET
WASHINGTON, D.C. 20503

February 18, 2010

The Honorable Jo Ellen Darcy
Assistant Secretary of the Army (Civil Works)
108 Army Pentagon
Washington D.C. 20310-0108

Dear Ms. Darcy:

As required by Executive Order 12322, the Office of Management and Budget completed its review, on February 9, 2010, of your recommendation for the Topeka, Kansas flood risk management project.

Based on our review of the project, we concluded that your recommendation is consistent with the policy and programs of the President. The Office of Management and Budget does not object to you submitting this report to Congress for authorization.

Sincerely,

Richard A. Mertens
Deputy Associate Director
Energy, Science, and Water

HQUSACE Analysis of Proposed Topeka Design Deficiency
16 August 2007

Engineering Regulation 1165-2-119: There is no conclusive analysis provided to justify design deficiency for Topeka, Kansas, Flood Damage Reduction Feasibility Study, Determination of Design Deficiency. There is not enough information provided to recommend this as design deficiency. One has to demonstrate an application of an unproven innovative technology that did not perform; something that was designed and constructed in way that made it impossible to maintain; a structure such as a gate that just does not work; or a documented case of a clear miscalculation or poor construction.

The deficiencies are applicable to many aged projects. How do you demonstrate conditions have not changed? The judgments applied and construction methods used were conventional. A change in the assumptions to compute baseline conditions is not a design deficiency, but a change condition and/or assumption per ER 1105-2-100 and requires a post authorization study.

Design Discharge: The information provided pertaining to the design discharge and related design stage/freeboard is not sufficient to justify a design deficiency. Shifts in rating curves are normal for alluvial rivers and would not constitute a design deficiency. A shift of 0.5 feet is certainly within expected values. It should be noted that the use of freeboard as a design criteria was eliminated in 1997. If the levee were being evaluated today, the top of levee would be based on a 90% assurance value for the design discharge and the current estimated "freeboard" may meet that criteria. CECW-CE is certain that a high percentage of our projects would be deficient if USACE re-evaluated them based on updated rating curves. It was not common engineering practice to incorporate movable bed/ratings shift as a design parameter unless there was geomorphic evidence of continuing trends. CECW-CE does not see how this constitutes a design deficiency.

Design Discharge and De-Authorized Projects: Based on the information provided, it appears that there may have been a mistake made in establishing the base conditions for basin hydrology. The information provided is insufficient to identify how the determination of the base conditions was made. USACE normally only considers existing projects and/or authorized projects to be in place as part of the base conditions. Otherwise, this constitutes an assumption that has changed and would require a post authorization study in accordance with ER 1105-2-100.

Existing Levee Units:

South Topeka, Oakland, North Topeka Units: The write-up points out several deficiencies but does not note whether these deficiencies were treated as design deficiencies in previous repairs. These deficiencies are just as applicable to the aging of an old system.

Waterworks Units: Based on the information presented form the current analysis, it appears that the North Topeka levee segment was added to the system and resulted in a restriction of the floodway. There is not enough information provided for pre and post North Topeka hydraulic modeling results. CECW-CE could not make a determination of design deficiency based on this document. In order to establish a design deficiency there would have to be some demonstration through comparisons of H&H models that the levee was added without considering the impact to the floodwall.

NOTICE

TOPEKA, KANSAS, FLOOD RISK MANAGEMENT PROJECT

Since Congress has authorized the project, the Army Corps of Engineers does not request that the report be printed. If there are any questions about this, please call Chuck Moeslein of the LRD-RIT at Corps Headquarters. You can reach Chuck Moeslein at (202) 761-4616.

US Army Corps
of Engineers
Kansas City District

TOPEKA, KANSAS
FLOOD RISK MANAGEMENT PROJECT

FEASIBILITY STUDY REPORT
AND
ENVIRONMENTAL ASSESSMENT
WITH APPENDICES

DECEMBER 2008

BUILDING STRONG℠

TOPEKA, KANSAS
FLOOD RISK MANGEMENT PROJECT
FEASIBILITY STUDY REPORT AND ENVIRONMENTAL ASSESSMENT

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Syllabus

Flood risk in the metropolitan area of Topeka, Kansas, the state capitol, is managed by a Federal levee system which began construction in the late 1930's and was expanded in the mid-1960s. This system consists of six separately authorized units and is a component of a larger system of levees and reservoirs that provides flood risk management benefits to the Kansas River basin. The study area includes significant industrial, commercial, and residential areas, public facilities and transportation infrastructure, and agricultural property.

While this flood risk management system is designated as a Federal project, it has long been turned over to the local sponsors for operation and maintenance. The Corps of Engineers continues to conduct regular inspections and technical review of significant modifications to the system. The non-Federal sponsors are the City of Topeka, Kansas, and the North Topeka Drainage District.

In the early 1990's, studies conducted by a consultant working for the Kansas State Department of Transportation as part of a new highway crossing of the river and the levee raised concern that the levees may not be high enough to provide the intended level of flood risk management. By letter in March, 1992, the City of Topeka requested the U.S. Army Corps of Engineers to conduct a Reconnaissance Study to review the existing levees. The Reconnaissance Study was completed in September 1997 and concluded that there was sufficient Federal interest to proceed to the Feasibility Study phase. The Feasibility Study began in 1998 to evaluate the existing project and determine alternatives for possible improvement. Section 216 of the 1970 Flood Control Act provided the study authority.

The feasibility study evaluated various alternatives including the no-action plan using a risk-based analysis. During the analysis, it was determined that the levee height was sufficient, but that there was a risk of levee failure at less than the design flood due to structural and geotechnical concerns. The recommended plan includes corrective action to address identified weaknesses in the geotechnical and structural features of the existing project units. The levee alignment will remain the same. This plan will have minimal local disruption to both the populace and the environment. Potential borrow areas have been identified close to the existing levee.

The recommended plan is the National Economic Development (NED) plan which maximizes the net economic benefits of the project. The NED plan is also the locally preferred plan. There are no significant direct or cumulative environmental impacts of the NED plan primarily because it sustains the existing levee rather then encumbering additional resources for a "new" project. The long-term environmental and cultural consequences of plan implementation are positive as the increased reliability of the units act to guard the social and environmental fabric that has developed within the study area.

The total estimated implementation cost of the NED plan is $21,157,000 (Oct 2008 price level) shared between the Corps and two non-Federal levee sponsors. The average annual costs of the NED plan are $1,168,100; benefits, $15,427,600; net benefits, $14,259,500. The resulting benefit to cost ratio is 13.2 to 1. The sponsors would receive credit for any necessary lands, easements, rights-of-way, relocations or disposal areas (LERRD). The total Federal share of the plan is $13,752,050 or 65 percent of the total cost and the sponsors share is $7,404,950 or 35 percent. The sponsors will take ownership of project improvements and assume all operation, maintenance, repair, and replacement costs of the completed works.

TOPEKA, KANSAS, LOCAL PROTECTION PROJECT
FEASIBILITY REPORT AND ENVIRONMENTAL ASSESSMENT

I. Introduction

The Topeka, Kansas, Local Flood Protection Project (the Project) is a part of the general comprehensive plan for flood risk management and other purposes in the Missouri River Basin. The original project plan was included in House Document 195, 73rd Congress, 2nd Session (The Kansas River "308" Report) and was authorized by the Flood Control Act approved 22 June 1936 (Public Law 738, 74th Congress). The authorized plan provided for the construction of flood risk management works for South Topeka, North Topeka, and the municipal waterworks. As detailed in the Definite Project Report of 27 October 1936, modifications were made to the authorized plan to reflect more recent studies, and a partial implementation plan was proposed for South Topeka to meet the funding limitations of the 1936 Act. Construction of the partial South Topeka plan and the Waterworks portion was completed in 1939. The North Topeka levee construction was postponed in 1940 when local interests requested modifications of the proposed levee system to include a larger area.

Additional studies undertaken in the Kansas River Basin resulted in the development of the project outlined in H. Doc. 642, 81st Congress, 2nd Session, "Kansas River and Tributaries, Colorado, Nebraska, and Kansas", published 13 July 1950. This plan proposed the expansion of the North Topeka levee to encompass a larger area and also included the cutoff and diversion of several local tributaries, including Soldier Creek. Prior to authorization of this plan, the July 1951 flood necessitated additional modifications, including the completion of those portions of the South Topeka unit not constructed in the 1930's. These proposed modifications were outlined during Committee Hearings in May 1954, and the modified plan was authorized by the Flood Control Act approved 2 September 1954 (P.L. 780, 83rd Congress).

Final construction and modification of all project units and appurtenant features was completed in 1973. The completed Project consisted of six levee units along the Kansas River and its tributaries, Soldier and Shunganunga Creeks, providing flood risk management for the City of Topeka, (see Figure 1). The Waterworks, Auburndale, South Topeka, and Oakland Units lie on the south side, or right bank, of the Kansas River, with the Oakland Unit extending up the left bank of Shunganunga Creek. The North Topeka Unit lies on the north side (left bank) of the Kansas River and connects at each end to the Soldier Creek Diversion Unit which includes levees on both banks of Soldier Creek Local sponsorship of the existing system is provided by the City of Topeka and the North Topeka Drainage District.

In the early 1990's, a private engineering consultant working for the Kansas Department of Transportation conducted studies for the Oakland Expressway, a new highway bridge to cross the Kansas River within the project area. Concern arose from their review that the levee in the area of the new highway may no longer be providing the expected level of flood risk management. As a result of these concerns, the City of Topeka requested a Reconnaissance

Study in a letter dated March 26, 1992.

A Reconnaissance Study, initiated in September 1996 and completed in September 1997, found that there was a Federal interest in one or more alternatives to improve the level of flood risk management at Topeka by raising the top of levee elevation. This Feasibility Study was initiated in August 1998 with the signing of a Feasibility Cost Sharing Agreement between the Corps and the City of Topeka. The study is financed on a cost-share basis in accordance with the Water Resources Development Act of 1986. The cost of the study is shared between the Corps (50%) and the non-Federal Sponsors (50%).

Early in the feasibility study, a delay in study activities was authorized to await completion of the Upper Mississippi River Flow Frequency Study (UMRFFS). As part of this study, updated hydraulic models were developed for the Upper Mississippi and Missouri River and several tributaries, including the Kansas River, using updated gage records and state of the art technology – the UNET model. The UMRFFS study was completed in 2003. When the feasibility study resumed with updated hydraulic data, it was determined that the hydraulic overtopping reliabilities for the existing levee units range from 94 to 99 percent for the 1-percent chance (100-year) flood. A raise in the system would not be necessary to meet the criteria to allow FEMA to accredit the system as providing protection from the 1-percent chance flood.

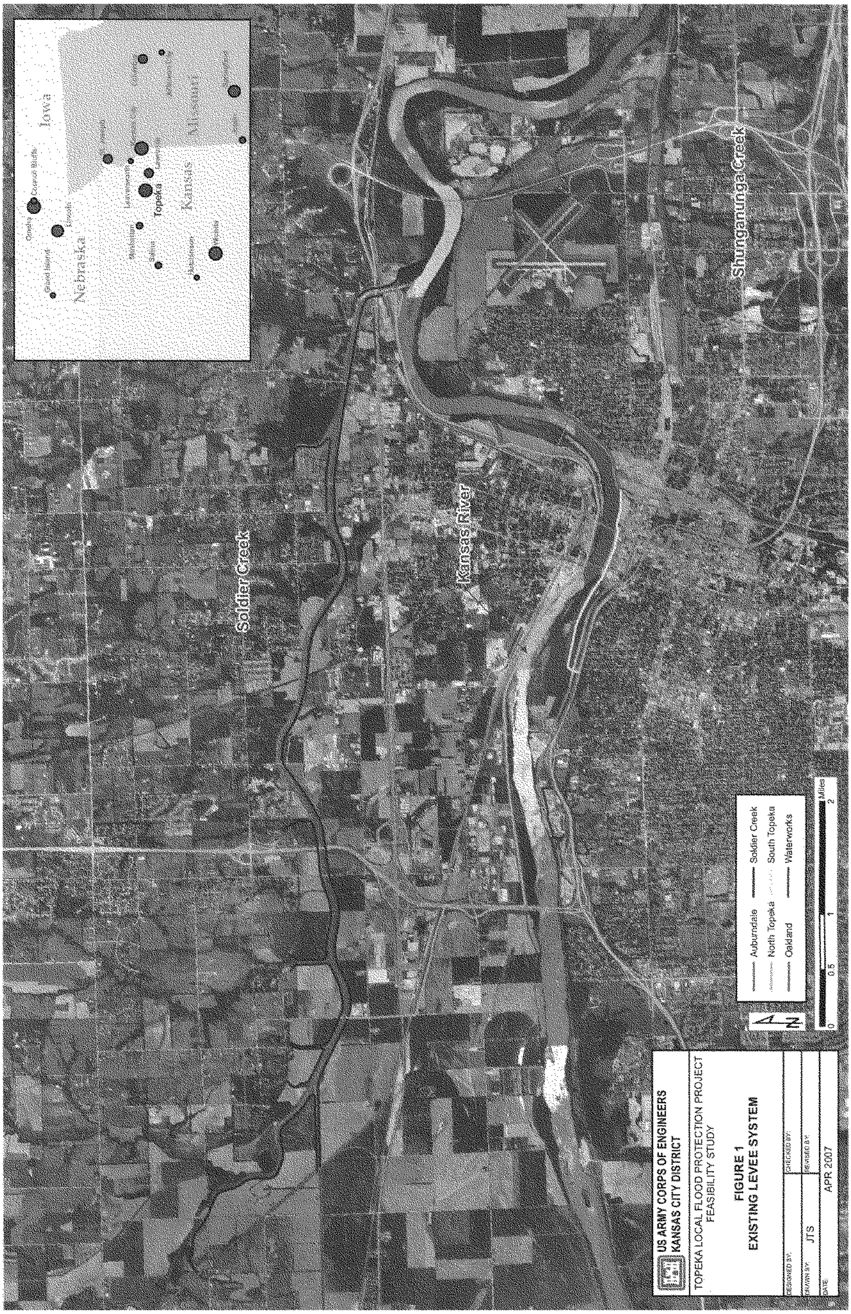
The focus of the study was then directed to examining the reliabilities of the geotechnical and structural features of the system. The reliabilities of several features within the system have been found deficient, creating potential failure locations within the levee system. Further description of these deficiencies will be presented in later sections of this document.

This study report is written using current risk and reliability analysis and flood frequency terminology that may not be familiar to all readers. The reliability of specific features is typically expressed as a percentage probability of failure as a measure of the likelihood of that feature to withstand a certain level of flooding. The frequency of a flood of a certain size is expressed both in terms of the percent chance of that flood occurring in a single year (i.e. 1% chance event) and also using the return interval designation (i.e. 100 year flood).

II. Study Authority

This report details the analysis, results, and recommendations resulting from the Topeka, Kansas, Flood Risk Management Feasibility Study (the Study). The Study was authorized under Section 216 of the 1970 Flood Control Act, which reads as follows:

> *The Secretary of the Army, acting through the Chief of Engineers, is authorized to review the operation of projects, the construction of which has been completed and which were constructed by the Corps of Engineers in the interest of navigation, flood control, water supply, and related purposes, when found advisable due to the significantly changed physical or economic conditions, and to report thereon to Congress with recommendations on the advisability of modifying structures or their operation, and for improving the quality*


Soldier Creek
Kansas River
Shunganunga Creek
Nebraska
Iowa
Kansas
Missouri
Topeka
Council Bluffs
Auburndale
North Topeka
Oakland
Soldier Creek
South Topeka
Waterworks
0
0.5
1
2
Miles
US ARMY CORPS OF ENGINEERS
KANSAS CITY DISTRICT
TOPEKA LOCAL FLOOD PROTECTION PROJECT
FEASIBILITY STUDY
FIGURE 1
EXISTING LEVEE SYSTEM
DESIGNED BY:
CHECKED BY:
DRAWN BY:
JTS
REVISED BY:
DATE:
APR 2007

of the environment in the overall public interest

III. Study Purpose and Scope

The purpose of the feasibility study is twofold. First, the study serves to update and verify data on the reliability of the existing flood risk management units. Secondly, the study provides a means to examine and develop alternative plans (including a review of the "no Federal action" alternative) for reliability (performance) improvement of the units to reduce damages from potential flooding on the Kansas River in the vicinity of Topeka, with the ultimate aim of a final recommended plan for authorization and implementation. The recommended plan for increasing the reliability of the system will be selected through the basic tests of technical effectiveness and completeness, economic feasibility, and environmental acceptability.

IV. Prior Project Documents, Studies, and Reports

Several studies and reports have been completed pertaining to the study area and surrounding areas. These reports were used to gather information regarding the levee units and past flood events.

Definite Project Report, Levee System at Topeka, Kansas, 27 October 1936. This document was prepared subsequent to the Flood Control Act of 1936 and contains general discussion of the purpose, layout, and costs of the original Federal levee project at Topeka.

Design Memorandums, Volumes 1-15, Topeka, Kansas, Flood Protection Project, Kansas City District, U.S. Army Corps of Engineers, 1956 through 1967. The design memorandums are the justification documents, subsequent to the Flood Control Act of 1954, which recommend proceeding with plans and specifications for the various units within the Topeka, Kansas, Project. They include general design data, previous projects, and a general description of the authorized project.

Operation and Maintenance Manuals, Volumes 1-8, Topeka, Kansas, Flood Protection Project, Kansas City District, U.S. Army Corps of Engineers, 1961 through 1978. These document present detailed information for the use and guidance of the local interests in the operation and maintenance of the Topeka, Kansas, Project.

Flood Plain Information Report, Kansas River, Kansas, Junction City to the Mouth, Kansas City District, U.S. Army Corps of Engineers, April 1956. This report evaluated flood hazards along the Kansas River from Junction City downstream to the confluence with the Missouri River in Kansas City, Kansas. This document examines the hydrology and hydraulics of the Kansas River Valley.

Review Report on the Kansas River, Appendix IV, Hydrology, September 1960. This report examines the hydrology on the Kansas River as part of the extensive study to review the adequacy of the Kansas River and downstream flood risk management systems. Congress authorized this study in 1953.

Senate Document No. 122, 87th Congress, 2nd Session, Kansas River and Tributaries, Kansas, Nebraska and Colorado, U.S. Army Corps of Engineers, August 1962. This is the final report submitted to Congress that reviews the Kansas River and tributaries, Kansas, Nebraska, and Colorado, which was requested by resolution of the Committee on Public Works, United States Senate, adopted on August 20, 1953 and June 16, 1954.

Flood Insurance Study (FIS), City of Topeka, Kansas, Federal Emergency Management Agency, June 1981. This report published by the Federal Emergency Management Agency (FEMA) included flood discharges, water surface profiles, and flooded area and floodway maps for use in developing flood insurance rates. Since the City of Topeka, Kansas is a participating community in the Flood Insurance Program, all properties are eligible for flood insurance.

Modification to Completed Project, Soldier Creek Diversion Unit, Topeka Local Protection Project, Kansas, Kansas City District, U.S. Army Corps of Engineers, March 1987. This report describes channel degradation concerns in, and upstream of the Soldier Creek Project.

Draft Kansas River and Shunganunga Creek, Flood Plain Study, Oakland Expressway KDOT Project No. 4-89, K-3362-01, May 1992. This study examines the effects to the Kansas River and Shunganunga Creek of the proposed Oakland Expressway.

Flood Insurance Study (FIS), Shawnee County, Kansas, Federal Emergency Management Agency, May 1993. This report published by the Federal Emergency Management Agency (FEMA) included flood discharges, water surface profiles, and flooded area and floodway maps for use in developing flood insurance rates. Since Shawnee County, Kansas is a participating community in the Flood Insurance Program, all properties are eligible for flood insurance.

The Great Flood of 1993 Post-Flood Report, Lower Missouri River Basin, Kansas City District, U.S. Army Corps of Engineers, September 1994. The report presents a picture of the Great Flood of 1993 to be used in the analysis of the flood risk management system on the lower Missouri River and tributaries.

The Upper Mississippi and Missouri River Flow Frequency Study, U.S. Army Corps of Engineers, 2003. This study developed updated hydraulic modeling for the Upper Mississippi and Missouri Rives, and several tributaries, including the Kansas River, using updated gage records and state of the art technology, the UNET model.

V. Other Existing Projects in the Kansas River Basin

The Topeka levee units are a part of a larger flood risk management system in the Kansas River basin, shown in Figure 2. Additional levee units are located along the Kansas River at several locations, both upstream and downstream of Topeka. Downstream units are located at Lawrence, Kansas, approximately 25 river miles below Topeka, and at the river mouth at Kansas

City. Upstream units are located at the cities of Manhattan and Abilene.

The basin wide system includes seven reservoirs managed by the Corps of Engineers. The five reservoirs upstream of Topeka, and the waterways on which they are located in order of increasing distance from Topeka, are: Tuttle Creek (Big Blue River), Milford (Republican River), Kanopolis (Smoky Hill River), Wilson (Saline River), and Harlan County (Republican River). The two downstream reservoirs are Perry Lake on the Delaware River and Clinton Lake on the Wakarusa River.

There are an additional eleven reservoirs in the watershed managed by the Bureau of Reclamation, all located upstream of Topeka in the Republican, Saline, and Smoky Hill watersheds. These reservoirs are generally smaller projects and are not operated for flood risk management purposes. They are not considered to have a significant effect on Kansas River flows at Topeka.

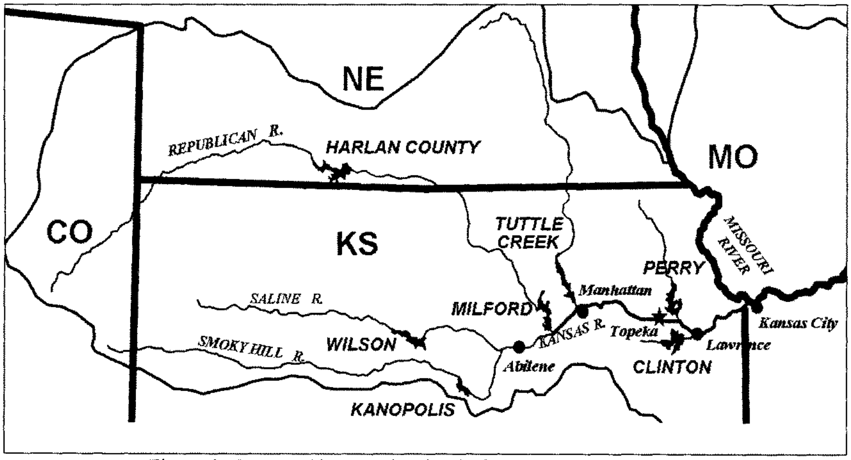


Figure 2 –Kansas River Basin Flood Risk Management System.

VI. Problem Identification

A. Existing Conditions and Flood History

1.0 Study Area

The Study Area includes those portions of the Kansas River, Soldier Creek, and Shunganunga Creek drainage basins that are located within the City of Topeka. It is important to examine how the areas of these basins outside the city may affect the flood conditions at Topeka.

The Kansas River flows through the center of the City and is leveed between approximately river miles 77 and 88.5. The Kansas River drainage basin above Topeka includes 56,720 square miles of contributing and non-contributing surface area. Of this drainage, approximately 42,000 square miles are modified by sixteen existing Federal reservoirs located on tributaries of the Kansas River. The Kansas River basin and tributaries are predominately in a wide valley of well-developed agricultural lands used for general farming. This basin typically produces floods at Topeka that are slow to develop and slow to recede. The basin has shown, as in the 1951 flood of record, that relatively rapid flooding can occur and is also a serious threat.

The study area includes the confluence of Soldier Creek and the Kansas River. Soldier Creek flows through north Topeka and enters the Kansas River at river mile 80.6. The Soldier Creek basin is 331 square miles located to the north of the Kansas River. The predominant use of the basin is for general farming. The general basin shape is quite narrow (2.5 to 3 miles) near the headwaters and increases in width as it approaches the confluence with the Kansas River to a maximum width of 12 miles. This basin produces floods that are quite sudden and recede quickly.

Shunganunga Creek flows through southeast Topeka and enters the Kansas River at river mile 76.4. The total drainage area of the basin is 75.7 square miles of which 22.5 square miles lay within the city limits of Topeka. The basin is about 20 miles long and 7 miles wide at its widest point. The land is flat in the lower part of the basin and hilly in the headwater areas. There are four detention dams within the basin. In 1935, Lake Shawnee on Deer Creek, a tributary within the Shunganunga basin, was constructed. However, no provision was made for floodwater storage in this lake. After the flood of 1951, two more detention basins were constructed; Burnett Dam on Shunganunga Creek in 1952 and South Branch Dam on South Branch Shunganunga Creek in 1953. In 1962, Sherwood Lake was constructed upstream from Burnett Dam.

2.0 Description of Existing Overall Project

General. The existing levee system project was authorized to pass a design flood flow of 314,000 cfs. As constructed the existing system includes approximately 40 miles of main river levees and 2.91 miles of tieback levees, 4,120 linear feet of concrete floodwall, 9.2 miles of improved channel on Soldier Creek, 5.5 miles of improved channel on Shunganunga Creek, and 2.6 miles of improved and enlarged channel along the Kansas River. The project also includes twelve pumping plants, 76 pressure relief wells, 121 gated outlets for drainage structures, four sandbag gaps, seven stoplog gaps, and a designated interior ponding area.

Analysis of the existing conditions of the levee system has determined that there are areas with reliability less than the acceptable level of 90% to pass intended design flow due to the potential for levee underseepage, structural uplift, and structural stability failures under flood conditions. Restoring project reliability and performance is dependent on the proper functioning of the entire system and all appurtenant features.

The six flood risk management units, although authorized and constructed as separate units, were designed in coordination with the others as a complete levee system. While some of these separate units are operationally independent, a direct risk dependency exists between the South Topeka and Oakland units, i.e. if the South Topeka Unit were to flood; the Oakland Unit immediately downstream would also flood. This dependency will be then taken into consideration in the economic and future performance analyses presented later in this report, where the South Topeka and Oakland areas generally will be treated as a single reach.

The specific physical features found within each unit of the system are described further in the following paragraphs. The locations of each unit within the system are shown in Figure 1.

Waterworks Unit. The Waterworks Unit is located on the right bank of the Kansas River in the western portion of the City of Topeka and forms a "U" shape with Interstate 70 serving as the southern boundary. This unit encloses the City of Topeka's municipal water treatment plant which also provides service to a large portion of Shawnee County.

The unit consists of 1,998 feet of levee and 1,662 feet of floodwall. The crest of the levee is 10 feet wide and varies from 10 feet to 14 feet in height above the ground surface. The spread footing floodwall has an average exposed wall height of between eight and twelve feet. A sheetpile cutoff wall is embedded in the heel of the floodwall. The unit also includes a system of nine individually pumped relief wells with header, four stoplog gaps, one sandbag gap, four gated drainage structures, and intake lines from the Kansas River for the treatment facility. The floodwall was constructed in 1938 and the rest of the unit was completed in June 1959.

Auburndale Unit. The Auburndale Unit connects the Waterworks and South Topeka Units and is primarily the Interstate 70 highway embankment. The unit consists of approximately 1.3 miles of zoned highway fill and some separate levee embankment fill. Also included in the unit is the Waite Street Levee, an 850-foot sub-levee which is the upstream boundary for a ponding area.

The Auburndale Unit also has fifteen relief wells, one sandbag closure gap structure, two pumping plants (Waite Street and Ward-Martin), four gated interior drainage structures and sewers through the levee, and a ponding area to protect a residential area. The area landside of the Interstate 70 embankment was re-graded to provide the ponding area for collection of interior drainage. This ponding area is bound by the Interstate 70 embankment to the north, high ground to the east and south, and the Waite Street tieback levee to the west. The relief wells are located on a rock fill berm at the landside toe of the Interstate 70 embankment. The unit was constructed under three separate contracts with the latest being completed in October 1962.

South Topeka Unit. The South Topeka Unit is located in the central portion of the City of Topeka, on the right bank of the Kansas River. The unit begins at the east end of the Auburndale Unit and extends to approximately 500 feet upstream of the Burlington, Northern, & Santa Fe (formerly the Atchison, Topeka & Santa Fe) Railroad bridge, which is the west end of the Oakland Unit.

The levee portion of the unit is approximately 1.4 miles long with a 10-foot crest that ranges from three to 16 feet above the natural ground surface. The levee generally follows the alignment of a concrete floodwall constructed in 1908 by local interests. Where the original wall and levee location coincided, portions of the wall were left in place within the new levee embankment. The levee is founded on an impervious blanket varying in thickness between 5 and 24 feet, with an average of 15.5 feet. The blanket, consisting of silty clays and silty sands, overlays a sand deposit more than 80 feet thick. Fill placed on the top of the natural blanket between station 50+00 and 74+30 contains debris, rock, rubble, and sand requiring the construction of riverside cut-off trenches to reduce seepage. The levee was originally constructed in 1938 and a raise was completed in 1971.

At Station 74+41, the levee portion of the unit abuts downstream with a 1,945 linear foot concrete timber-pile founded floodwall that rises ten to twelve feet above the natural ground surface. A steel sheet pile cutoff wall is embedded in the heel of the levee. The floodwall was also originally constructed in 1938. Because of the nature of the blanket materials, and the effects of underseepage observed during the 1951 flood, an elaborate underseepage control system consisting of approximately twenty manholes and drop inlets, 27 relief wells with headers, and a new pump station (Kansas Ave.), was installed landward of the floodwall at the same time as the upstream levee raise. The blanket beneath this fill averages only a few feet in thickness and appears to be entirely missing between stations 77+50 and 80+50.

The Morrell, Madison Street, and City Park pump stations were constructed by the City of Topeka in 1931, 1946, and 1956, respectively, for the discharge of storm water to the Kansas River. The Morrell and City Park stations still exist as originally constructed. A new Madison Street pump station was constructed in 1970 by the City of Topeka with cost-share assistance from the Corps.

The unit contains fifteen drainage structures and was originally constructed with two sandbag railroad closure structures. The closure structure at the Chicago, Rock Island, and Pacific railroad bridge was converted to a stoplog structure in 1964 and the nine-track closure at the upstream end of the unit was converted in 1973.

Oakland Unit. The Oakland Unit is located in the eastern portion of the City of Topeka and is bound by the Kansas River on the north and Shunganunga Creek on the south. It begins approximately 500 feet upstream of the Burlington Northern Santa Fe (formerly the Atchison, Topeka & Santa Fe) railroad bridge. The unit creates the right bank levee of the Kansas River and becomes the left bank levee of Shunganunga Creek until its termination just north of Interstate Highway 70.

The unit consists of 10 miles of levee, 515 feet of concrete floodwall on Shunganunga Creek, and 5.5 miles of channel modification. The crest of the levee is 10 feet wide and varies from five feet to greater than fifteen feet in height above the ground surface. The floodwall height varies from seven to nine feet above existing ground surface. The Oakland Unit includes 22 relief wells, one sandbag gap closure structure, two pump stations, and 48 drainage structures. The unit was constructed under four separate contracts with the latest being completed in April 1969.

North Topeka Unit. The North Topeka Unit was constructed under two contracts and completed in January of 1967. The unit encompasses the portion of the city that lies north of the Kansas River. The unit provides damage reduction from U.S. Highway 4 to Chester Avenue. On the west, the unit begins at the Soldier Creek Diversion Unit along Menoken Road. The levee then runs southeast and parallels the left bank of the Kansas River to just above the mouth of Soldier Creek. At this point the North Topeka Unit connects again with the Soldier Creek Diversion Unit on the east end.

The unit consists of nine miles of levee with crest heights varying from 3 feet to 17 feet above the natural ground elevation. The natural blanket for the entire levee unit, consisting predominantly of silt, varies in thickness from 1 to 23 feet, with an average thickness of 12 feet. Underseepage is controlled by landside underseepage berms between stations 83+00 and 220+00. Cut-off trenches are present between stations 205+00 and 462+50 at locations where the blanket is overlain by a sand layer or by existing pervious fill. Three (3) relief wells were placed at station 392+05 where the natural impervious blanket had been excavated for the basement of a warehouse building.

The North Topeka Unit includes three pump stations, Quincy Street, Fairchild, and Soldier Creek, fifteen drainage structures, and one sandbag and stoplog closure each. In 2003, the City redirected the sanitary and storm sewers that were connected to the Fairchild pump station as part of local infrastructure improvement. This action removed the majority of the flow for which the station was originally designed. The Fairchild station still provides removal of interior drainage from a two to three block residential neighborhood.

Soldier Creek Diversion Unit. Soldier Creek is located on the north side of the City of Topeka. It is a left bank tributary of, and flows generally parallel, to the Kansas River. Soldier Creek drains into the Kansas River at approximately river mile 80.6, but originally its mouth was located approximately 1.6 miles further upstream. The Soldier Creek channel was relocated to the north to intersect and follow the previous Indian Creek channel.

The Soldier Creek Diversion Unit consists of 9.2 miles of new or modified channel and 17.9 miles of levee on both banks. There are short tieback levees on several small tributaries and 35 drainage structures. The unit was constructed under eight separate contracts with the latest completed in 1961.

3.0 Existing Flood Threat

Prior to the construction of the levee units, this reach of the Kansas River routinely flooded river bottomland in the vicinity of Topeka. Also, without the levees, flood stages in excess of 15 feet caused significant flood damage. For this study, a detailed update of the hydraulics was completed with current state-of-the-art hydraulic modeling, utilizing calibration to the 1993 flood event. The discharge-frequency data for this study were taken from regulated and unregulated flow data for the Kansas River developed for the Upper Mississippi River Flow Frequency Study (UMRFFS), completed in 2003. UMRFFS was a major reevaluation of regulated and unregulated flows in the subject basin, including the Missouri River and its Kansas River tributary. The UMRFFS currently estimates the 1-percent event discharge at Topeka to be 217,000 cfs. The authorized design discharge from the project Design Memorandum, published in 1956, is 314,000 cfs with freeboard, which is approximately a 0.29-percent annual occurrence event (approximately a 350-yr flood). Further detail of the hydraulic analysis and the design discharge is presented in later sections of this report.

4.0 Historic Floods and Damages

Kansas River. Major floods on the Kansas River are usually caused by a series of short-duration, high intensity storms following a prolonged period of general rains. Table 1 lists the five largest annual peaks at the United States Geological Survey (USGS) gage on the Kansas River at Topeka, Kansas. The period of record for this gage is from 1904 to the present. The USGS gage (06889000) is located on the Sardou Bridge, river mile 83.1, 2.3 miles upstream of Soldier Creek.

Table 1. Kansas River - Five Largest Recorded Annual Peaks at Topeka

Year	Discharge (cfs)
July 1951	469,000
May 1903	253,000 (estimated)
August 1908	200,000
July 1993	170,000
June 1935	154,000

It is also known that a great flood occurred on the Kansas River in June of 1844, for which records do not exist. Various estimations and accounts of the flood indicate that this event may have been the largest ever to occur on the Kansas River.

In addition to the large historical events noted in Table 1, smaller floods occurred in 1904, 1919, and 1928; all of which contributed to the inclusion of Topeka in the Flood Control Act of 1936. However, the cycle of flooding continued through the Forties with notable events in 1941, 1943, 1944, 1945, and 1949, reaching a peak with the flood of July 1951.

The Flood of Record of 1951 was a catastrophic event that impacted the entire Kansas River. The damages caused by the event in Topeka were estimated at over $34 million (1951 price level), or about $414 million in 2008 prices. As a result, Federal involvement in Topeka, as well as other cities in the basin, significantly increased with the passage of the Flood Control Act of 1954. The modifications and additional work implemented in the 1960's and 70's were the result. However, it should be noted that the South Topeka Unit was not fully tested during this flood event. Historical records indicate that the interior of the unit flooded prior to any levee overtopping or structural failure due to flow through a railroad sandbag gap that was not closed.

Of the discharges shown in Table 1, only the 1993 flood was influenced by full reservoir control of the upstream basin. Of the sixteen Federal reservoirs, the two most influential lakes that affect the Kansas River flows at Topeka are Tuttle Creek Lake and Milford Lake. Tuttle Creek Lake is located on the Big Blue River above Manhattan, Kansas, and began operation in March 1962. The Big Blue enters the Kansas near river mile 145. Milford Lake is located on the Republican River above Junction City, Kansas, and began operation in January 1967. The confluence of the Republican and the Smoky Hill River creates the Kansas River at approximately river mile 171. Studies indicate that without this upstream flow regulation, the peak discharge of the 1993 flood at Topeka would have been approximately 192,000 cfs. Additionally, it is estimated that the 1951 flood would have been about 288,000 with full regulation.

Soldier Creek. Floods on Soldier Creek are caused by short duration storms that quickly develop and recede. Table 2 lists the five largest annual peaks at the USGS gage located approximately one-third of a mile upstream of the U.S. Highway 75 bridge over Soldier Creek. The period of record for this gage is from 1929 to the present. There are no upstream reservoirs that impact the flows of Soldier Creek in Topeka.

Table 2. Soldier Creek - Five Largest Recorded Annual Peaks at Topeka

Year	**Discharge (cfs)**
October 2005	47,800
June 1982	30,400
July 1981	25,000
June 1999	24,000
September 1977	21,900

Other floods of interest: the July 1993 flood of 18,900 cfs, approximately the 6th largest, and the June 1951 flood of 11,400 cfs, approximately the 9th highest.

Shunganunga Creek. USGS gage record data is only available for the years 1980-81. Historic peak discharges are unavailable.

5.0 Floodplain Conditions

The City of Topeka, Kansas, participates in the National Flood Insurance Program (NFIP). Property owners in a participating community within the 1 percent chance flood zone, and other specially designated zones, can obtain flood insurance. Any proposed construction in the 1 percent chance floodplain must generally be elevated above the 1 percent chance flood elevation, or in compliance with local ordinances. The floodway is an area hydraulically defined that must be reserved in an unobstructed condition in order to pass the base (1 percent chance) flood without increasing flood levels more than one foot. Existing floodplain ordinances generally prohibit construction or development within the floodway.

6.0 Geotechnical Conditions

The Engineering Appendix presents the results of the geotechnical evaluation of the existing conditions performed as part of the feasibility flood study. The flood risk management project within the study area was designed by the Kansas City District U. S. Army Corps of Engineers and was constructed under its supervision.

The primary goal of this phase of the geotechnical evaluation was to gather and review all available data and develop an assessment of the existing conditions of each levee unit by identifying the critical reaches for each unit and their probability of failure for different river stages. Additionally, the past performance of the levee system was evaluated. This information is to assist in an assessment of the future performance of the levee during flood events. In particular, the following tasks were performed for this study:

- Review of existing sources of information,
- Description of each existing levee unit including design features and subsurface conditions.
- Reliability analyses of each unit and identification of critical reaches of each unit

The evaluation of the existing condition was based on the original subsurface investigation performed for the design of the project. This was supplemented with additional investigations, such as cone penetrometer tests and laboratory testing performed on selected samples collected from borings drilled in areas considered critical.

7.0 Economic Setting

The City of Topeka, Kansas, the State Capital, is centrally located in Shawnee County, in west central Kansas, near the geographic center of the continental United States. The city covers 57.6 square miles surrounded by unincorporated areas of Shawnee County. The development in Topeka represents all the features of a mid-sized urban area including transportation by road, rail, and air, and social and cultural infrastructure including a wide variety of public and private educational facilities and a particularly diverse selection of health care providers. In addition to the State government administration, Topeka hosts a wide variety of industries including preparation of packaged foods, printing and publishing, warehousing and distribution, and transportation.

Topeka, with a 2006 estimated population of 122,113, is the fourth largest city in Kansas, after Wichita, Kansas City, and Overland Park, and ranks 195th among all U.S. cities in population. Population is down slightly from the 123,101 recorded in the 2000 Census, as the area's population continues to redistribute itself from the center city to the suburbs, but is up about 2% from the 1990 total of 119,883. Shawnee County grew 5.5% during the 1990-2000 period and has grown 1.5% since the 2000 Census to its current (2006) estimated population of 172,693. The Topeka Metropolitan Statistical Area (MSA), meanwhile, has seen a 1.9% increase in population from 224,551 in 2000 to 228,894 in 2006.

The study area, or the areas within the Federal levee project, had an estimated 2000 population of 16,098 (about 13.1% of the total Topeka population) and a total of 7,153 housing units. These totals are based on data from the Census blocks comprising the study area.

Per capita income in the study area (i.e., the Census block groups comprising the protected areas) was $17,596 in 2000, which was only 90% of the Topeka per capita income, 84% of Shawnee County, 86% of the state, and 82% of the national total. Study area residents were more likely than city and county residents in general to have sub-poverty level incomes or to be unemployed, and they were somewhat less educated. In housing, the average value of owner units in the study area was $66,148, which was only 81% of the Topeka average, 70% of the county average, and 64% of the statewide average. The relatively low home values probably resulted in part from the age of the study area housing stock, which was 46.1 years old on average compared to 39.7 for Topeka and 36.9 for the county. The study area vacancy rate of 7.9% exceeded the city rate of 7.5% and the county rate of 6.6%. Refer to Appendix D, Section 2 for further discussion of area demographics.

Commercial, industrial, and residential developments are located in the floodplain of the study area behind the different levee units. Numerous city streets, county roadways, state and Federal highways, and railroads cross the floodplain. The Philip Billard Airport, one water treatment plant, two wastewater treatment plants, and other public utilities are located in the floodplain. In addition, open land already protected by the levees could be developed for commercial and industrial uses. Pressures for additional development of the floodplain within the existing levee system will continue to intensify during the period of analysis due to the concentration in Oakland and North Topeka of several sites amenable to large-scale commercial or industrial development. Topeka has only a few other sites available outside of these areas.

The Federal project protects a total of 11,059 acres in Topeka, representing about 31% of the city's total area. The largest leveed areas are the North Topeka area (6,076 acres – protected by two units of the system: North Topeka and Soldier Creek) and the combined Oakland/South Topeka area (3,582 acres). The four right bank Kansas River main stem units account for a total of 10.7 miles of leveed riverfront and protect 3,926 acres, while the right bank main stem unit accounts for 8 miles of leveed riverfront and protects 6,076 acres. In addition to the urban North Topeka area, the Soldier Creek unit protects an additional 1,057 acres in rural areas. These seven leveed areas range from 39 to 449 acres in area.

Densely populated urban neighborhoods characterize Auburndale, most of the western two-thirds of Oakland, and the eastern two-thirds of North Topeka. Industrial land uses dominate the Waterworks area, the western portion of North Topeka, almost all of South Topeka, and the southwestern and eastern portions of the Oakland area. A number of neighborhood retail and service areas are scattered throughout Oakland and North Topeka, which also has a riverfront old town area of offices, stores and services. Agricultural land uses are found primarily in the northern portions of Oakland and western portions of North Topeka.

The left bank area protected by the North Topeka unit contains significant heavy industry, including a Goodyear Tire plant, as well as residences and farm acreage on the east and west ends of the area. Properties in the North Topeka area include 2,752 residences and 539 businesses and public facilities which, together with highways, roads, and rail, have a total estimated investment of $1.47 billion. Rural sections of the Soldier Creek unit along the north edge of North Topeka protect a few dozen homes as well as several areas planted in crops, with a total estimated value of about $30.7 million. The main section of the Soldier Creek unit protects the same urban North Topeka area that is also protected from the Kansas River by the North Topeka unit.

On the right bank, the Waterworks unit's sole protected property is a water treatment plant. The Auburndale unit protects an estimated investment of $119.2 million, including 616 residences and 18 businesses. The South Topeka Unit contains investment valued at $407.6 million, including 142 businesses and facilities and 80 homes. The Oakland area contains 2,942 residences and 89 businesses and facilities comprising an estimated investment of $577.7 million. In total, the Topeka federal levee system protects an estimated $2.67 billion in investment, including 6,487 residences and 790 businesses and public facilities.

8.0 Environmental Setting

The study area is an urban wildlife setting characterized by industrial, residential, and commercial development. The small areas of natural habitat available are generally confined to riparian woodland strips along the river corridor. Portions of the Kansas River have been channelized and, in some locations, the levees are almost right at the riverbank, constraining the extent of riverine habitat.

Vegetation types present in the study area include: floodplain habitat of cottonwood and willow trees, oak-hickory forest, and bluestem prairie. Additional detail of the vegetation, climate, and soil characteristics of the study area is presented in Section 9.0 of the attached Environmental Assessment.

9.0 Fish and Wildlife

Typical fish species found in the Kansas River include various species of bass, shiner, catfish, chub, and others. The fisheries resources in this reach of the Kansas River are greatly influenced by releases from Tuttle Creek Lake. The spring spawning season is a particularly sensitive period when releases from the lake provide high flows which are critical for spawning success.

Many species of mammals, birds, reptiles and amphibians utilize the riparian woodlands and grasslands adjacent to the banks of the Kansas River. This riparian corridor, although severely reduced in much of the study area, continues to represent a significant amount of important wildlife habitat.

There are three Federally-listed species that may occur within the project area: bald eagle, piping plover, and least tern.

State listed endangered species in Shawnee County include the American burying beetle, Eskimo curlew, least tern, peregrine falcon, silver chub, and whooping crane. State listed threatened species include the bald eagle, eastern spotted skunk, piping plover, smooth earth snake, snowy plover, sturgeon chub, and Topeka shiner.

More detailed information on fish and wildlife resources, and threatened and endangered species, is provided in Sections 10 of the attached Environmental Assessment. Lists of typical fish and wildlife species found in the project area are included in the 2007 USFWS Coordination Act Report (EA, appendix C).

10.0 Wetlands

Based on a review of National Wetland Inventory mapping and site investigations by Corps of Engineers personnel, there are no wetlands currently present within the project study area.

11.0 Cultural Resources

The Corps conducted a review of the National Register of Historic Places (NHRP), an appropriate records search at the Kansas State Historical Society, and a field reconnaissance of the project area. No NRHP properties are recorded in the study area. Also, the records search found no other archeological sites, historic structures, or shipwrecks recorded within any of these areas. For additional information see the attached Environmental Assessment, Section 10.6.

12.0 Hazardous, Toxic, and Radioactive Waste

A Hazardous, Toxic, and Radioactive Waste (HTRW) assessment was completed as part of the Topeka, Kansas, Reconnaissance Report (USACE, 1997), and a more recent assessment (USACE, 2007) of potential HTRW resources was completed.

Overall, the assessment found very little risk associated with HTRW contamination in the study area; however, there were three areas of potential HTRW or solid waste impact. Former city dump sites were identified in parts of the South Topeka and Oakland Units that will need to be avoided. The description from the Scotch Cleaners site, located in the southeast portion of the South Topeka Unit, indicates a groundwater plume of chlorinated solvents is emanating from this site and extends north-northeast to the Kansas River. This plume may be present below the existing floodwall.

The conclusions of the 2007 HTRW assessment are summarized in the attached Environmental Assessment, Section 11.0, and the complete investigation report is included with the EA as Appendix I.

B. Future Conditions Without Project

1.0 Future Flooding

The existing conditions of each unit described earlier were analyzed using current methods and criteria for factor of safety and reliability. Each unit was systematically analyzed to determine if any critical reaches for geotechnical and structural concern were evident. For those reaches that did not meet current factor of safety criteria, an additional reliability analysis was conducted to calculate the probability of failure. Table 3 presents the current estimates of the reliability of passing the 1-percent annual chance event for each unit.

As stated earlier, the overtopping reliabilities of the Kansas River units are all above 93%. The values in Table 3 indicate the significance of the geotechnical and structural weaknesses identified for each unit.

Table 3. Existing Conditions Reliability of Kansas River Units

Levee Unit	Reliability Against the 1% event
Waterworks	92.8%
Auburndale	96.8%
South Topeka	84.2%
Oakland	2.9%
North Topeka	14.1%

Supporting detail for the geotechnical and structural analyses is found in Appendix A (Engineering). Additional detail supporting exceedance probabilities and the consequences of failure in each unit are presented in Appendix D (Socioeconomics).

Large areas of existing residential, business, and industrial development are now in a zone that is vulnerable to flood damage due to unacceptable reliability. If a project is not authorized and implemented, FEMA could initiate a revision of the Flood Insurance Rate Map. The area currently shown as protected from the 1-percent flood would be placed in the Special Flood Hazard Area. The designation requires additional considerations for new construction and substantial improvements, and requires the mandatory purchase of flood insurance as a condition to financial assistance from a federally regulated source, potentially causing the area to enter into an economic decline with less viability for improvement or enhancement. Modifications or improvements to existing businesses, and any new investment within the area, would be constrained due to flood insurance requirements. If the project recommended by this study is not implemented by the Federal government, then the non-Federal sponsors will be faced with a significant financial burden of trying to implement the project themselves, or they will have to rely on temporary flood-fighting to protect the area from future floods.

The primary goal of evaluating these areas of concern was to identify potential failure modes and impacts on the ability of the project to continue to perform as intended. Knowing how the system can be expected to react provides the basis for identifying the types of alternatives that will be most effective in restoring project performance. The specific areas of concern for each unit and their expected failure modes area discussed in the following paragraphs.

Waterworks

Floodwall Stability. Six analyzed floodwall cross sections failed to meet sliding stability criteria. Sliding factors of safety calculated vary from 0.78 to 1.15; the minimum requirement is 1.3. Additionally, the four stoplog closure structures within the floodwall were analyzed with water to the top of the wall. Each closure showed a factor of safety of less than 1.3 for sliding stability (values ranged from 0.75 to 1.04). Sliding failure of the wall could lead to separation of the wall sections, water infiltration through opened wall joints, scour around the openings, and rapid wall failure.

South Topeka Unit

Underseepage. The critical geotechnical reach for the unit with respect to underseepage was identified within the earth levee section between stations 22+00 and 48+00. The Probable Failure Point (PFP), being the water surface elevation corresponding to an 85-percent probability of failure, occurs 0.2 feet below the top of the levee at that section. This is an excessively high probability at the top of the levee and indicates that the existing underseepage control fill in this area is inadequate. Excessive underseepage underneath the levee could cause internal erosion, undermining the foundation and resulting in collapse of the levee.

Structural Uplift. Uplift concerns are created when the hydraulic pressures in the ground pushing up on a structure during high flow events are greater than the weight of the structure itself. Calculations assumed fifty percent efficiency in existing pressure relief wells and up to three feet of water in the existing underseepage collector system to meet uplift requirements. Four manhole boxes failed to meet uplift criteria under these conditions (Sta. 16+07, 84+10, 84+10a, and 85+57). The existing factors of safety range from 0.84 to 0.96; 1.1 is the required uplift factor of safety. Uplift failure of a manhole could result in a path for floodwaters to enter the unit, causing a failure mode similar to the underseepage failure discussed in the previous paragraph. Furthermore, three of these manholes are part of the floodwall underseepage control system. Loss of one manhole could cause loss of the entire underseepage collector system.

Floodwall Stability. The original 1936 construction drawings for the floodwall are available, but accompanying specifications and design calculations are not. The construction drawings were employed along with other incomplete records of design and construction, memoranda of investigations and activities related to 1960's era modifications to the drainage systems, inspection reports, and site visit information collected during the feasibility study to conduct a preliminary stability and strength analysis of the wall.

From the information available, the structural analysis initially found that the loads on the timber piles supporting the wall exceeded the allowable shear stress. By exceeding the allowable stresses, the piles did not meet the factor of safety included in the allowable loads which suggested a reliability concern. However, a reliability analysis showed that the combined axial and bending stresses in the timber piles were less than the allowable stresses, indicating an acceptable reliability in resistance to shear loads.

A geotechnical analysis was also performed to determine the axial capacity of the existing piles. Two locations were selected. The first is a reach between station 83+00 and 87+00, where the foundation conditions were found to be the least desirable. The second is at station 89+00, which is more representative of the majority of the floodwall foundation conditions. A deterministic analysis of the axial pile capacity was initially performed for the design loading condition with water to the top of the wall. The piles at station 89+00 were found to meet the required factor of safety; however the piles at station 83+75 did not. A reliability analysis was subsequently performed for station 83+75 starting with water at the top of the floodwall and lowering the water level in one foot intervals to determine the water surface at which the probability of failure approaches zero. The probability of failure for the design loading condition was found to be 45%; a 55% reliability to pass the flood event. A foundation failure could result in excessive floodwall deflections and rapidly lead to a wall failure.

Pump Station Strength. At the Kansas Avenue pump station, an interior foundation wall exhibits a factor of safety of 0.97, failing to meet the required 1.5 strength factor. A failure of the steel within the wall will lead to cracking of the wall and possible loss of the foundation of the pump station, leading to water infiltration and the inability of the station to operate as intended. As this pump station is an important part of the floodwall underseepage control system, loss of the station could contribute to failure of the wall itself.

<u>Oakland Unit</u>

Underseepage. The critical geotechnical section for underseepage was identified between stations 64+00 and 80+00. The PFP for this section occurs 7.3 feet below the top of levee at this section. Flood flow elevations higher than the PFP could cause excessive underseepage, resulting in undermining of the levee foundation and possible loss of the levee. This reach is immediately adjacent to the Oakland Wastewater Treatment Plant.

Structural Uplift. The 5.5 ft. by 4.5 ft. drop inlet, 6.5 ft. deep, at station 75+50 fails to meet uplift criteria. The existing structure shows a factor of safety of 0.93. Almost 4 ft of water would be necessary to meet the minimum required 1.1 uplift factor of safety. An uplift failure of the manhole would provide a path of floodwaters to enter the unit and potentially undermine the levee.

The East Oakland Pump station exhibits an uplift factor of safety of 0.76, failing to meet the minimum of 1.1. An uplift failure would create a path for floodwaters to enter the protected area. Additionally, a pump station failure would prevent interior drainage from being evacuated to the river, contributing to interior flood damages.

Floodwall Stability. Two cross-sections analyzed of the floodwall on Shunganunga Creek failed to meet sliding stability, exhibiting factors of safety of 0.76 and 0.85, compared to the minimum requirement of 1.3. Sliding failure can lead to separation of the floodwall sections, infiltration of water, scour around the openings, and possible rapid loss of the wall. The wall is adjacent to an industrial business area.

North Topeka.

Underseepage. Analysis identified the areas between stations 165+00 and 180+00 and stations 246+00 to 250+00 as having piping safety factors less than 1.0. These areas are considered critical for reliability evaluation. The existing underseepage berm between 165+00 and 180+00 is inadequate and the reach from 246+00 to 250+00 does not have any existing underseepage control measures. The PFP for the section between stations 165+00 and 180+00 occurs 7.5 feet below the top of levee at that section. For the reach between stations 246+00 and 250+00, the PFP occurs 5.8 feet below the top of levee at that location. Flood flow elevations higher than the PFP could cause excessive underseepage, resulting in undermining of the levee foundation and possible loss of the levee. These reaches are located adjacent to agricultural and industrial areas, including such facilities as the North Topeka Wastewater Treatment Plant, grain elevators, and a railroad switching yard.

Structural Uplift. The Fairchild pump station uplift calculations are based on field measurements of exterior footprint dimensions, interior sump dimensions, and assumptions for floor member thickness. Using these dimensions and varying hydraulic grade lines (based on possible variations in blanket thickness, blanket permeability, and foundation permeability) the uplift factor of safety was determined to be 0.72. The required minimum is 1.1. Uplift failure of the pump station could result in a pathway for flood water to enter the unit. The pump station is located near a small residential neighborhood.

2.0 Socioeconomic Considerations

Continuing neglect of the deficiencies in the Topeka levee system eventually would result in catastrophic flood losses affecting large urban neighborhoods and industrial areas, as can be seen from the summary in Table 4. There is at least a 1 in 2 chance that the two largest units, Oakland and North Topeka, will experience at least one flood in the next 25 years. The probabilities of failure indicate a serious safety risk due to the fact that some features of the system, such as the South Topeka floodwall, may catastrophically fail with little or no warning. A "no action" condition would have negative impacts on the national economic development (NED), regional economic development (RED), and other social effects (OSE) accounts, as enumerated below.

Table 4. Future Without Project Condition Summary

	Equiv. annual damages	Expected damages in 1%-chance flood	Expected damages in 0.2%-chance flood	Affected population	Affected homes	Affected businesses and facilities	Annual exceedance probability	1%-chance event nonexceedance probability	Chance of failure or overtopping over 25 yrs
Waterworks	$221.8	$0.0	$54,536.5	0	0	1	0.003	0.928	1 in 10
Auburndale	$203.7	$0.0	$55,088.0	1,468	616	18	0.003	0.968	1 in 13
South Topeka/ Oakland	$6,357.6	$182,504.0	$595,883.8	7,241	3,022	231			
South Topeka							0.004	0.842	1 in 9
Oakland							0.057	0.029	1 in 1.3
North Topeka	$16,031.7	$585,917.4	$1,231,906.9	6,725	2,752	539	0.024	0.141	1 in 2
Soldier Creek							0.006	0.668	1 in 5
Urban	$1,872.0	$0.0	$250,677.6	(6,725)	(2,752)	(539)			
Rural	$51.1	$0.0	$11,757.8	664	97	1			
Total	$22,865.9	$768,421.4	$1,949,173.0	16,098	6,487	790			

Costs in $1,000's. Soldier Creek urban damages are not included in overall total because North Topeka damages covering the same area are included.

NED (National Economic Development) Effects of No Action - Losses to national economic output can be quantified to a considerable extent by reference to the equivalent annual damages (EAD) estimated for this study. EAD is the average damage expected annually over the long term if existing conditions are maintained - i.e., if the levee system remains in its current condition. EAD totals an estimated $22.87 million in the study area. This is only an average annual total; little or no damage might occur in some years, while other years would bring flood events causing as much as $2 billion in damages. Listed below are several aspects of these losses.

- Residential - Many residents in the study area would sustain heavy personal losses from flooding. A 0.2%-chance flood would be expected to damage more than 6,300 homes in Topeka. Even a smaller 1%-chance flood would damage more than 5,000 homes.

- Businesses - Many businesses and public facilities, large and small, would be seriously damaged by flooding and possibly driven out of business. A 0.2%-chance flood could damage more than 750 businesses in the city, and a smaller 1%-chance flood could damage nearly 600 businesses.

- Public sector - Public sector losses would be catastrophic, to include: (a) Sewage treatment facilities in the North Topeka and Oakland areas would be subject to relatively frequent damage and their operations would be interrupted periodically. (b) The Waterworks plant also would face marginally greater periodic damage to its facilities. (c) Highways and streets would require very costly repairs. (d) Police and fire-fighting services employed in flood fights, along with other emergency personnel and their equipment and temporary offices, would cost the city millions of dollars in significant floods. (e) Relocation and reoccupation assistance to residents forced from their homes by flooding would be required for thousands of residents at an average of $7,500 per home.

- Water supply - The Topeka region's water supply plant behind the Waterworks levee unit would suffer periodic operational interruptions or damage, affecting water supply delivery to 160,000 people and likely resulting in net income losses due to the need to implement alternative water supply arrangements.

- Traffic interruptions - Periodic closures during flooding (threatened flooding as well as actual) would interrupt traffic and commerce along key transportation arteries such as U.S. Highways 24 and 75, Kansas Route 4, and the two railroad lines in the area. Lengthy closures could lead to long detours and time-consuming delays on these routes.

- Business income losses from shutdowns - Production losses at some study area companies probably could not be made up by other companies or other branches of the same company, at least not quickly enough to meet consumer needs. Some production losses probably would represent unquantified NED losses at the Goodyear tire plant, Hallmark, and the Kansas Lottery, among others.

RED (Regional Economic Development) Effects of No Action - Regional economic development considerations are factors affecting the Topeka regional economy while not necessarily affecting national economic outputs. Several such effects in this study would be in connection with the danger that one or more Federal levee units in the Topeka system could be decertified. This action would loom large in the area's business climate. RED effects resulting from this and other factors would include the following:

- Residential flood insurance premium costs *(probable adverse income impact)* - Residents would face onerous new flood insurance requirements in the event of levee decertification.

- Threats to existing local/regional businesses *(probable adverse income and jobs impacts)* - Topeka businesses in and around the study area would be threatened by multiple factors related to flood risk, including (a) catastrophic periodic flood damage; (b) frequent business closures or scale backs; (c) employee safety during flood events; (d) the cost of new flood insurance requirements in the event of levee decertification; (e) stiffer building codes, also in the event of levee decertification, that would work against firms needing to expand in the floodplain. Large employers in the study area such as BNSF Railroad, Goodyear, Hallmark, Del Monte, Hill's and others could decide to relocate from the city and region. Particularly affected would be manufacturing jobs which are declining nationally but have been a strong part of the Topeka jobs base, and which are concentrated in floodplain locations.

- Threats to economic development prospects *(probable adverse income and jobs impacts)* - The same considerations listed just above that would affect existing jobs in the city also would discourage new development and growth in the form of businesses migrating into the city or region or the development of new areas. Large companies considering moving into the study area, bringing job concentrations with them, probably would not do so in a flood-prone area with a decertified levee and the attendant regulatory environment. In addition, many of the city's most attractive developable parcels are located in Oakland and North Topeka, which are the two units with the highest flood risk. Land uses would in many cases be downgraded from higher valued commercial and residential uses to greenways and possibly agriculture, resulting in income losses.

- Threats to riverfront redevelopment *(possible adverse income impacts)* - Topeka's emerging strategy to rehabilitate and revive its riverfront, which has resulted in the recent redevelopment of the old Union Pacific depot in North Topeka and is likely to spawn hiking and biking trails and other amenities in the future, could be stymied by periodic flood damage, resulting in impacts to recreation and tourism revenues.

Other Social Effects of No Action

- Public safety *(probable adverse impacts on human life)* - The chance of a major flood in the next 10 years is 1 in 4 in North Topeka and 1 in 2 in Oakland. At risk are more than 13,700 residents and more than 5,700 homes in these two areas, in addition to large daytime populations of workers in North Topeka. Warning times would be expected to be relatively short, since the overwhelmingly likely failure mode would be structural or geotechnical failure rather than overtopping. Public safety impacts would take the form of drowning, electrocution, and illness from exposure to contaminated flood waters.

- Low income residents suffer greatest flood risk *(probable adverse socioeconomic impacts)* - The South Topeka, Oakland, and North Topeka neighborhoods collectively had a 2000 poverty rate of 18.4%. This rate was 48% greater than the Topeka city and national rates of 12.4% and was 92% greater than the Shawnee County rate of 9.6%. In some portions of these areas, poverty rates exceeded 40%. The 2000 unemployment rate of 8.1% in these three areas was 69% greater than the city rate, 93% greater than the Kansas rate, and 103% greater than the county rate, and some block groups reached rates as high as 19%. Per capita income for these areas in 2000 was $14,403, which was only three-quarters of the Topeka per capita income, about seven-tenths of Shawnee County, and two-thirds of the national figure. (See sections 2.1.2, 2.4.2, 2.5.2, and 2.6.2 as well as Table D-4.)

- Minority residents suffer greater flood risk *(probable adverse socioeconomic impacts)* - Hispanics account for 20.4% of South Topeka's population and 27.1% of Oakland's residents. These percentages are approximately twice the national percentage of 12.5%, two to three times the Topeka percentage of 8.9%, and three to four times the state percentage of 7.0%. In about half of the Oakland and South Topeka block groups, Hispanics account for more than 25% of the population, and a few areas have majority Hispanic populations. (Again, see sections 2.1.2, 2.4.2, and 2.5.2 as well as Table D-4.)

- Threats to center city redevelopment *(probable adverse cultural impacts)* - Topeka's long-term efforts to maintain and rebuild center city areas would be dealt a crippling blow. The floodplain areas of North Topeka, Oakland and South Topeka comprise a substantial portion of the center city. Population losses from the center city would occur as residents flee the likelihood of flood damage and react to the shrinkage in area job opportunities. High vacancy rates would characterize commercial properties and the housing stock.

- Threats to riverfront redevelopment *(possible adverse cultural, historical and aesthetic impacts)* - Also touched on above under R.E.D. impacts; if redevelopment is indeed hampered, it would negatively affect aesthetic values (removal of blight followed by orderly, planned redevelopment) and historical values (the riverfront is where the city began).

- Untreated sewage releases *(adverse health and environmental impacts)* - The city sewage treatment plants in Oakland and North Topeka would likely be subject to frequent short-term operational interruptions, and the interruptions would be much longer term in flood events causing physical damages at the facilities. Service interruptions would result in large releases of unprocessed sewage into the Kansas River, adversely affecting public health (potentially) and environmental values (certainly).

3.0 Environmental Considerations

The future without project condition of the natural environment in the study area is discussed in the attached Environmental Assessment. Generally, the remaining habitat within the study area is confined to the riparian corridor and this area is not expected to be subject to impact or change from future development. However, as development of the City of Topeka increases outside the current study area, the importance of the existing riparian corridor within the larger environmental context is expected to increase.

C. Planning Problems and Opportunities

The primary study area problem is that the existing levee system does not reliably provide the design level of flood risk management. This is supported by the research of design and authorizing documents, engineering analysis performed using current criteria, and mathematical modeling. The specific problem areas of the system that cause low reliability include floodwalls, pump stations, manholes, and areas of underseepage concern. The low reliabilities exhibited in this system pose a public safety risk to a significant population and sizeable area of economic investment.

This study presents the opportunity to restore the reliability of the local flood risk management system and thereby minimize damages from future flood events. By doing so, there is the opportunity to provide the affected community the confidence to continue with future economic development. Opportunities for protection or enhancement of the natural and cultural resources of the area also exist and may be addressed by the study or by other related activities taking place or proposed in the study area.

VII. Hydrologic and Hydraulic Analysis

As part of the feasibility study, hydraulic investigations were conducted on the Kansas River, Soldier Creek, and Shunganunga Creek using the HEC-RAS computer software developed by the Hydrologic Engineering Center, U.S. Army Corps of Engineers. Hydraulic models were developed using 1997 survey data supplemented with 1995 four-foot aerial contour maps supplied by the City of Topeka and calibrated using high water marks from the 1993 Flood. Water surface profiles were then generated for eight different discharge events. These include the 10, 2, 1, 0.5, 0.2, 0.133, 0.1, and 0.04-percent chance (10, 50, 100, 200, 500, 750, 1000, and 2500-year) flood events. The discharge uncertainty results are detailed in Chapter 2 of Appendix A for a range of frequencies.

A. Kansas River

The area of hydraulic investigation extends from Kansas River mile 73.0 through mile 96.5. A HEC-RAS hydraulic model was developed to determine the expected flood discharge based on statistical analysis of the Topeka Gage located on the Sardou Avenue Bridge. The uncertainty in both stage and discharge were calculated. The standard deviation of stage is 0.85 feet.

The Kansas River discharges and associated flood frequencies, up to the 0.2% (500-year) event, are shown in Table 5. Model results for larger events and the associated discharge-frequency curve are provided in Chapter 2 of Appendix A.

Table 5. Kansas River Discharge-Frequency Relationship

Annual Percent Chance of Exceedance	Flow at Topeka Gage (cfs)
0.2	348,000
0.5	268,000
1	217,000
2	173,000
5	123,000
10	93,600
20	67,200
50	36,600

The current authorized design discharge is 314,000 cfs, which corresponds to an approximate annual percent chance of exceedance of 0.33% (300-year flood). The currently authorized discharge is less than the discharge of 340,000 cfs originally authorized in 1936. The discharge was lowered due to the influence of the upstream reservoir control system that was under development at the time of the 1954 Flood Control Act. However, two of the proposed upstream reservoirs considered in the discharge determination were later deauthorized and not constructed.

Today's methods of hydraulic analyses are based on risk and uncertainty calculation (reliability) instead of the freeboard concept used in the past. Current practice is to establish the water surface elevation at which the intended river flow can be contained by the levee with 90% reliability. Using the current hydraulic model, the 90% reliable elevations for the design flow are higher than the top of the existing project in each of the four units where improvements are proposed; overtopping margins range from 0.3 to 1.47 feet.

According to the current hydraulic model, the North and South Topeka units will begin overtopping at 300,000 cfs, and the Oakland unit at 305,000 cfs. The average difference in water surface elevation between 300,000 cfs and the authorized discharge of 314,000 cfs is only 0.4 feet and the standard deviation of the model itself is 0.85 feet, thus making these differences statistically insignificant.

While an understanding of the hydraulic performance of the levee system at high Kansas River flows is important, it is secondary to the fact that many of the geotechnical and structural issues discussed in other sections of this report occur at elevations at, or below, the top of the existing project, causing a significant risk of project failure before overtopping. Furthermore, the formulation of alternatives to address a small stage discrepancy at a high flood level is not considered practical or cost-effective. The potential for increased benefits stemming from such a raise would be very limited since incremental damage prevention benefits would be associated with only the most extreme flood events. Thus, no further consideration was given to a levee raise in this study.

B. Soldier Creek

The hydraulic investigation was completed on the first ten miles of Soldier Creek. The hydrologic analysis was completed to determine the expected discharges at the flood risk management works based upon statistical analyses of four stream flow gages in the watershed.

The model shows that the existing Soldier Creek levees are not overtopped until the 0.5% chance exceedance (200-year) flood event. The uncertainty in both stage and discharge were calculated. The standard deviation of stage is 1.68 feet.

C. Shunganunga Creek

The hydraulic investigation was completed to calculate water surface profiles on approximately the first five miles of Shunganunga Creek adjacent to the Oakland Levee Unit, from the mouth of Shunganunga Creek to the 10th Street Bridge. To determine the expected discharges within the Oakland Levee Unit, a watershed analysis was completed using the Storm Water Management Model (SWMM) computer software developed by the U.S. Environmental Protection Agency. The model was calibrated using data from a U.S.G.S. gage that was located at the upstream face of Rice Bridge from May 1980 to September 1981.

The model shows that the existing Shunganunga Creek levees are not overtopped until the 0.04% chance exceedance (2500-year) flood event (with a 50% chance of non-exceedance).

VIII. Flood Damage Estimates

A. Economic Damage Analysis Methodology

This section provides a summary of the data and methods used to perform the economic risk analysis of the study area. A detailed discussion is provided in Appendix D of this report. The study area was divided into reaches for the economic analysis, as summarized in Table 6.

Table 6. Economic Study Reaches

Name	Stream	Bank	Reach Description	Beg. Station	End Station	Index Station
WW	Kansas River	Right	Waterworks unit	86.7	87.2	87.0
AUB	Kansas River	Right	Auburndale unit	85.5	86.7	86.1
ST	Kansas River	Right	South Topeka unit	83.7	85.5	84.8
OAK	Kansas River	Right	Oakland unit	76.0	83.7	82.3
NT	Kansas River	Left	North Topeka unit	80.8	88.8	85.6
SC-RB1	Soldier Creek	Right	Urban subunit - North Topeka	0.2	7.2	4.2
SC-RB2	Soldier Creek	Right	Rural subunit @ Silver Creek ditch	8.1	10.0	8.7
SC-LB1	Soldier Creek	Left	Rural subunit @ Hwy. 24	0.2	0.6	0.4
SC-LB2	Soldier Creek	Left	Rural subunit @ Kansas Ave.	1.9	2.3	2.2
SC-LB3	Soldier Creek	Left	Rural subunit @ Rochester Rd.	2.7	3.1	3.0
SC-LB4	Soldier Creek	Left	Rural subunit @ Brickyard Rd	5.5	6.7	6.2
SC-LB5	Soldier Creek	Left	Rural subunit @ Menoken Rd	6.8	7.5	7.3
SC-LB6	Soldier Creek	Left	Rural subunit @ NW 33rd St. west end	7.6	8.0	7.9

Kansas City District economics staff carried out a structure-by-structure field survey of all buildings in the study area. The economic structure inventory is categorized in terms of four basic land uses: residential (including farm sets), non-residential (including businesses, non-profit institutions such as churches and schools, public facilities and utilities), roads and streets, and agriculture (crops).

Data obtained from county and city tax and GIS data, the field survey, and discussions with businesses were further developed, refined, and organized to produce the three key variables for each property to be used in the damage analysis: beginning damage elevations, property values, and depth-damage relationships. The risk analysis program used for the damage analysis also requires specification of uncertainty factors for each of these variables.

The comprehensive structure inventory for the study area – including elevations, values, and depth-damage functions for each property – was entered into the HEC-FDA software (Hydrologic Engineering Center's Flood Damage Analysis program), a risk analysis software product that is standard for Corps of Engineers flood risk management analyses. All engineering and economic data are entered into the program in terms of median or most likely values and accompanied by appropriate uncertainty parameters specifying the range of possible values for each variable. The subsequent risk analysis simulates tens of thousands of theoretical flood events, synthetically extending the period of record to thousands of years and thereby producing results that embody uncertainties in assumptions and the dynamic interaction of variables over time. For each event, the program samples the range of possible values for each variable and determines (a) whether the flood event results in damage, and (b) how much damage occurs.

A complicating factor in the economic analysis for the Oakland and South Topeka units is presented by the issue of hydraulic independence. Despite the longstanding practice in older reports of treating the two units as separate and independent, further inspection determined that they are instead "partially dependent." Overland flows from any flood event not contained by the South Topeka levee can also enter and flood the Oakland area immediately downstream. Flooding originating in Oakland, on the other hand, cannot overcome the rising land elevations as it tries to back up into the upstream South Topeka area.

It is apparent from the nature of this relationship that any evaluation of damages or benefits of proposed alternatives properly attributable to the South Topeka levee unit must account for damages in Oakland as well as in South Topeka. Damages in the Oakland area can be attributed to both of these units to some extent. At the same time, computational methods must head off the potential for double-counting Oakland damages since they can be attributed to either the Oakland levee or the South Topeka levee. Computations of economic outputs -- damages and benefits -- in this report will consider the South Topeka and Oakland areas as a single combined reach in order to avoid double-counting while accounting for the full impact of project deficiencies. On the other hand, the two units will be rated separately in terms of engineering performance.

The North Topeka unit along the Kansas River and the main subunit of the Soldier Creek unit each protect essentially the same urban area of North Topeka. Separate analyses evaluate the damages attributable to each unit - i.e., the model contains no assumptions or data linking stages and discharges on Soldier Creek with corresponding data for the Kansas River, and the economic structure inventory used is identical for both streams. For this reason, the damages for the two units are not additive. Double counting would result from any summation of North Topeka and Soldier Creek urban damages. Damage totals for the North Topeka area cited in this analysis will reflect damages attributable to the North Topeka unit on the Kansas River unless otherwise stated. It also should be noted that the foregoing discussion applies only to the main urban subunit of the Soldier Creek unit. The other subunits protect small rural areas primarily on the left bank of Soldier Creek that are distinct from the urban North Topeka area. These properties are protected only by the Soldier Creek unit. Damages identified as "Soldier Creek rural" are distinct from North Topeka area damages and are additive with North Topeka damages, unlike the "Soldier Creek urban" damages.

The base year for the economic analysis - i.e., the year when the project would be completed and operational - is 2015. The base year condition also is used to describe the existing condition in this analysis. Existing conditions data would not differ from base year data in any respect, including economic structure inventory, hydraulic and hydrologic conditions, or structural and geotechnical estimates. A future condition also is defined for 2038, but it again is based on exactly the same data sets as the 2015 condition. All available information on prospective economic development in the floodplain areas was obtained in 2008 as this study was being completed. Of the possible projects on the horizon, most were not yet definite, while others that were definite were not far enough along to identify specific locations and estimate investment and damage potential. Ultimately, expected future development was not included in any of the conditions used - existing, base, or future.

B. Study Area Investment

The Topeka Federal Levee system collectively protects property valued at $2.67 billion, as summarized in Table 7. The study area includes 6,487 homes and 790 businesses and public facilities as well as 164 miles of roads and streets (including 28 miles of railroad) and more than 800 crop acres. North Topeka accounts for more than half of total investment (55.1%), while South Topeka and Oakland combined account for about 36.8%. The other units of the system - Waterworks, Auburndale, and the Soldier Creek rural areas - have much smaller property bases that collectively account for about 8% of total investment.

Table 7. Study Area Investment

	WW	AUB	S TOP	OAK	N TOP	SOLD CK RURAL	TOTAL STUDY AREA	% OF TOTAL
Non-residential (businesses and public facilities)								
Quantity	1	18	142	89	539	1	790	
Structures	$26,961.1	$11,218 4	$151,326.4	$54,279.2	$250,341.5	$83.7	$494,210.3	
Contents (equipment/ inventories)	$35,642.6	$11,028.6	$224,581.2	$151,588 0	$886,698.7	$107.1	$495,000.3	
Total Value	$62,603.7	$22,247.0	$375,907.6	$205,867.2	$1,137,040.2	$190 8	$1,803,856.5	67.5%
Residential								
# Homes	0	616	80	2,942	2,752	97	6,487	
Structures	$0.0	$47,711.3	$2,318.2	$186,925.9	$129,664.2	$14,638.0	$381,257.6	
Contents (including autos and landscaping)	$0.0	$33,397.9	$1,622.7	$130,848.1	$90,764.9	$10,246 6	$387,744.6	
Total Value	$0.0	$81,109.2	$3,940.9	$317,774.0	$220,429 1	$24,884.6	$648,137.8	24.3%
Roads & Streets (railroads, highways, city streets & county roads)								
Miles	0.6	11.2	20.0	45.9	82.9	3.3	163.9	
Total Value	$1,301.2	$15,824.6	$27,758.8	$53,750.3	$113,967.5	$3,561.6	$216,164.0	8.1%
Agriculture								
Cropped Acres	0	0	0	90	15	700	805	
Total Value	$0.0	$0.0	$0.0	$270.0	$45.0	$2,100.0	$2,415.0	0.1%
Total Value	**$63,904.9**	**$119,180.8**	**$407,607.3**	**$577,661.5**	**$1,471,481.8**	**$30,737.0**	**$2,670,573.3**	100.0%
% of total	2.4%	4.5%	15.3%	21.6%	55.1%	1.2%		
October 2008 prices; all structure and content values reflect depreciated replacement values								

C. Damage Results

This section summarizes the results of the without-project economic analysis as they pertain to beginning damage points and selected flood events. Table 8 presents the Equivalent Annual Damages (EAD) expected and Table 9 details the expected engineering performance of the system. A more detailed analysis and discussion of the without-project condition damages is presented in Appendix D.

Table 8. Equivalent Annual Damages (Existing Conditions)

Oct 2008 prices, 4.625% interest rate; $1,000s

Levee Unit	Non-Residential	Residential	Roads	Ag	Emergency	Disaster Relief	Lost Production	Total	% of Total
KANSAS RIVER									
WATERWORKS	$193.1	$0.0	$0.3	$0.0	$28.5	$0.0	$0.0	$221.8	1.0%
AUBURNDALE	$39.9	$125.7	$9.2	$0.0	$14.2	$14.7	$0.0	$203.7	0.9%
SOUTH TOPEKA/OAKLAND	$2,579.6	$2,786.3	$184.6	$0.1	$506.8	$247.3	$52.9	$6,357.6	27.8%
NORTH TOPEKA	$11,694.8	$2,857.8	$480.8	$0.1	$737.0	$149.3	$111.9	$16,031.7	70.1%
TOTAL KANSAS RIVER	$14,507.3	$5,769.8	$674.9	$0.1	$1,286.5	$411.3	$164.9	$22,814.8	99.8%
SOLDIER CREEK									
Urban (North Topeka)	$1,258.4	$202.2	$19.3	$0.0	$324.5	$55.3	$12.3	$1,872.0	
Rural	$0.2	$42.3	$1.3	$0.9	$3.6	$2.9	$0.0	$51.1	0.2%
TOTAL SOLDIER CREEK	$1,258.6	$244.5	$20.6	$0.9	$328.0	$58.2	$12.3	$1,923.1	
TOTAL	**$14,507.5**	**$5,812.1**	**$676.1**	**$1.0**	**$1,290.1**	**$414.3**	**$164.9**	**$22,865.9**	100.0%

Soldier Creek urban damages are for the same area covered by the North Topeka unit and are not counted in the study area total

Oakland totals reflect combined probabilities of failure for both Oakland and South Topeka. The Oakland totals represent all damage that would occur in Oakland without regard to the source of the flooding, which can be either the Oakland unit or the South Topeka unit. South Topeka totals include only damage occurring in South Topeka and do not include damages in Oakland attributable to the South Topeka unit.

Table 9. Engineering Performance (Existing Conditions)

	WW	AUB	S TOP	OAK	N TOP	SOLD CRK URBAN
ANNUAL EXCEEDANCE PROBABILITY (median)	0.003	0.003	0.004	0.057	0.024	0.006
Return interval (years)	333	333	250	18	42	167
LONG-TERM RISK						
(chance of exceedance during indicated period)						
over 10 years	1 in 25	1 in 32	1 in 23	1 in 2	1 in 4	1 in 13
over 25 years	1 in 10	1 in 13	1 in 9	1 in 1.3	1 in 2	1 in 5
over 50 years	1 in 5	1 in 7	1 in 5	1 in 1	1 in 1.4	1 in 3
PERFORMANCE VS. 1% FLOOD						
Initial overtopping elevation margin over nominal 1% flood elevation (feet)	5.9	8.2	6.5	3.7	6.6	1.7
Conditional exceedance probability - overtopping or failure	0.072	0.032	0.158	0.971	0.860	0.332
Conditional exceedance probability - overtopping only	0.067	0.032	0.054	0.058	0.054	0.332
OTHER FLOOD EVENTS - EXCEEDANCE PROBABILITIES						
10.0%	0.000	0.000	0.000	0.165	0.004	0.000
4.0%	0.000	0.000	0.003	0.589	0.180	0.002
2.0%	0.003	0.032	0.031	0.857	0.554	0.094
0.4%	0.331	0.213	0.436	0.995	0.970	0.661
0.2%	0.758	0.644	0.806	1.000	0.998	0.817

Annual exceedance probability is the chance of experiencing any flood event - of whatever magnitude - within any year.
Conditional exceedance probability is the probability that a specified flood event would overtop or breach the levee.

In general, the analysis produces two conclusions regarding engineering performance:

(1) Hydraulically, all of the Kansas River units at Topeka are sufficiently high to offer protection against all but the most extreme events.

(2) Significant geotechnical and structural concerns are compromising the reliability of the three largest units - North Topeka, Oakland, and South Topeka. There also are significant but lesser concerns at Waterworks, while Auburndale and Soldier Creek have no identified problem areas.

IX. Plan Formulation

A. Planning Constraints

The following planning constraints affect many decisions related to study execution:

- The study shall be conducted in accordance with the *Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies,* as approved by President Ronald Reagan, February 3, 1983 and accepted by the United States Water Resources Council on February 22, 1983. These guidelines are contained in the U.S. Army Corps of Engineers Engineering Regulation (ER) 1105-2-100, *Policy and Planning, Guidance for Conducting Civil Works Planning Studies.*

- Feasible projects will comply with the principles of Executive Order 11988 which addresses floodplain management and Section 404 of the Clean Water Act concerning the protection of wetlands. Project planning must be accomplished to minimize project effects on floodplains in general, and wetlands and other environmental features. Mitigation must be considered where applicable

- Project formulation will adhere to FEMA minimum requirements adopted by the City of Topeka and Shawnee County regarding the regulatory floodway. These guidelines require that construction in the base floodplain be accomplished in such a manner as to limit any resulting increase in the 1.0-percent-chance flood elevation to one foot or less.

- Project Design alternatives recognize the provisions of Section 404 of the Robert T. Stafford Disaster Relief and Emergency Assistance Act and the Hazard Mitigation Grant Program administered by FEMA and the Kansas State Division of Emergency Management.

- Relationships between the levee units will be maintained. For this feasibility study, the examination of measures to increase the performance of the system will be guided by an overarching principle that seeks to achieve a relatively consistent level of performance throughout the system. This essentially means that the study should avoid recommending:
    - Any measures which would directly or indirectly exacerbate any performance weaknesses (or relative weaknesses) of another unit.

- Any measures that would contribute to increasing the level of performance of one unit without a commensurate increase or at the expense another unit.

- Project alternative screening will consider the financial capability of the local sponsor. Feasibility phase financial constraints play a very significant role in the execution of this study. Sponsor affordability and associated financial constraints demand that feasibility analysis, scoping, and planning decisions must first focus on those areas, measures and solutions which address pressing needs or significant performance weaknesses within the overall system as these will provide the greatest relative opportunity for reliability improvements.

- All other items of the study will be in accordance with the standards of the U.S. Army Corps of Engineers.

B. Planning Objectives

A primary objective of Corps feasibility studies is to comply with the national objective of water and related land resources planning. This includes contributing to the National Economic Development (NED) consistent with protecting the Nation's environment. Contributions to NED are increases in the net value of the national output of goods and services, expressed in monetary units. The NED Plan is that alternative that maximizes net benefits over the period of analysis.

Other planning objectives for the Feasibility Study include:

- Update and verify data on the reliability of the existing project performance under flood conditions.

- Formulate measures/components (to include the "no Federal action" alternative) that provide each levee unit a complete plan to restore unit reliability to acceptable levels as needed.

- Identify the National Economic Development (NED) Plan that maximizes net economic benefits for each unit.

- Develop a comprehensive plan that provides for acceptable reliability of the entire existing system and increases economic flood risk management benefits.

- Provide a complete final recommended plan for implementation that is technically sound, economically feasible, and environmentally acceptable.

- Reduce the potential for loss of life and human suffering caused by flooding within the project area.

- Integrate the Environmental Operating Principles into the project plan by minimizing the impact of the proposed project, maintaining or improving the current environmental conditions, and preserving the cultural and historical resources within the project area.

C. Development and Screening of Alternatives

The results of the existing conditions analysis and observations and effects from historic and recent flood events were used to formulate potential engineered solutions aimed at lowering the risk of flooding for units under study. Often these alternatives needed to address problems with specific segments or locations within a unit (the problem areas are termed "areas of interest", or AOI in this report).

An initial set of alternative measures was developed using experience from other levee system studies and investigation of current engineering practices. These alternatives were screened and refined for their application at each AOI. As the process continued, additional alternatives surfaced and were examined. Alternatives were examined and compared considering the Federal criteria of completeness, efficiency, effectiveness, and acceptability. Alternatives were closely examined for their potential to impact the environment. As the alternatives passed through this evaluation and screening process, the economic analysis of each alternative's incremental cost was used as a ranking factor in the final selection. Having passed review for engineering adequacy, environmental and public acceptability, and other evaluation criteria as described below, the remaining alternative with the highest net benefits to the national economy was identified as a component of the overall recommended NED plan.

The development and screening of alternatives involved the consideration of a number of evaluation factors or criteria. Primary among those factors were the following:

- Engineering adequacy of the proposed solutions (effectiveness)
- Contribution to planning objectives (related to completeness of solution)
- Consistency with planning constraints and authorities
- Environmental, cultural, and public acceptability
- Early cost indicators (early efficiency indicators for screening purposes)
- Floodway conveyance considerations
- Hazardous and regulated waste site constraints (where applicable)
- Constructability (are construction techniques and quality difficult to attain at reasonable price)
- Construction site constraints (given existing features and development)

Engineering Adequacy: The engineering adequacy of alternatives was analyzed and reviewed during the initial screening process. Any alternatives which could not meet the minimum technical criteria for the expected flood conditions were eliminated from further review. This is a key effectiveness criterion and normally must be met. The amount of engineering analysis necessary to perform the engineering review was generally considerable and is contained in the Engineering Appendix.

Environmental Acceptability: Environmental acceptability of alternatives was reviewed in concert with appropriate resource agency guidance. Any alternative which had major disruptive effects on the environment was normally screened out. A typical formulation exercise would involve adjusting some of the alternative measures so as to minimize any environmental impacts when such impacts could not reasonably be avoided.

Cultural Acceptability: As the alternatives were developed, the areas likely to be affected by implementation were reviewed for the presence of any known cultural and historical resources. Steps were taken during the alternatives screening and refinement process to generally avoid any impacts to culturally significant sites.

Early Cost Indicators (efficiency): Early approximate cost indicators related to the various alternatives were used to determine if an alternative was prudent for further examination. As the evaluation process continued, cost estimates and economics were refined. The detailed cost estimating and economic analysis normally focused only on those alternatives that remained viable solutions after early screening criteria were passed.

Floodway Conveyance Considerations: Very early in the plan formulation process, a general guiding rule was adopted: any measures which negatively impacted the established floodway conveyance should be avoided. This was deemed essential as in most cases levees lie along both banks of the river reaches within the study area, and are often located either upstream or downstream of another unit. This principle is consistent with floodway "no rise" criteria as promulgated under FEMA regulations. This criterion was maintained during feasibility and the final alternatives are essentially benign in respect to any adverse floodway impact.

The following sections describe the specific measures considered and the results of the screening and evaluation process.

D. Measures Considered for Plan Formulation

Traditional Corps analyses for identification of the NED plan (the plan with the highest net benefits) involve identifying an array of measures (structural and non-structural) to achieve the stated objectives and then determining the most cost-effective combination of those measures that fully addresses the identified problems.

The initial plan formulation concepts which guided early portions of the feasibility study were based on producing a plan and report which addressed all units within the six levee system. This approach had its genesis in the abbreviated studies conducted during the reconnaissance phase which indicated the possibility of system-wide levee raises. While no feasibility level plans were developed along these lines, it was the original guiding expectation.

The initial broad feasibility evaluations of existing conditions undertaken during the first several years of this study allowed subsequent formulation efforts more focus. The development of measures to increase reliability was narrowed to the candidate sites which indicated significant risk, offered the best opportunity for significant reliability improvements, and had the greatest potential for economic return on investment. These candidates were also reviewed for compatibility with the basic planning objectives and constraints which emphasized the desirability of a relatively uniform level of flood risk management across the system.

As feasibility progressed, the development of reliability improvements were thus focused on those areas of interest (AOI) with relatively low reliability; i.e. areas where low reliability significantly compromised the project's original intended level of performance. Engineered reliability remedies and improvements were developed considering both the improvements to individual unit performance and the performance of the whole system.

1.0 Non-Structural Measures

Beginning with the Flood Control Act of 1936, the Federal government has led the nation's flood risk management efforts, and as a result, also led the nation's floodplain management activity. Historically, structural programs such as levees, floodwalls, channelization, and dam and reservoir projects played the lead role in preventing flood damages. In more recent years, the Federal government has endeavored to support nonstructural approaches (such as flood warning systems, flood-proofing of structures, floodplain management, etc.).

Nonstructural approaches have merit when the site characteristics and the flooding threat are compatible with the nonstructural capabilities. In the case of the existing Topeka flood risk management system, nonstructural methods were eliminated early as potential solutions due to:

- Planning objectives for this study (which address existing structural flood risk management systems) cannot be met through the use of nonstructural measures.
- The need for large-scale risk reduction within the extensive protected areas is best accomplished through performance improvements to the existing Topeka structural flood risk management system.
- The performance of the existing Topeka flood risk management system far exceeds the normal performance parameters of nonstructural measures.

No opportunity for large-scale application of nonstructural measures is foreseen within this study other than continuing to effectively manage the floodplain using FEMA NFIP guidelines. It may be possible to find some limited use for nonstructural measures along the fringe of the protected area and for the prevention of damages due to localized interior flooding. These potential limited applications are outside the scope of this study and doe not warrant Federal involvement.

2.0 Flood Fighting Alternative

The flood fight alternative normally requires a stockpile of sandbags to be stored near areas subject to high underseepage pressures or overtopping. Sandbags are then deployed to strategic locations and placed (or stacked) in accordance with proven flood fighting techniques. These stacks of sandbags serve to add mass or height in an attempt to temporarily reinforce the permanent features already in place. When working with major levee systems, flood fighting is generally best thought of as an aid to manage unpredictable and unforeseen problems during flood events.

For large levee units where substantial investment is protected, some flood fighting can be planned and implemented for limited low-risk situations. But, in general, when exposed to massive flood events, flood fighting measures will often prove unreliable. For the levee units and problems under examination in this study, flood fighting is generally not an acceptable planning alternative when compared to engineered solutions. Flood fighting generally will not prevent underseepage failures when dealing with very high pressures, nor can flood fighting reliably prevent structural floodwall failures under extreme load conditions.

3.0 Structural Measures

Underseepage Measures

- Landside Seepage Berm. Constructing a seepage berm of pervious fill to control underseepage during a flood event is considered an effective and relatively reliable alternative. Direct construction costs associated with this alternative are typically moderate. Indirect costs such as extending the right-of-way and conducting subsurface investigations can add additional costs. If sufficient real estate is not available, structural demolition and relocating of utilities, residences and businesses will greatly increase the total cost and logistics problems associated with this alternative.

- Buried Collector System. A buried collector is constructed using perforated pipe placed within an excavated trench adjacent to the levee on the landside. Typically, buried collectors include a drainage pipe or ditch, which collects and removes seep water. Buried collectors require greater maintenance than underseepage berms but are effective in areas with restricted construction space.

- Pressure Relief Wells. This alternative consists of installing a series of pressure relief wells along the landside toe of the levee. Wells can normally discharge directly to ground or if needed a header system may serve to transfer seep-water from the wells to a selected discharge area or to a pump station. Relief wells are a highly effective apparatus used to control underseepage. However, pressure relief well performance is very dependent upon the quality of construction, and the long-term maintenance costs associated with this alternative are greater than installing a buried collector system.

Uplift Measures

- Structure Abandonment. If a structure is determined to no longer be a necessary component of the flood risk management system, it can be removed and/or properly abandoned in place. This should not be confused with the No Action alternative as proper abandonment of a deficient structure removes a potential avenue of levee failure and contributes to lowering the risk of flooding.

- Pump Station Operational Change Alternative. In the case of a pump station, it may be possible to change the operations plan to keep more water in the wet well and thereby increase the weight of the station and counteract the uplift pressures. Leaving more water in the well may require changes in the pumps themselves.

- Heel Extension Alternative. A heel extension is another method of increasing the weight of a structure to counteract uplift pressures. The area around the structure (pump station or manhole) is excavated to expose the foundation base, or heel, of the structure. The heel is extended using additional concrete to increase the weight and size of the structure.

- Remove and Replace Alternative. The most expensive alternative for correcting an uplift concern is to remove the existing structure and replace with a new structure designed to counteract the hydraulic pressures. However, for structures where required factors of safety cannot be obtained by other alternatives, replacement is the preferred alternative.

Floodwall Sliding Stability Measures

- Wall Replacement. Replacement of the affected wall sections with new sections designed to better withstand the sliding forces can be complex and construction intensive, requiring the provision of temporary flood risk management during construction, and protection of the integrity of the existing sections not being replaced.

- Foundation Modification. Foundation modifications may increase the factor of safety against sliding, but would require excavation of the existing foundation which may place increased stress on the existing wall during construction. Foundation modifications under an existing wall are technically complex and the quality of installation can be difficult to maintain. These factors increase the cost of this alternative comparative to other available alternatives.

- Landside Stability Berm. The placement of an earthen stability berm along the landside of the wall would provide the needed additional stability with minimal impact to the integrity of the existing wall and foundation. A stability berm typically consists of compacted soil extending from the wall landward and then tapering to the existing ground surface. Berm dimensions will depend on the degree of stability required. Comparison of the stability berm alternative to wall replacement or foundation modification indicates that a berm is typically more cost effective by orders of magnitude and can provides the same benefits. However, as the need for stability support increases, the size of the berm can become excessive, requiring additional easement space and the provision of large quantities of soil material. For floodwalls exhibiting high degrees of instability, a stability berm may not be as effective as other alternatives.

Pump Station Strength Measures

- Reinforcement. Interior reinforcement of a pump station can be achieved by installation of a wall stiffener. A wall stiffener is a steel beam or plate attached to the inside of the station wall that shortens the effective length of the existing steel reinforcement, increasing its ability to resist bending.

- Remove and Replace. The removal and replacement of a pump station with a new structure designed to withstand hydraulic pressures is a much greater cost than reinforcement.

Floodwall Foundation Measures

- Construct a new floodwall on same alignment or landward of the existing wall. A new floodwall designed and constructed with current standards and methods would provide the risk management benefits intended by the existing wall. By constructing a new wall landward of the existing wall, costs of removal of the old wall are minimized. However, sufficient right-of-way would be required for the new structure. If sufficient right-of-way and clearances are not available the original wall and foundation would require complete removal.

- Earthen fill against landside of existing floodwall, temporary or permanent. Similar to a stability berm, the placement of earthen fill, essentially the same as earth levee construction, might help the wall to resist deflection during high flows.

- Structural modification of the existing floodwall and foundation. Structural reinforcement to resist wall deflection could be installed.

- Foundation soil strengthening by jet grouting. Soil strengthening may increase the capacity of the soil to resist pile movement during high flows.

E. Screening of Measures

The measures presented in the previous section were examined to address their ability to adequately address the deficiencies and potential failure modes described earlier in this document. Those found lacking sufficient validity were screened-out. A preliminary assessment of the potential environmental impact of each measure was also considered. Environmental impacts of measures carried forward for additional analysis are discussed more fully in the attached Environmental Assessment.

Table 10 lists the initial array of measures for each AOI, the results of the screening review, and indicates whether the measure was carried forward for more detailed analysis. The rest of this section presents more detailed discussions of the screening.

1.0 North Topeka Unit

Geotechnical Concerns

Geotechnical analysis of the North Topeka Unit revealed two areas of underseepage risk between approximately stations 165+00 to 189+00 and stations 246+00 to 250+00.

The area from station 165+00 to 189+00 has a sufficient amount of landward open space to construct an underseepage berm. A berm in this location would need to be seven feet thick at the levee toe, sloping down to three feet thick at a distance of 220 feet landward of the levee. This will require the acquisition of 122,250 cubic yards of fill material and temporary easements for borrow excavation and construction activities. Borrow source locations and potential impacts are discussed in the next section.

A relief well system installed in this same area would require a series of thirty-two wells installed at an average spacing of 75 feet. Installation of a relief well system would not require the impacts caused by borrow site excavation and would likely require less easement acquisition. However, relief wells would require expanded future operation and maintenance activities for periodic cleaning and testing, and eventual replacement.

Neither measure at this location would create an apparent environmental impact. Both the underseepage berm and relief well measures at this location were carried forward for additional study at this site.

The area from station 246+00 to 250+00 is constrained by existing railroad tracks and does not provide enough area to construct a seepage berm without substantial and expensive relocations. Furthermore, uplift pressures are not high enough to allow ground discharge through a buried collector system or relief wells.

A pumped relief well and collector system would address the underseepage concern in this area. Specifically, seven evenly spaced relief wells connected to a header are needed, with temporary or permanent pumping during high flow events. Temporary pumping does create an added requirement on the local sponsor during flood fighting and will increase the cost of operation. A permanent pump station would eliminate the potential logistical issues of providing a temporary pump during a flood event, but would also substantially increase construction and future operation and maintenance costs.

The pumped well system measure would not be expected to create an environmental impact and was carried forward for additional consideration at this site

Table 10
Topeka, Kansas, Feasibility Study
Alternatives Matrix

Description of Problem by Levee Unit and Location	Possible Alternative Corrective Measures					Discussion
	1	2	3	4	5	
North Topeka Unit, Station 364+60 Fairchild Pump Station Problem: Uplift	Operational changes	Heel Extension	Remove and replace	Abandon		Fairchild Pump Station out-dated and no longer used or maintained by sponsor. Recommend measure 4.
North Topeka Unit, Station 246+00 to 250+00 Problem: Underseepage	Underseepage berm.	Buried collector system.	Relief wells discharging to ground.	Relief wells discharging to manhole w/ temporary pumping.	Relief wells discharging to permanent pump station.	Insufficient area is available to install measure 1. Uplift pressures are not high enough to allow for ground discharge. Pumping only required at times of high flow. Permanent pump station would increase construction cost and future O&M. Recommend measure 4.
North Topeka Unit, Station 165+00 to 189+00 Problem: Underseepage	Underseepage berm.	Buried collector system.	Relief wells discharging to ground.	Relief wells discharging to manhole w/ temporary pumping.	Relief wells discharging to permanent pump station.	Sufficient open land is available to install measure 1. Recommend berm 7 feet thick and 220 feet wide consisting of 140,000 cy of random fill material.
Oakland Unit, Station 220+00 East Oakland Pump Station Problem: Uplift	Operational changes	Heel Extension	Remove and Replace	Abandon		Measure 1 will not provide sufficient uplift factor of safety. Recommend measure 2.
Oakland Unit, Station 75+50 - Manhole Problem: Uplift	Heel Extension	Remove and Replace				Measure 1 will provide minimum uplift factor of safety.
Oakland Unit, Station 485+86 to 491+01 Problem: Sliding Stability	Stability berm	Foundation Mod				Measure 1 will provide minimum sliding stability factor of safety.
Oakland Unit, Station 64+00 to 80+00 Problem: Underseepage	Underseepage berm.	Buried collector system.	Relief wells discharging to ground.	Relief wells discharging to manhole w/ temporary pumping.	Relief wells discharging to permanent pump station.	Sufficient open land is available to install measure 1. Recommend berm 6.5 feet thick and 240 feet wide consisting of 70,000 cy of random fill material.
South Topeka Unit, Station 75+84 Kansas Avenue Pump Station Problem: Strength	Wall Stiffener	Remove and Replace	Abandon			Measure 1 will provide minimum strength factor of safety.
South Topeka Unit, Station 86+00 Madison St. Pump Station Problem: Uplift	Operational changes	Heel Extension	Remove and Replace	Abandon		Measures 1 will not provide required minimum uplift factor of safety. Insufficient area is available for excavation to install measure 2. Recommend measure 3.
South Topeka Unit, Station 16+07 - Manhole Problem: Uplift	Heel Extension	Remove and Replace				Measure 1 will provide minimum uplift factor of safety.
South Topeka Unit, Station 84+10 - Manhole Problem: Uplift	Heel Extension	Remove and Replace				Measure 1 will provide minimum uplift factor of safety.
South Topeka Unit, Station 84+10a - Manhole Problem: Uplift	Heel Extension	Remove and Replace				Measure 1 will provide minimum uplift factor of safety.
South Topeka Unit, Station 85+57 - Manhole Problem: Uplift	Heel Extension	Remove and Replace				Measure 1 will provide minimum uplift factor of safety.
South Topeka Unit. Station 74+41 to 93+86 Problem: Floodwall foundation weakness	New wall on offset alignment	New wall on existing alignment	Earthen Levee behind existing wall	Modify existing wall		Insufficient area is available to implement measure 1. Recommend measure 2.
South Topeka Unit, Station 22+00 to 48+00 Problem: Underseepage	Underseepage berm.	Buried collector system.	Relief wells discharging to ground.	Relief wells discharging to manhole w/ temporary pumping.	Relief wells discharging to permanent pump station.	Sufficient open land is available to install measure 1. Recommend berm 5 feet thick and 100 feet wide consisting of 71,000 cy of random fill material.
Waterworks Unit, Station 0+78 to 7+00, 10+00 to 16+50 Problem: Sliding Stability	Stability berm	Foundation Mod	Wall replacement			Measure 1 will provide minimum sliding stability factor of safety.
Waterworks Unit, Station 13+07 to 15+95 Problem: Sliding Stability	Stability berm	Foundation Mod	Wall replacement			Measure 1 will provide minimum sliding stability factor of safety.

Structural Concerns: Uplift

Structural analysis identified uplift concerns at the Fairchild Pump Station (station 364+40). The Fairchild Pump Station is no longer used or maintained as an active part of the levee system. Whereas the probability of failure at this location would be eliminated by installation of a heel extension or replacement of the structure, the same increase in project reliability could be gained by removal of the station without the loss of project benefits. The above ground structure would be removed and the debris properly hauled away and disposed of in a licensed commercial landfill The below ground portion of the structure, and any pipes running through the levee, would be abandoned by filling with grout, cement, or other suitable material, and then buried in place. This would also eliminate the need for future operation and maintenance costs.

Removal of the pump station creates no apparent environmental impact and was carried forward as the preferred measure at this site.

2.0 Oakland Unit

Geotechnical Concerns

Geotechnical analysis of the Oakland Unit identified one area prone to underseepage, from station 64+00 to station 80+00. Sufficient open land is available adjacent to the levee at this location to construct an underseepage berm six and one-half feet thick at the levee toe sloping to three feet thick at a distance of 240 feet landward of the levee. This installation would require 84,500 cubic yards of material and associated material borrow areas and easements.

A relief well system in this same reach would require the installation of 22 wells at an average spacing of 75 feet. Installation of a relief well system would not require the impacts caused by borrow site excavation and would likely require less construction easement acquisition.

This area of the Oakland Unit is adjacent to the Oakland Wastewater Treatment Plant and is already clear of vegetation or other environmental habitat. Both measures were carried forward for additional detailed evaluation.

Structural Concerns: Floodwall Stability

Structural analysis found that the concrete floodwall section of the Oakland Unit tieback on Shunganunga Creek is at risk of a sliding failure when loaded with water near the top of the wall. Potential weaknesses were found the entire length of the wall from Station 485+86 to 491+01. A landside stability berm approximately 2 feet thick, extending 5 feet landward, and then sloping at a 1:3 slope will address the instability. Approximately 388 cubic yards of material would be required to construct this berm. The floodwall is adjacent to a developed industrial area with little or nor environmental features to be impacted. The stability berm measure was carried forward for additional evaluation.

Structural Concerns: Uplift

Structural analysis identified uplift concerns at the East Oakland Pump Station at station 220+00 and one utility manhole at station 75+50. Sufficient area is available around each structure for the installation of a heel extension, which will improve the necessary factors of safety to an acceptable value. The area around the pump station contains no habitat features that may be impacted. This measure was carried forward for additional evaluation.

3.0 South Topeka Unit

Geotechnical Concerns: Underseepage

Geotechnical analysis of the south Topeka unit identified one area of underseepage concern, from station 22+00 to station 48+00.

Sufficient undeveloped land is available adjacent to the levee to construct an underseepage berm five feet thick at the levee toe sloping to three feet thick at a distance of 100 feet landward. This installation would require 48,150 cubic yards of material and associated material borrow areas and easements. Approximately 7.5 acres of existing trees and shrubs would be removed to allow for access and construction of the berm. Requirements for establishing offsetting habitat to address this environmental loss are discussed in the Environmental Assessment.

A relief well system in this reach would require the installation of 35 wells at an average spacing of 75 feet. Installation of a relief well system would not require the removal of existing trees or the impacts caused by borrow site excavation, and would likely require less construction easement acquisition. However, relief wells would require additional future expenditures for maintenance, repair, and eventual replacement.

Both measures were carried forward for additional detailed evaluation.

Structural Concerns: Uplift on Utility Manholes

Structural analysis identified uplift concerns with several utility manholes on the landside of the levee. Heel extensions will be sufficient to achieve the required uplift factor of safety of the utility manholes adjacent to the South Topeka unit. This measure does not cause an apparent environmental impact and was carried forward for additional evaluation.

Structural Concerns: Strength

The Kansas Avenue Pump Station was analyzed and an interior foundation wall was found deficient for meeting the required strength factor of safety. A wall stiffener installed inside the Kansas Avenue Pump Station will redistribute the pressure loads and allow the structure to achieve the required factor of safety for structural strength without the added expense of removal and replacement of the existing structure. Work will take place inside the existing structure, causing no environmental impacts. This measure was carried forward for additional evaluation.

Geotechnical Concerns: Floodwall Foundation

A risk and reliability analysis of the South Topeka floodwall axial pile capacity was conducted using the original construction drawings, on-site inspections, assumptions based on typical 1930's construction methods from other similar facilities studied by the Kansas City District, and research on the design limitations of this type of construction. The axial pile capacity of the foundation of the South Topeka floodwall for wall type B between station 83+00 and 87+00 was found not to meet the required minimum factor of safety for the extreme loading condition of water to the top of the wall. Pile overloading could result in excessive floodwall deflections, water infiltration through opened wall joints, scour around the openings, and rapid wall failure. A lateral deformation analysis, however, was not performed due to the limited knowledge of the piles and the foundation conditions.

There is very little foreshore on the riverside of the floodwall, preventing any improvement measures from being installed on that side. On the landside, several large operating industrial facilities are located along the entire length of the floodwall, some as close as 40 feet. The area between the existing floodwall and these facilities is congested with underground and overhead utilities, two flood pump stations and associated collector wells, several railroad spurs used by the industrial facilities, and other assorted obstacles. These physical site characteristics and the potential cost and complexity of relocations place severe limitations on the practicality and feasibility of constructing an additional floodwall or earthen levee landward of the existing wall.

Temporarily placing earthen fill against the landside of the floodwall as flood waters rise, and removing it when high water recedes, is essentially a time intensive flood fighting measure with little or no long-term reliability impact and could be excessively costly over the course of several flood events. Whereas the placement of fill material could counteract the pressures exerted on the wall by high flood waters, if the temporary fill material is not removed coincident with the receding of high water, the weight of the fill could excessively stress the existing wall and foundation and may cause the wall damage similar to that which it is attempting to prevent.

Piles could be added to improve the identified reliability concern. However, doing so would be very costly due to the new piles and the required stem and footing modifications to tie those piles into the wall. Additionally, the existing, aging timber piles would still need to be relied on while their remaining useful life is in question.

Jet grouting or pressure grouting is used in a variety of construction applications to modify soil properties, but it is not considered a long-term viable solution for floodwall strengthening. Within the Kansas City District, jet grouting was attempted on some levee features after the 1993 flood with very limited success. Due to the limited capacity of the existing soils, the entire floodwall foundation (approx. 1,900 feet) would require grout injection. Ensuring the quality of grout installation sufficient to stabilize the foundation soils over the full distance of the wall would be difficult and controlling injection pressures to simultaneously achieve sufficient grouting without damaging existing adjacent utilities is problematic. Furthermore, installation would be complicated and construction quality difficult to maintain with the existing wall remaining in place.

Due to technical infeasibility and low confidence in the long-term results, wall and foundation modification measures were eliminated from further consideration.

A new floodwall on the existing alignment would accommodate the physical limitations of the work site and would include a higher capacity pile foundation system and stronger structural elements consistent with current construction criteria. New floodwall installation would include such factors as excavation, raw materials transport, and general construction activity that can disrupt activities on the adjacent properties, but would overcome space limitations of the area and may potentially avoid many of the utility relocations and extra excavation needs of other alternatives. However, the other factors listed previously remain with the addition that temporary flood risk management capability must be maintained during demolition of the existing wall. This additional factor could be minimized by maintaining a separation of no more than three wall sections between demolition activities and new construction activities. Additionally, an earthen work platform would need to be constructed on the riverside of the existing wall to allow movement of construction equipment.

No environmental habitat would be disturbed by any of the discussed floodwall stability measures. Replacing the existing floodwall with a new wall was carried forward for additional detailed evaluation.

4.0 Waterworks Unit

Structural Concerns: Floodwall Stability

Structural analysis found that some sections of the concrete floodwall portion of the Waterworks Unit are at risk of a sliding failure when loaded with water near the top of the wall. Potential weaknesses were found from Station 0+78 to 7+00 and station 10+00 to 16+50. Sufficient area is available behind the floodwall to construct a stability berm two feet high extending from the wall five feet and then tapering at a one on three slope to the existing ground surface. Comparison of this measure to wall replacement or foundation modification indicates that a berm is more cost effective by orders of magnitude; therefore it was retained for further analysis. Approximately 958 cubic yards of material would be required to construct this berm. This measure was carried forward for additional analysis.

F. Borrow Areas

Borrow material sources are required for underseepage and stability berm construction in three units of the Topeka Levee system. Two potential borrow sites have been chosen, each on the riverside of the levee and in close proximity to the areas of work to limit the distance that material must be hauled. Each site has been reviewed for environmental and cultural resources.

Easements and rights-of-way for entrance and removal of material from each site will be obtained by the non-Federal sponsor during the Pre-Construction Engineering and Design Phase (PED).

The sites are currently in agricultural production. As possible, steps will be taken to allow these areas to return to agricultural use after borrow operations have ceased. The top one foot of topsoil will be removed, stockpiled, and returned to the site after completion of excavation. Excavation depths in agricultural areas will be kept to a minimum to reduce impacts to the drainage of fields. Encroachment into adjacent trees and environmental habitat areas is prevented by the implementation of a minimum separation of 50 feet, although greater distances are applied in this preliminary plan where allowable.

Preliminary layouts of borrow cells were prepared to determine the availability of the required quantities of material within the confines of each site and in accordance with the borrow area guidelines contained in EM 1110-2-1913, "Design and Construction of Levees". The calculations used to determine borrow cell sizes, excavation depths, and excavation quantities are preliminary and subject to change. Borings and surveys will be conducted early in PED to ensure adequate depth of suitable material and ensure that the proposed excavations will not adversely affect existing underseepage conditions, foreshore stability, or river bank stability.

To account for shrinkage of material during compaction and losses during excavation and hauling, all material quantities for the planned levee features are increased by 25%. Table 11 provides the quantities for each feature and the corresponding quantity of borrow needed.

Table 11. Borrow Quantities Required

Unit	Feature	Fill Quantity (cy)	Borrow Quantity (cy)
South Topeka	Underseepage Berm	38,520	48,150
Waterworks	Stability Berm	766	958
North Topeka	Underseepage Berm	97,800	122,250
Oakland	Underseepage Berm	67,600	84,500
Oakland	Stability Berm	310	388
Total		204,996	256,246

South Topeka Borrow Site

The South Topeka Borrow Site is located on the riverside of the Auburndale and South Topeka Levee Units. This site will be used to provide borrow material for the South Topeka underseepage berm, the Waterworks floodwall stability berm, and the North Topeka underseepage berm on the opposite side of the Kansas River.

A cell measuring 1000 ft by 400 ft can provide an estimated 59,259 cubic yards of fill material when excavated to a depth of four (4.0) feet. At these dimensions, three cells are required. The cell layout maintains a 100 foot separation between pits for the movement of equipment and to maintain foreshore stability. The preliminary plan utilizes a minimum 200 foot buffer between the borrow cells and adjacent treed areas although this could be reduced to increase borrow efficiency and minimize overall impact to the property. All cells are located over 500 feet from the existing levee and at least 300 feet from the Kansas River. These distances should prevent adverse underseepage impacts and to maintain bank stabilization.

Oakland Borrow Site

The Oakland Borrow Site is located on the riverside of the Oakland Unit, between levee stations 100+00 and 110+00. This site will be used to provide material for the underseepage and stability berms in the Oakland Unit.

A cell measuring 1400 ft by 300 ft can provide 46,667 cubic yards of fill material when excavated to a depth of three (3.0) feet. At these dimensions, a total of 2 cells are required. The cell layout maintains a 100 foot separation between cells for the movement of equipment and foreshore stability and provides a 50 foot buffer from adjacent treed areas. All cells are located over 100 feet from the existing levee and more than 400 feet from the Kansas River.

Effect of Relief Well Alternatives on Borrow Needs

Alternatives utilizing relief wells instead of underseepage berms have also been formulated. If relief wells prove to be economical and are selected as the preferred alternative, the need for borrow material will be greatly reduced. Borrow material would only be required for the Waterworks and Oakland unit stability berms, in the quantities detailed above. This would significantly decrease the impacts to the designated borrow areas in those units. The Waterworks stability berm could be supplied by a single borrow cell 175 ft. by 150 ft. by 1 ft. deep. The Oakland stability berm could be supplied by a single borrow cell 105 ft. by 100 ft. by 1 ft. deep.

Alternatives to Land Based Borrow

Several sand dredging and excavation companies operate in the Topeka area and may be able to provide material without disturbance to existing lands and property owners. This could possibly provide a cost savings and minimize the environmental impact of borrow operations. There is concern that these operators may not be able to provide the quantities necessary in addition to satisfying their existing commercial demands. Furthermore, conditions on the Kansas River have recently caused the Corps of Engineers to restrict the regulatory permits of those operators dredging from the river. The future possibility of sand dredging in the river is unknown. The availability of these alternative sources will be reevaluated nearer to the time of construction.

G. Initial Plan Formulation and Screening Results

1.0 No Federal Action Alternative

For each AOI, the No Federal Action alternative was considered. When examining the No

Federal Action alternative, it is necessary to project what course of action local entities may take given the lack of Federal involvement. It is possible that some of the recommended measures may be undertaken by the local sponsors. These local initiatives are likely to be focused on the underseepage measures which are the least costly of the recommendations offered herein. However, the major requirements associated with the South Topeka floodwall are just as likely not to be accomplished under a local initiative. This would mean significant long-term risk remaining for at least one of the units analyzed in this report.

The No Federal Action alternative does nothing to alleviate risks to public health and safety. While some local emergency preparedness plans can be updated and general awareness of the risks can be increased, this could be considered an inappropriate small scale response to significant life and safety risks.

The economic implications of the No Federal Action alternative are broadly negative. The investment at risk within each unit is so large that No Federal Action will subject the study area to the possibility of an overall long-term adverse impact on the local economy, and dislocations of industry may even result. In the short term, with an absence of flooding, the current trends in-place for the local economy, tax base, population, and employment may remain intact. However, if major flooding occurred and one or more of the levee units failed, the long term effects are likely to include: diminished economic stability, business interruptions that could jeopardize workers jobs and wages, potential losses in population and employment, and reductions in the tax base (given net movement out of the protected areas) and generally diminished property values.

Levee failure(s) would halt or at least significantly impede the nationwide movement of goods by rail, and major interstate highways could also shut down. During any such failure, it is also expected that production centers, wholesale distribution, and containerized shipping centers would close. Following the flood, subsequent restoration periods could be months or years depending on the damage involved.

The No Federal Action alternative also raises the possibility of permanent loss of local manufacturing employment through industrial relocation to developing countries. Certain industries may see moving outside the United States as a more viable option in lieu of industrial re-investment and rebuilding after any widespread flood damage. Were this to occur, it could severely degrade the industrial base of the metropolitan area for decades.

The No Federal Action alternative results in no changes to the existing environment in and around the levee units unless catastrophic levee failure occurs. Levee failure at specific locations or across the system could result in direct and indirect impacts through inundation of habitat of terrestrial populations and through release of contaminants to the river systems or floodplain environment. Direct impacts during flood events would be the displacement of mobile organisms and the loss of organisms unable to escape inundated areas. Direct and indirect impacts could also result from the introduction of contaminants currently controlled or contained by businesses and industries landward of the levee system. Levee failure and inundation of stored chemicals, and the variety of chemicals released within the protected community, would allow introduction of these contaminants into the Kansas River impacting water quality and contaminant loading of the rivers during these events. Potential impact to aquatic populations (fish and benthic communities) from the degradation of water quality and contaminant loading would result from chemical release during flood events. Subsidence of flood waters could also result in the introduction or redistribution of chemical contaminants across the foreshore floodplain and impact terrestrial communities (plants and animals) utilizing the foreshore habitat. Impacts from the No Federal Action alternative could range from no significant impact under non-flood events, to minor to significant impact depending on location of levee failure and the resulting duration of inundation.

2.0 Structural Alternatives

Those measures identified in Table 10 as being carried forward for further analysis were labeled and combined into alternative plans for each levee unit. In some cases only one measure was carried forward for a particular area of interest. Measures within a unit that are consistent among different alternative plans were combined for simplicity. Measures from the same area of interest cannot be combined. The implementation of corrective measures at each area of interest was evaluated for its impact on the overall system reliability. It was determined that each alternative plan must include a measure from each area of interest in order to provide a complete plan for obtaining the desired overall system reliability.

H. Detailed Plan Formulation – Final Array of Plans

1.0 No Federal Action

No additional flood risk management would be provided under the "No Action" Alternative. Without modification to the existing flood risk management system, the study area would continue to be at risk from large flooding events and the affected community would be faced with continued economic development concerns. The problem would worsen with time if no action is taken because flood-insurance rates could rise and prevent new development and may force existing development out of the study area.

2.0 Structural Plans

The structural plans consist of reliability improvements to each unit in the system. These plans are confined to modification or replacement of existing unit features on the existing unit alignment. Two alternative plans each have been prepared for the North Topeka, South Topeka, and Oakland Units, and one plan for the Waterworks Unit. Each plan includes a measure for addressing the reliability concern at each area of interest. Multiple plans for the same unit differ only in their treatment of underseepage concerns (berms versus relief wells).

I. Economic Analysis and Screening of Plans

The economic analysis identifies the extent of the economic impact from flooding with the existing project and, on a comparable basis, evaluates the range of plans to increase project performance considered in the study. The analysis first requires a risk-based analysis of the flood problem under the existing condition (existing levees and floodwalls). The future without project condition is then determined, and finally a risk-based evaluation in terms of benefits, costs, and performance of the various alternatives under the with-project condition is completed. The analysis encompasses all flood-prone properties within the study area.

Screening-level costs were prepared by cost engineering staff for each of the seven alternatives and are summarized in Table 12. Discussion of the screening results for each unit can be found in Appendix D. Economic performance results for each of the alternatives screened are shown in Table 13. Screening costs were completed in 2006 based on October 2005 prices. Only the NED plan elements were subsequently updated. Therefore, the data shown in Tables 12 and 13 are in October 2005 prices.

Table 12. Screening Costs Summary

October 2005 prices, 4.875% interest rate; 50 year period of analysis; $1,000s								
ITEM	**PED**	**LERRD**	**CONSTR**	**S&A**	**TOTAL FIRST COST**	**IDC**	**O&M**	**TOTAL ANN. COSTS**
WATERWORKS ALT 1								
Stability berm	$3 7	$1.5	$37.1	$2.4	**$44.7**	$2.6	$0.0	**$2.5**
SOUTH TOPEKA ALT 1								
Underseepage berm	$81.7	$849.0	$457.5	$53.1	$1,441 3	$82.9	$0.0	$81.9
Floodwall replacement	$1,001.6	$27 5	$10,015.7	$650.0	$11,694.8	$672.4	$0.0	$664.4
Kansas Avenue pump plant wall stiffener	$0.5	$0.0	$5.5	$0.4	$6.4	$0.4	$0.0	$0 4
Misc. heel extensions	$39.0	$0 0	$390.3	$25.3	$454.6	$26.1	$0.0	$25.8
Total	$1,122.9	$876.5	$10,868.9	$728.8	**$13,597.0**	$781.8	$0.0	**$772.5**
SOUTH TOPEKA ALT 2								
Relief wells	$115.6	$0.0	$1,155.6	$75.0	$1,346.2	$77.4	$51.0	$127 5
Floodwall replacement	$1,001.6	$27.5	$10,015.7	$650.0	$11,694 8	$672.4	$0.0	$664.4
Kansas Avenue pump plant wall stiffener	$0.5	$0.0	$5 5	$0.4	$6.4	$0.4	$0.0	$0.4
Misc. heel extensions	$39.0	$0 0	$390.3	$25.3	$454.6	$26.1	$0 0	$25 8
Total	$1,156.7	$27.5	$11,567.1	$750.7	**$13,502.0**	$776.4	$51.0	**$818.1**
OAKLAND ALT 1								
Underseepage berm	$94.2	$215.3	$942.3	$61.2	$1,313.1	$75 5	$0.0	$74.6
East Oakland pump station heel extension	$19.0	$0.0	$189.9	$12.3	$221.2	$12.7	$0.0	$12.6
Shunganunga tieback stability berm	$2 0	$14.8	$19.6	$1.3	$37 6	$2.2	$0.0	$2.1
Misc. heel extensions	$1.1	$0 0	$11.3	$0.7	$13.2	$0 8	$0.0	$0.8
Total	$116.3	$230.2	$1,163.2	$75.5	**$1,585.1**	$91.1	$0.0	**$90.1**
OAKLAND ALT 2								
Relief wells	$73.4	$0.0	$733.8	$47 6	$854 8	$49.1	$31.3	$79.9
East Oakland pump station heel extension	$19.0	$0.0	$189.9	$12 3	$221.2	$12.7	$0.0	$12.6
Shunganunga tieback stability berm	$2.0	$14 8	$19 6	$1.3	$37.6	$2.2	$0.0	$2.1
Misc. heel extensions	$1.1	$0.0	$11.3	$0.7	$13.2	$0.8	$0.0	$0.8
Total	$95.5	$14.8	$954.6	$62.0	**$1,126.8**	$64.8	$31.3	**$95.3**

Table 12. Screening Costs Summary (Cont.)

NORTH TOP ALT 1								
Underseepage berm (site 1)	$153.5	$181.2	$1,534.5	$99.6	$1,968.8	$113.2	$0.0	$111.8
Relief wells & collector system (site 2)	$39.8	$0.0	$398.1	$25.8	$463.7	$26.7	$10.7	$37.0
Fairchild pump station abandonment	$4.0	$0.0	$40.2	$2.6	$46.8	$2.7	$0 0	$2.7
Total	$197.3	$181.2	$1,972.8	$128.0	**$2,479.3**	$142.6	$10.7	**$151.6**
NORTH TOP ALT 2								
Relief wells (site 1)	$105.8	$110.3	$1,057.6	$68.6	$1,342.3	$77.2	$46.7	$122.9
Relief wells & collector system (site 2)	$39 8	$0.0	$398.1	$25.8	$463.7	$26.7	$10.7	$37.0
Fairchild pump station abandonment	$4.0	$0.0	$40.2	$2.6	$46.8	$2.7	$0.0	$2.7
Total	$149.6	$110.3	$1,495.8	$97.1	**$1,852.8**	$106 5	$57.4	**$162.6**

Interest During Construction (IDC) assumes project schedule of PED-Oct 2008 to Sept 2011, LERRD-Oct 2011 to Jun 2012; Construction-Jul 2012 to Apr 2014.
Total first costs = PED + LERRD + construction + S&A
Annual costs = ((Total first costs + IDC) X interest & amortization factor of 0.053722) + O&M
Annual O&M costs include only additional or net costs over and above comparable existing costs.

Table 13. Screening Alternatives - Benefits & Costs Summary

October 2005 prices; 50 year period of analysis; 4.875% interest rate

Unit	WW	SOUTH TOPEKA				OAKLAND		NORTH TOPEKA	
Alternative	**Alt 1**	**EAD South Top**	**EAD Oakland**	**Alt 1**	**Alt 2**	**Alt 1**	**Alt 2**	**Alt 1**	**Alt 2**
DAMAGES & BENEFITS									
EAD without project	$198.4	$957.3	$1,809 0	$2,766.3		$4,563.8		$14,228.1	
EAD residual	$193.5	$775.3	$1,058.7	$1,834.0		$2,005.3		$4,110.1	
Residual as % of without project	97.5%	81.0%	58.5%	66.3%		43.9%		28.9%	
EAD reduction									
Mean	$4.9	$182.0	$750.3	$932.3		$2,558.5		$10,118.0	
Probabilistic estimates*									
0.75	$3.9	$81.6	$395.2	$476.8		$1,516.9		$5,829.4	
0.5	$4.6	$139.1	$612 2	$751.3		$2,379.9		$9,070.0	
0.25	$6.1	$270 6	$1,164.0	$1,434.6		$3,362 3		$13,635 0	
Annual benefits – screening level	**$4.9**	$182.0	$750 3	**$932.3**		**$2,558.5**		**$10,118.0**	
COSTS									
First costs	$44.7	--	--	$13,597.0	$13,502.0	$1,585 1	$1,126 8	$2,479.3	$1,852.8
Annual costs – screening level	**$2.5**	--	--	**$772.5**	**$818.1**	**$90.1**	**$95.3**	**$151.6**	**$162.6**
BENEFIT-COST RATIO	**1.9**			**1.2**	**1.1**	**28.4**	**26.8**	**66.8**	**62.2**
NET BENEFITS	**$2.4**			**$159.8**	**$114.2**	**$2,468.4**	**$2,463.1**	**$9,966.5**	**$9,955.4**

* Probabilistic EAD reduction shows the minimum level of benefits expected at the indicated probability, resulting in a range of possible benefit values rather than a single value. For example, North Topeka benefits, expressed as a mean value, equal $10,118.0, but there is 75% confidence that benefits are at least $5,829.4 and 25% confidence that they exceed $13,635.0.
Alternatives within each reach have identical benefits since they accomplish the same project purposes. The economic performance of the alternatives differs only in costs.
Screening BCR data will not match the BCR data for the selected plan in Table D-26. This table includes a portion of Oakland damages and damages reduced that is double-counted in both Oakland and South Topeka benefits for screening purposes. For the NED plan benefits in Table D-26, the Oakland benefits are accounted incrementally and the double-counting is eliminated. The NED plan benefits also include additional categories of benefits not considered in the screening analysis.

Annual costs for operations and maintenance (O&M) are included only for the alternatives that produce additional O&M costs over and above current without-project levels. The three alternatives with net additional O&M costs are the alternatives that include relief wells. For these alternatives, the life-cycle cost analysis for each alternative assumes that each pump will require servicing every four years at $5,000 per pump. There are 22 wells for the Oakland relief wells alternative, 35 for South Topeka, and 38 for North Topeka. Complete replacement of the wells is assumed after 40 years at a cost equal to the current construction cost plus 17% to account for E&D and S&A.

In addition to the relief wells, the North Topeka alternative also includes underground collector systems and a temporary pumping component. O&M costs for the collector systems assume that flushing and cleaning would be required every 25 years and would cost $10,900 in each instance. This total includes three days of labor by a two-man crew as well as equipment costs. The temporary pumping plan would be needed when the water surface elevation comes within three feet of top of levee, which would require an event of about a 0.5% magnitude. It is assumed that the pumping capability will be needed three times over the 50-year period of analysis. Each event would require one pump rental for one week costing $700, which includes installation, use, removal and return.

Results of the Risk-Based Screening

Waterworks – Only one alternative was carried forward from initial screening. This alternative maximizes the net benefits over the No Action alternative and is recommended as the NED Plan.

South Topeka – Two alternatives were carried forward from the initial screening. Alternative 1 maximizes the net benefits and is recommended as the NED Plan.

Oakland – Two alternatives were carried forward from the initial screening. Alternative 1 maximizes the net benefits and is recommended as the NED Plan.

North Topeka – Two alternative were carried forward from the initial screening. Alternative 1 maximizes the net benefits and is recommended as the NED Plan.

The combination of the individual unit NED plans will constitute the overall NED plan for the Topeka levee system.

J. Environmental Considerations

1.0 No Federal Action

In the absence of any Federal action addressing levee improvements, a high water event should cause failure of the levee resulting in the release of a variety of industrial chemicals and substantially adversely impact the natural and human environment.

2.0 Structural Alternatives

The reliability measures proposed will impact a small amount of existing riparian wildlife habitat. Specifically, the installation of the South Topeka underseepage berm will require the removal of seven and one-half acres of trees. These impacts will be mitigated on available riparian area riverward of the North Topeka levee between stations 165+00 and 184+00. A detailed description of proposed mitigation efforts is found in the attached Environmental Assessment. The North Topeka underseepage berm and the proposed borrow areas will impact agricultural properties that are already cleared for crop use. The remaining measures will have no impact on environmental resources.

K. Hydraulic and Floodplain Considerations

Implementation of the proposed reliability measures will not change the height of the levee nor otherwise impact the floodway conveyance. Water surface profiles will not be changed from the current existing condition.

L. HTRW Considerations

As presented previously in the discussion of existing conditions, an HTRW site assessment of the study area was conducted. All proposed plans will stay within the previously assessed corridor, precluding the need for additional study. Borrow areas have been reviewed and selected to avoid impacting former solid waste dumping sites. Proposed work in the South Topeka floodwall area will be reviewed during the project design phase to determine the potential for encountering contaminated groundwater during construction.

M. Engineering Considerations

There are no engineering features associated with the No Action plan. The proposed structural plans have primarily the same engineering characteristics with only minor variations. Each plan addresses the same reliability risks with a similar level of complexity. There are no special or unique construction methods required by any of the plans. The only difference of note is the added future operation and maintenance procedures required by the relief well alternatives.

N. Plan Selection

Based upon consideration of all pertinent factors, Alternative 1 was selected as the recommended plan for implementation in each levee unit. For each unit, Alternative 1 is the NED plan, meeting the planning objectives and the National Economic objectives of maximizing net project benefits while providing the lowest cost. The combination of each individual unit NED plan is selected and recommended as the NED plan for the overall Topeka levee system.

Implementation of the project will improve the reliability of the system to provide flood risk management benefits to the local community. Negative impacts from the project would be minimal. Some disruption during construction could be expected, affecting traffic and agricultural activities. No relocation of homes or businesses is required.

The evaluation results show strong economic justification for the project in the Topeka areas. The existing project would be improved to provide greater than 90% reliability against damages from the base flood.

Plans Considered and Eliminated

Other combinations of reliability improvements were considered and eliminated since they produce lower levels of net benefits over the period of analysis. The "No Action" alternative would not resolve the continuing risk to which the area is subject. The no action plan would have detrimental long term effects to the business and home owners in the area and to the economy of the local community.

X. Description of the Selected Plan

The NED Plan consists of a combination of remedial measures and improvements for multiple sites as summarized in the descriptions below. The NED plan essentially grows from an assembly of the recommended alternatives from each of the four levee units addressed in the Feasibility Report. If examined on a unit by unit basis, each unit's recommendations are also the NED measures for the unit. The NED Plan assembles these individual recommendations into one complete set of recommendations (one plan). The economic analysis of the NED plan shows that it is economically viable and furthers national economic development in manner consistent with Corps of Engineers economic regulations and Administration economic polices.

Plate 1, located at the end of this report, provides a map of the Topeka levees system showing the location of the sites included in the Recommended Plan for this Feasibility Report

A. Recommended Plan - Work Components

Major components of the Recommended Plan are discussed in the following paragraphs.

North Topeka Unit

<u>Station 165+00 to 189+00 (Plate 2)</u>: Recommended Plan provides for controlling underseepage at the interior toe of the existing levee by installing an underseepage control berm 220 feet wide, seven feet thick at the levee toe, and sloping to three feet thick at the end of the berm. This will require the acquisition of 122,250 cubic yards of fill material and temporary easements for borrow excavation and construction activities.

<u>Station 246+00 to 250+00 (Plate 9)</u>: Recommended Plan provides for controlling underseepage at the interior toe of the existing levee by installing a series of six stainless steel pressure relief wells located along the thin blanket zone from station 246+00 to station 250+00. Adequate pressure control at this site requires removal of seep-water through below grade header piping. This header piping discharges into a cast-in-place concrete pump pit which collects the seep water and then allows pumping to discharge the seep water to the river in a controlled manner.

Station 364+60 (Plate 10): Recommended plan provides for controlling uplift at the Fairchild Pump Station by proper in-place abandonment of the structure. The above-grade structure will be removed and properly disposed of while the below-grade structure and outlet lines will be filled with flowable fill or other suitable material and buried in-place.

Station 165+00 to 184+00 (Plate 13): An area of approximately 13 acres on the riverside of the North Topeka Levee was identified as a potential Mitigation Area for planting of riparian habitat to offset losses caused by construction of features in the South Topeka Unit (discussed below). The Mitigation area is currently cleared of trees and shrubs and used for agriculture. The property is adjacent to existing riverward riparian habitat. Details of the proposed plantings are included in the attached Environmental Assessment.

South Topeka Unit

Station 22+00 to 48+00 (Plate 4): Recommended Plan provides for controlling underseepage at the interior toe of the existing levee by installing an underseepage control berm 100 feet wide, five feet thick at the levee toe, and sloping to three feet thick at the end of the berm. This will require 48,150 cubic yards of material and temporary easements for borrow excavation and construction activities. The removal of 7.5 acres of trees and shrubs will be required. Planting of additional habitat to offset these losses is proposed adjacent to the North Topeka levee as discussed previously.

Kansas Avenue Pump Station (Plate 3): Recommended Plan provides for increasing the strength factor of safety by installation of a wall stiffener on the interior foundation of the pump station.

Manholes (Plates 3 and 4): Recommended Plan provides for increasing the uplift factor of safety of several manholes by installation of heel extensions.

Floodwall (Plate 3): Recommended Plan provides for construction of a new concrete wall on concrete foundation piles following the existing wall alignment to the same length and height dimensions. Approximately 3,685 cubic yards of concrete will be needed to construct the new wall. The following construction sequence is recommended:

- Stockpile sufficient fill material (approximately 5,000 CY) on site or within easy access for emergency closure in the event of a flood event during construction.
- Remove one monolith section (~84ft) to allow ease of riverside access. This monolith will be rebuilt at the completion of the project.
- Construct riverside construction and haul road to serve as working platform.
- Remove three additional floodwall monoliths.
- Drive foundation piles, form and place the two monolith pile caps.
- The following five sequential construction steps will be repeated until the length of the wall has been replaced.

1. Construct floodwall stem (completing monolith)
2. Remove next floodwall monolith. (No more than four monoliths will be open at any one time, one for construction access and three for separation between existing wall removal and new wall construction).
3. Drive pile foundation system. (There is always a separation of at least one monolith (~84 ft) between piles being driven and freshly poured "green" concrete.)
4. Pour monolith pile cap.
5. Repeat Steps 1-4

As noted, a river side construction and work road will be constructed as a working platform. This will consist of material placed on the riverside slope adjacent to the existing wall to provide an area wide enough for the movement of construction equipment. This platform is not anticipated to extend into or otherwise impact the river itself. Access to this area for construction of the platform will be from the landside through the first removed section of the existing wall. After completion of the access/working area on the riverside of the existing wall, removal of the remaining existing wall, and construction of the new wall, will be conducted from both sides of the wall alignment.

South Topeka Borrow Area (Plate 11): An agricultural area of approximately 95 acres riverward of the west end of the South Topeka Unit was identified as a potential source of borrow material. It is estimated that 27.3 acres of the site can be employed to provide borrow for the construction of features in the South Topeka, North Topeka, and Waterworks Units.

Waterworks Unit

Stations 0+78 to 7+00 and 10+00 to 16+50 (Plate 5): Recommended Plan provides for increasing the stability factor of safety by installation of stability berms on the landside of the affected wall sections. Berms in these locations would consist of compacted soil approximately two feet high extending from the wall five feet and then tapering at a one on three slope to the existing ground surface. Approximately 958 cubic yards of material would be required as well as temporary easements for borrow excavation and construction activities.

Oakland Unit

64+00 to station 80+00 (Plate 6): Recommended Plan provides for controlling underseepage at the interior toe of the existing levee by installing an underseepage control berm 240 feet wide, six and one-half feet thick at the levee toe, sloping to three feet thick at the end of the berm. This will require the acquisition of 84,500 cubic yards of fill material and temporary easements for borrow excavation and construction activities.

485+86 to 491+01(Plate 7): Recommended Plan provides for increasing the stability factor of safety by installation of a stability berm two feet high extending from the wall five feet and then tapering at a one on three slope to the existing ground surface. Approximately 382 cubic yards of material would be required as well as temporary easements for borrow excavation and construction activities.

East Oakland Pump Station (Plate 8): Recommended Plan provides for increasing the uplift factor of safety of the station by installation of a heel extension.

Manhole at station 75+50 (Plate 6): Recommended Plan provides for increasing the uplift factor of safety of the manhole by installation of a heel extension.

Oakland West Borrow Area (Plate 12): An area of 28 acres of agricultural property riverward of the levee between Stations 100+00 tand110+00 was identified as a potential borrow source. It is estimated that 19.3 acres will be impacted to provide the required borrow for construction of features in the Oakland Unit.

B. Economic Performance of the Selected Plan

1.0 Economic Performance

Table 14 summarizes the economic performance of the selected plan. For further elaboration of the NED plan benefits and how they were calculated, please refer to Tables D-31 and D-32, as well as section 7.4, of Appendix D.

Table 14. Total NED Project Benefits & Costs

October 2008 prices; 4.625% interest rate; $1,000s					
Unit	Annual Benefits	First Costs	Annual Costs	**BCR**	**Net Benefits**
NORTH TOPEKA UNIT	$11,408.2	$2,867.0	$169.2	**67.4**	**$11,239.0**
WATERWORKS UNIT	$5.5	$51.0	$2.8	**2.0**	**$2.7**
SOUTH TOPEKA / OAKLAND UNIT	$4,013.9	$18,239.0	$996.1	**4.0**	**$3,017.8**
TOTAL	**$15,427.6**	**$21,157.0**	**$1,168.1**	**13.2**	**$14,259.5**

2.0 Engineering Performance

Table 15 compares with and without-project condition reliability statistics for the NED plan.

The key results of implementing the NED plan would be as follows:

- The median annual exceedance probability would increase to 0.003 (333-year) for the overall levee system. In other words, there would be a 0.3% chance of a damaging flood in any year. Currently, it is as much as 0.057 (18-year) for Oakland, 0.024 (42-year) for North Topeka, and 0.004 (250-year) for South Topeka (See Table 9 – Engineering Performance Without Project).

Table 15. Engineering Performance for NED Plan, With vs. Without-Project Conditions

	WATERWORKS		AUBURNDALE		SOUTH TOPEKA		OAKLAND		NORTH TOPEKA		SOLDIER CREEK URBAN	
	WITHOUT	WITH	WITHOUT	WITH	WITHOUT	WITH	WITHOUT	WITH	WITHOUT	WITH	WITHOUT	WITH
ANNUAL EXCEEDANCE PROBABILITY*												
Median	0.003	0.003	0.003	no change	0.004	0.003	0.057	0.003	0.024	0.003	0.006	no change
Return interval (years)	333	333	333		250	333	18	333	42	333	167	
LONG-TERM RISK (chance of flooding during period)												
over 10 years	1 in 25	1 in 26	1 in 32	no change	1 in 23	1 in 27	1 in 2	1 in 27	1 in 4	1 in 27	1 in 13	no change
over 25 years	1 in 10	1 in 11	1 in 13		1 in 9	1 in 11	1 in 1.3	1 in 11	1 in 2	1 in 11	1 in 5	
over 50 years	1 in 5	1 in 6	1 in 7		1 in 5	1 in 6	1 in 1	1 in 6	1 in 1.4	1 in 6	1 in 3	
PERFORMANCE VS. 1%-CHANCE FLOOD												
Top of levee margin (feet) over flood elevation**	5.9		8.2	no change	6.5		3.7		6.6		1.7	no change
Conditional nonexceedance probability	0.928	0.933	0.968		0.842	0.946	0.029	0.942	0.141	0.946	0.668	
Conditional exceedance probability	0.072	0.067	0.032		0.158	0.054	0.971	0.058	0.860	0.054	0.332	
OTHER FLOOD EVENTS - EXCEEDANCE PROBABILITY												
10.0%	0.000	0.000	0.000	no change	0.000	0.000	0.165	0.000	0.004	0.000	0.000	no change
4.0%	0.000	0.000	0.000		0.003	0.000	0.589	0.000	0.180	0.000	0.002	
1951 flood-3.5%***	0.001	0.001	0.008		0.010	0.001	0.656	0.001	0.273	0.001	0.025	
2.0%	0.003	0.003	0.032		0.031	0.002	0.857	0.003	0.554	0.002	0.094	
0.4%	0.331	0.321	0.213		0.436	0.285	0.995	0.280	0.970	0.285	0.661	
0.2%	0.758	0.750	0.644		0.806	0.721	1.000	0.700	0.998	0.721	0.817	

* Annual exceedance probability is the chance of a damaging flood in any year. The statistic implies nothing about the magnitude of the flood except that it would be large enough to exceed the system's capacity.

** Top of levee here means initial overtopping margin, i.e., the low point on the levee profile in the reach. The 1%-chance flood elevation refers to the nominal value of the elevation and is not risk-based.

*** 1951 flood statistics are interpolated between the nearest events evaluated in HEC-FDA (the 4% and 2% events).

- In a 1%-chance flood event, all Kansas River units would have between a 5% and 7% chance of experiencing damage. Currently, Oakland has a 97.1% chance of a damaging flood in an event of that magnitude, North Topeka an 86.0% chance, and South Topeka a 15.8% chance. For Waterworks, the nonexceedance probability would increase marginally to 93.3%, but the performance of other Kansas River units would be substantially improved.

- The long-term risk of a damaging flood in any of the Kansas River units over a 50-year period would be approximately 1 in 6. The risk over 25 years would be 1 in 11. Over 10 years, it would be 1 in 27.

3.0 Induced Damages

The NED Plan does not affect water surface profiles of the Kansas River or its tributaries and will not results in the creation of induced damages. No new levees would be constructed and no existing levees would be raised. All project elements involve only strengthening of the existing levee system to meet expected design levels of performance rather than enhancement of performance to new levels.

4.0 Residual Risk

Although floodplain users and occupants may desire total protection from flooding, it cannot be overemphasized that this is an unachievable goal. No flood risk management project can guarantee total elimination of flooding. A flood risk management project designed relative to a 1%-chance flood event (the event critical to levee certification) can be especially misleading. The reasoning is that an event of historical magnitude is not necessarily required to overwhelm the project and cause catastrophic damage, yet many floodplain tenants will feel that they have near-total protection against flooding. Therefore, it is important for floodplain users and occupants to be aware of the level of flood risk that remains even after project implementation.

The selected plan has substantial economic benefits and reduces study area equivalent annual damages in the existing condition by more than two-thirds. The probability and occurrence of flooding will be greatly diminished. There would remain a significant total of residual equivalent annual damages of $7.4 million. There still would be a 1 in 6 chance of exceedance over a 50-year period (see Appendix D Table 28). The median annual exceedance probability of 0.003 indicates that there is a 0.3% chance of a damaging flood event in any given year.

If the capacity of the Federal levee system is exceeded in a particular event, most of the areas inside the levees would be affected due to the flat floodplain topography in these areas. In general, if the amount of water that gets through or over the levees is sufficient to produce severe flood depths, damages in the study area would reach $2 billion or more. Prohibitive depths of water would remain inside the levees for at least two weeks. Large-scale evacuations of urban neighborhoods would be necessary in advance, followed by relocation assistance. A number of highly-traveled highways and streets as well as railroad track would be closed and in some cases inundated. Water supply delivery to the entire city would be interrupted, perhaps for a few weeks.

Local leadership and emergency operations staff will need to design plans for these extreme flood events, which may be infrequent, but would hold the potential for catastrophe if they occurred. Effective emergency planning in advance is the best way to protect communities and minimize the damage from these rare flood events. Meanwhile, those who currently hold flood insurance policies might very well find it advantageous to keep their policies, which usually are fairly inexpensive in areas with certified levees.

5.0 Future With-Project Condition Summary

A recently reinvigorated emphasis on collaborative planning within the Corps of Engineers has set the stage for greater consideration of the full range of Federal interest in water resources projects. This includes not only tangible NED effects of the project, but also non-NED economic impacts, social impacts, and environmental impacts on the city and region. Environmental aspects are discussed in later sections and the attached Environmental Assessment, while this section discusses some of the major economic and social considerations.

NED Effects of NED Plan - The overall NED contribution to the national economy is $14.3 million, which are the total net benefits of the project. The project would reduce the existing condition EAD of $22.9 million by more than two-thirds to $7.4 million in residual EAD. The chances of experiencing floods that could result in major inundation would be greatly reduced (although not eliminated completely). Most of the adverse impacts described previously under the future without-project condition would be headed off, including the following:

- Residential - Residents would be spared most of the heavy personal losses they would face from flood damage if no action was taken.

- Businesses - Business owners likewise would be spared most of their potential flood losses in buildings, equipment and inventories. This includes physical flood damages as well as income losses from shutdowns.

- Public sector - Public sector repair costs would be greatly reduced at public facilities such as parks, community centers, Billard Airport, and the Oakland and North Topeka sewage treatment plants. Costly repairs to city streets and roads would be reduced. Expenditures on flood-fighting by emergency personnel, as well as relocation and reoccupation assistance, would also be reduced.

- Water supply - Water supply delivery to 160,000 customers in and around Topeka would be favorably affected by reducing the chances of operational disruptions from flooding at the Waterworks plant. The city's major sewage treatment plants in North Topeka and Oakland, both of which would have been subject to frequent flood damage or operational interruptions in the without-project condition, would be subject to much less frequent damage and their operations also would be interrupted less frequently.

- Transportation networks - The risk of frequent flood-related closings and detours on heavily traveled routes would be greatly reduced along highways, city streets and railroads. Drivers would be favorably affected in avoiding lost time opportunity costs and increased vehicular operating costs. Costly flood-related physical damages to roads and railroad track also would be greatly reduced.

- Flood control works operation and maintenance costs *(probable minor adverse impact on income)* - The project would add net annual O&M costs of about $12,800 to the North Topeka unit.

RED Effects of NED Plan - Regional economic development factors associated with project implementation, mostly positive, include the following:

- Existing local jobs, income and tax base *(probable positive impacts on income and jobs)* - The planning horizon for existing companies in and around the study area would include a much reduced degree of flood risk. Discouraging factors in the business climate such as the potential of ruinous flood damage and income losses from shutdowns would be reduced, while the potential for flood insurance requirements and stiffer building codes would be removed. The risk of relocation from the city and region by large regional employers such as BNSF Railroad, Goodyear, Hallmark, Del Monte, Hill's and others would be sharply reduced. Population losses, likely to occur in the context of a serious and ongoing flood risk, would be far less likely. The threat of large-scale job losses from relocations as well as reductions of the city's tax base would be sharply reduced.

- Economic growth *(probable positive impacts on income and jobs)* - The project would greatly alleviate potential obstacles presented by high flood risk for attracting new businesses with new jobs. Certification of the Federal levees would not be called into question, meaning that the looming threats of new costs for flood insurance and stiffer construction codes could be removed from the planning horizon. This would at the very least forestall adverse impacts to local jobs and incomes by improving the regulatory climate for those businesses wishing to expand, build, or move into the market from the outside. Key areas targeted for future business growth in North Topeka and Oakland - among the few significant sites the city has available for significant business development - would gain a high enough degree of protection to minimize flood damage impacts and remove flood-related regulatory burdens. Commercial operations at Billard Airport would not face the prospect of frequent shutdowns and flood damage.

- Riverfront redevelopment *(possible positive impact on income)* - Topeka's planned redevelopment of the riverfront in the center city could proceed absent the likelihood of increasing blight from frequent flood damage. Successful redevelopment would be expected to bring tourism and recreation revenues into the city and the study area.

- Project construction impacts *(miscellaneous possible minor impacts, both positive and adverse, to jobs and income)* - (a) No businesses or homes are slated for acquisition or relocation due to the project. (b) The region would temporarily gain some jobs during construction of the project. (c) The temporary presence of construction workers may bring a temporary increase in demand for some local services, but also a temporary increase in volume, profits, and sales tax receipts at local retail and service businesses. (d) Modest transitory population increases could occur in the study area in connection with project construction. (e) Minor traffic disruption near the levees could occur during construction, although based on the best available information at this time, no roads are anticipated to be blocked or closed for extended periods. Most of the project area would be accessed from the levee road and should not interfere with the normal flow of traffic.

Other Social Effects of the NED Plan

- Public safety *(probable positive impacts to human life)* - Serious public safety concerns, particularly in Oakland and North Topeka, would be minimized by a large reduction in flood risk. The chance of project exceedance (i.e., a damaging flood event) over a 25-year period, which currently is no more than 1 in 2 for Oakland and North Topeka, would increase to 1 in 11 (see Table D-28). Moreover, any floods that did occur in extreme circumstances likely would be overtopping rather than breaching events, which would imply a greater warning time.

- Effects on minority and low-income residents *(probable positive socioeconomic impacts)* Topeka residents in lower-income areas and minority neighborhoods would be disproportionately affected by ongoing flood risk; refer to the detailed discussion of demographics in these neighborhoods in section 5.4.3 as well as section 2.2. Thus, the same groups in South Topeka, Oakland and North Topeka also would benefit disproportionately from the project.

- Threats to center city redevelopment *(probable positive cultural impacts)* - Local efforts to revitalize center city areas would avoid a substantial obstacle if flood risk is significantly reduced in the floodplain areas of North Topeka, Oakland and South Topeka. It bears repeating that much of the "center city" of Topeka is also floodplain terrain inside the Federal levees, and it would otherwise be subject to catastrophic flood damage in the future. Flood risk reduction would be a significant stabilizing influence for these neighborhoods.

- Threats to riverfront redevelopment *(possible positive cultural, historical and aesthetic impacts)* - The possibility that periodic flooding would blight the riverfront and interfere with successful redevelopment would be greatly reduced.

- Treatment plant operations *(positive health and environmental impacts)* - The likelihood of periodic service interruptions at the Oakland and North Topeka sewage treatment plants, resulting in large releases of untreated sewage into the Kansas River, would be greatly reduced

C. Environmental and Cultural Considerations

Detailed discussion of the environmental and cultural considerations of the recommended plan is included in the attached Environmental Assessment. Included here is a summary of the key environmental factors with references to the location of additional information.

1.0 Fish and Wildlife Resources

Construction of the NED plan requires excavations in several areas for modifications of existing structural features and the installation of relief wells and berms along portions of the levees. The construction of the South Topeka underseepage berm will result in the permanent removal of approximately 7.5 acres of woodland habitat landward of the levee. Compensatory mitigation is proposed for this impact (see Plate 13 for mitigation area location). Temporary impacts to wildlife will result from noise and traffic associated with the construction efforts.

Borrow excavation is needed within approximately 27.3 acres riverward of the South Topeka Unit and approximately 19.3 acres riverward of the Oakland Unit (see Plates 11 and 12 for potential borrow locations). Impacts within these agricultural borrow sites is considered temporary in nature and are expected to be less than significant. Standard construction site erosion and sediment control practices will be employed to prevent erosion and sediment deposition into adjacent waterways. The riverward borrow areas impacted will likely revert back to agricultural use after construction, unless the creation of ecosystem habitat is preferred by the non-Federal sponsor and the land owner. More information is available in the Environmental Assessment.

A detailed ecosystem mitigation plan is described in Appendix F of the attached Environmental Assessment. This plan has been coordinated with local and federal agencies including the U.S. Fish & Wildlife Service and the Kansas Department of Wildlife and Parks.

2.0 Cultural Resources

Record searches and field reconnaissance were performed for the project area. No NRHP properties or archeological sites are recorded in the proposed project locations or borrow areas. All cultural reviews in the project area determined that there are no cultural, historic, or archeological sites of any significance that would be affected by the proposed project. The Kansas State Historic Preservation Office concurred with the findings and recommended no further action. The potential extent of project features is the same at this time as presented to the agencies prior to the findings, and no changes in formulation of the project have occurred subsequently to affect these findings.

3.0 Cumulative Impacts

Section 14.0 of the Environmental Assessment, entitled "Cumulative Impacts", provides a detailed assessment of potential cumulative impacts of the levee modifications associated with the selected plan. Based on the analysis conducted, the recommended plan of flood risk management reliability improvements within the Topeka metropolitan area will not result in substantial adverse cumulative impacts.

4.0 Environmental Justice

Executive Order 12898 on Environmental Justice (EJ) requires consideration of social equity issues, particularly any potential disproportionate impacts to minority or low-income groups. The study evaluated demographic and census data for the project area and analyzed the potential effects of the proposed project on minority and low-income groups. Although the project area does contain EJ populations such as minority and low-income groups, they would not be disproportionately impacted in a negative way; rather these groups would equally benefit from increased public safety and a reduced risk of flooding if this project is implemented. The proposed levee modifications would be primarily constructed adjacent to and/or within industrial and agricultural areas, and are not anticipated to cause any disproportionate impacts to sensitive populations, but are anticipated to uniformly provide increased economic benefit and a safer living environment to populations living and working behind the levee systems on both sides of the Kansas River. Further, there are no induced impacts to the levee systems located upstream and downstream of the project area that would result from the proposed plan.

Public coordination of the project to the EJ communities within the affected area consisted of the following: The project was coordinated with EJ communities thru distribution of the project information to EJ contacts provided by EPA. Distribution of project information included notifications of the availability of information regarding the project, a project fact sheet, along with the project's website address, contact information for the project manager, an announcement of the public meeting that was held in Topeka, Kansas on October 22, 2008, and a media press release that was sent to local newspapers, radio stations in the Topeka and surrounding metropolitan area. No comments on the project were received from the EJ communities and contacts during the public involvement process. The public involvement process will continue to reach out and provide information to the communities affected by the proposed plan as implementation proceeds.

Based upon the analysis, the proposed plan meets the intent of Executive Order 12898 and does not provide any imbalance or disproportionate affects to minority or low-income populations within the project area. More information is available in Section 12.0 of the Environmental Assessment.

5.0 Environmental Operating Principles

Under the seven Environmental Operating Principles (EOP), the Corps of Engineers is mandated to proactively seek and consider ways to improve and sustain the environment. An existing project in an urban area such as Topeka, with permanent structural features dating back several decades, has inherent limitations to the inclusion of viable environmental improvements. EOP #1 "Strive to achieve Environmental Sustainability" is the most applicable to this project. The direct affects of the proposed levee modifications will be minimized and mitigated in order to sustain as much of the existing environmental resources as possible. The specific methods chosen to perform this mitigation will adhere to EOP #5, "Seek way and means to assess and mitigate cumulative impacts to the environment."

The data collection and analysis efforts of this Feasibility Report have helped satisfy EOP #6, which reads "Build and share an integrated scientific, economic, and social knowledge base that supports a greater understanding of the environment and impacts of our work." Application of Environmental Operating Principle #7, "Respect the views of individuals and groups interested in Corps activities," is evidenced by past and future public involvement activities to include public review of this document and presentation of the Recommended Plan at a public meeting.

While the potential for environmental improvements under associated with the existing levees is limited, the partnership between the Corps and the City Topeka has allowed for the identification of potential projects under other available authorities. Upstream of the current project study area, but still within the city limits of Topeka, a separate wetland restoration and creation project has been proposed under the Aquatic Ecosystem Restoration authority of Section 206 of the Water Resources Development Act (WRDA) of 1996. For several years now, the Kansas City District has been a partner with the City of Topeka and the Topeka Riverfront Authority in developing a master plan for the Topeka riverfront. The Corps has participated in cost-share studies of potential riverfront redevelopment efforts through the Planning Assistance to States program, authorized by Section 22 of the WRDA of 1974. This effort will assist the sponsors and other stakeholders in bringing additional compatible recreation opportunities to the area, and providing a linkage to comprehensive recreation master plans of other communities on the Kansas River.

D. Hydraulic and Floodplain Considerations

The recommended plan addresses only reliability improvements to the existing system and will not affect water surface profiles within the Kansas River for any flood event.

E. HTRW Considerations

HTRW considerations associated with the selected plan are the same as previously described.

F. Engineering and Construction Considerations

There are no unusual engineering/design or construction issues associated with this project. Conventional construction methods will be used, and space is sufficient on site to provide for contractor mobilization and staging of construction.

G. Real Estate Considerations

The non-Federal Sponsors currently hold permanent easements sufficient for the existing levees and these are available for implementation of the selected alternative. Temporary easements will be acquired and used for installation of the underseepage and stability berms, borrow areas, equipment storage, access roads, construction vehicles, and staging areas. The width of the work area easements will vary depending on the project site, as additional lands are required.

A detailed description of the Lands, Easements, Relocations, Rights-of-Way, and Disposal (LERRD) requirements is outlined in the Real Estate Plan (Appendix C). This includes acreage, estate required, estimated land values, borrow areas, non-federal incidental costs, and in-house government cost. The proposed borrow areas will be further refined as the project moves into Pre-Construction Engineering and Design (PED).

H. Operations and Maintenance Considerations

Operation, maintenance, repair, rehabilitation, and replacement (OMRR&R) considerations are the responsibility of the local sponsor. The Corps is responsible for inspections. Future OMRR&R practices would remain the same as current operations for inspection and monitoring, levee mowing, vegetation control, outfall cleaning, maintenance of wells, etc. Additional cost will be added by the project with respect to maintenance of six new relief wells and temporary pumping of the well header during high flood events. The appropriate Operation and Maintenance manuals will be updated accordingly at the conclusion of the project.

I. Value Engineering

A Value Engineering Study appropriate to the feasibility phase, as required by Corps Regulations, was conducted and completed in October 2008. This value engineering process identified one potentially beneficial improvement that might be implemented to realize cost savings for the project.

The possibility of employing drilled anchors instead of a heel extension for the control of the East Oakland Pump Station uplift concern was considered and is recommended for further review during the PED phase. Drilled anchors have recently been proposed for use in other levee systems to address pump station uplift concern. In other projects, the uplift concern has been of a greater magnitude, making a heel extension too large of an undertaking. The Topeka pump station concern is smaller resulting in the preliminary indication that the costs for a heel extension versus drilled anchors are very similar. Additional comparison using updated design information to be collected during the PED phase is needed to make a final determination.

XI. Plan Implementation

A. Cost Sharing Requirements

The project cost allocation is 100% Flood Risk Management. The non-Federal cost share is determined according to the cost sharing procedures prescribed in the Water Resources Development Act of 1986 (WRDA 86), as amended. In accordance with the typical allocation, the Federal government will be responsible for 65% of implementation costs and the Non-Federal sponsors for the remaining 35%.

Table 16 presents the estimated project costs and cost sharing portions divided by unit. Costs are presented in current (Oct 2008) dollars and as a fully funded estimate. The fully funded estimate includes inflation from Oct 2008 to the expected mid-point of the construction period. Additional detailed cost estimates are provided in Appendix E.

Table 16. Project Cost Sharing

Oct. 2008 Prices, $1,000's				
NED Plan Feature Summary	**Water Works**	**South Topeka/ Oakland**	**North Topeka**	**Total**
Planning, Engineering, and Design (PED)	$ 4	$ 1,580	$ 248	$ 1,832
Construction	$ 43	$ 14,523	$ 2,348	$ 16,914
Construction Management	$ 3	$ 975	$ 154	$ 1,132
LERRD	$ 1	$ 1,161	$ 117	$ 1,279
Total NED Project Cost	$ 51	$ 18,239	$ 2,867	$ 21,157
NED Project Cost Sharing and Credit				
Non-Federal Share:				
Cash Contribution	$ 17	$ 5,223	$ 886	$ 6,126
LERRD	$ 1	$ 1,161	$ 117	$ 1,279
Total Non-Federal Share (35%)	$ 18	$ 6,384	$ 1,003	$ 7,405
Total Federal Share (65%)	$ 33	$ 11,855	$ 1,864	$ 13,752
Fully Funded, $1000's				
NED Plan Feature Summary	**Water Works**	**South Topeka/ Oakland**	**North Topeka**	**Total**
Planning, Engineering, and Design (PED)	$ 5	$ 1,726	$ 271	$ 2,002
Construction	$ 46	$ 16,064	$ 2,598	$ 18,708
Construction Management	$ 4	$ 1,222	$ 193	$ 1,419
LERRD	$ 1	$ 1,254	$ 125	$ 1,380
Total NED Project Cost	$ 56	$ 20,266	$ 3,187	$ 23,509
NED Project Cost Sharing and Credit				
Non-Federal Share:				
Cash Contribution	$ 13	$ 5,839	$ 990	$ 6,842
LERRD	$ 7	$ 1,254	$ 125	$ 1,386
Total Non-Federal Share (35%)	$ 20	$ 7,093	$ 1,115	$ 8,228
Total Federal Share (65%)	$ 36	$ 13,173	$ 2,072	$ 15,281

The local sponsor share for the Waterworks, South Topeka, and Oakland Units will be the responsibility of the City of Topeka. The share for the North Topeka Unit will be the responsibility of the North Topeka Drainage District.

B. Sponsor's Intent

The sponsor's intent to participate in the feasibility study was originally stated in letters received in 1992 requesting the initiation of the study. The sponsors committed to the study financially by signing the original Feasibility Cost Sharing Agreement (FCSA) in 1998. Several schedule and cost changes have been enacted during the study, each with the written approval of the local sponsor. The sponsors have shown every indication that they fully intend to progress into the design and construction phase of the project with the same support given to this Feasibility Study.

C. Project Financing and Sponsor Capability

The project and local cost sharing requirements have been discussed with the sponsors during the study. They are legally constituted bodies under State statutes with taxing authority, and the Corps' assessment indicates that they have the necessary financial basis to cost share a project of this magnitude. The districts have expressed their intent to fund the non-Federal share and are expected to issue general obligation bonds under authority granted them by the State or implement other financing option that may involve a levy on property owners and/or additional contributions by selected large facilities in the protected area. The sponsors have continually expressed very strong support for the project.

D. Summary of Coordination and Public Views

1.0 Study Coordination

The non-Federal sponsors strongly support the Recommended Plan. Each of the sponsors continues to keep the project in good condition as evidenced by recent annual inspection reports and by the evaluations undertaken in the feasibility study. The sponsors will continue to provide full cooperation and are prepared to meet the necessary financial obligation associated with the recommendations contained in the Feasibility Report.

Extensive coordination with several State and Federal agencies took place during development and evaluation of the Recommended Plan and the Environmental Assessment. The following agencies were coordinated with and in some cases have provided comments or participated in the review of this project:

- Federal Emergency Management Agency
- U.S. Environmental Protection Agency

- U.S. Fish and Wildlife Service
- Natural Resources Conservation Service
- Kansas Department of Wildlife & Parks
- Kansas Department of Health and Environment
- Kansas State Historic Preservation Office

2.0 Public Involvement

Public involvement and coordination is discussed in Appendix B.

E. Future Project Schedule

The project designs, cost estimates and economic analyses presented in this report are based on a future project milestone schedule as follows:

DEC 2008	Feasibility Report Approval
APR 2009	Execution of Project Design Agreement with Local Sponsor and initiation of Pre-Construction Engineering and Design Phase
OCT 2011	Initiation of Land and Easement Acquisition by the Local Sponsor
MAR 2012	Execution of the Project Cooperation Agreement with the Local Sponsor
APR 2012	Initiation of Construction Phase
OCT 2014	Completion of Project Construction

Cost estimates were prepared on the basis of one construction contract per levee unit, for a total of four separate contracts. These contracts are anticipated to be scheduled simultaneously.

Costs and economic analyses are periodically reviewed during future project phases and reevaluated as needed based on actual project progress and status.

XII. Conclusions

The Recommended Plan (NED Plan) reduces the risk of flooding through project improvements and remedies planned within the existing flood risk management system examined in this Feasibility Report. In general, the Recommended Plan would implement several geotechnical and structural reliability improvements at different areas of interest within the system.

This plan helps to restore a uniform level of flood risk management for the study area. The NED plan will provide a project that functions in a safe, viable, and reliable manner, as was initially intended by its designers. It is not required as a result of changed conditions or inadequate maintenance, is generally limited to the existing features and does not change the scope or function of the authorized project. It is also economically justified.

There are no significant long-term social or environmental impacts. Design considerations of the plan include avoidance of environmental resources, cultural resources, and HTRW where possible. The long-term environmental and cultural consequences of plan implementation are positive as the increased reliability of the units act to guard the social and environmental fabric that has developed within the protected areas for the last 50 years. A minimal amount of tree and shrub habitat would be lost and mitigation is planned accordingly.

The Recommended Plan carries a small increase in OMRR&R. The sponsors have sufficiency to provide all real estate requirements.

XIII. Recommendation

Upon considering the economic, environmental, social, and engineering aspects of making improvements to the existing Topeka, Kansas, Local Flood Protection Project, it has been determined that a project to reduce the risk of flooding is in the public interest. Accordingly, the Corps of Engineers recommends that the Recommended Plan, as described in this report, be submitted to Congress for implementation with such modifications as the Chief of Engineers may find advisable, and in accordance with existing cost sharing and financing requirements.

The estimated implementation cost of the Recommended Plan is $13,752,050 Federal and $7,404,950 Non-Federal for a total estimated cost of $21,157,000 at October 2008 price levels. The net benefits of the Recommended Plan are $14.26 million, indicating a very strong contribution to the nation's economic output by the project. The average annual flood risk management benefits of the Recommended Plan exceed the average annual cost by a ratio of 13.2 to 1.

All items included in the Recommended Plan are necessary to continue providing the flood risk management benefits as intended by Congress.

Federal implementation of the recommended project would be subject to the non-Federal sponsor agreeing to comply with applicable Federal laws and policies, including but not limited to:

a. Provide a minimum of 35 percent, but not to exceed 50 percent of total project costs as further specified below:

    1. Provide 25 percent of design costs in accordance with the terms of a design agreement entered into prior to commencement of design work for the project;

    2. Provide, during the first year of construction, any additional funds necessary to pay the full non-Federal share of design costs;

    3. Provide, during construction, a contribution of funds equal to 5 percent of total project costs;

    4. Provide all lands, easements, and rights-of-way, including those required for relocations, the borrowing of material, and the disposal of dredged or excavated

material; perform or ensure the performance of all relocations; and construct all improvements required on lands, easements, and rights-of-way to enable the disposal of dredged or excavated material all as determined by the Government to be required or to be necessary for the construction, operation, and maintenance of the project;

5. Provide, during construction, any additional funds necessary to make its total contribution equal to at least 35 percent of total project costs;

b. Shall not use funds from other Federal programs, including any non-Federal contribution required as a matching share therefore, to meet any of the non-Federal obligations for the project unless the Federal agency providing the Federal portion of such funds verifies in writing that expenditure of such funds for such purpose is authorized;

c. Not less than once each year, inform affected interests of the extent of protection afforded by the project;

d. Agree to participate in and comply with applicable Federal floodplain management and flood insurance programs;

e. Comply with Section 402 of the Water Resources Development Act of 1986, as amended (33 U.S.C. 701b-12), which requires a non-Federal interest to prepare a floodplain management plan within one year after the date of signing a project cooperation agreement, and to implement such plan not later than one year after completion of construction of the project;

f. Publicize floodplain information in the area concerned and provide this information to zoning and other regulatory agencies for their use in adopting regulations, or taking other actions, to prevent unwise future development and to ensure compatibility with protection levels provided by the project;

g. Prevent obstructions or encroachments on the project (including prescribing and enforcing regulations to prevent such obstructions or encroachments) such as any new developments on project lands, easements, and rights-of-way or the addition of facilities which might reduce the level of protection the project affords, hinder operation and maintenance of the project, or interfere with the project's proper function;

h. Comply with all applicable provisions of the Uniform Relocation Assistance and Real Property Acquisition Policies Act of 1970, Public Law 91-646, as amended (42 U.S.C. 4601-4655), and the Uniform Regulations contained in 49 CFR Part 24, in acquiring lands, easements, and rights-of-way required for construction, operation, and maintenance of the project, including those necessary for relocations, the borrowing of materials, or the disposal of dredged or excavated material; and inform all affected persons of applicable benefits, policies, and procedures in connection with said Act;

i. For so long as the project remains authorized, operate, maintain, repair, rehabilitate, and replace the project, or functional portions of the project, including any mitigation features, at no cost to the Federal Government, in a manner compatible with the project's authorized purposes and in accordance with applicable Federal and State laws and regulations and any specific directions prescribed by the Federal Government;

j. Give the Federal Government a right to enter, at reasonable times and in a reasonable manner, upon property that the non-Federal sponsor owns or controls for access to the project for the purpose of completing, inspecting, operating, maintaining, repairing, rehabilitating, or replacing the project;

k. Hold and save the United States free from all damages arising from the construction, operation, maintenance, repair, rehabilitation, and replacement of the project and any betterments, except for damages due to the fault or negligence of the United States or its contractors;

l. Keep and maintain books, records, documents, or other evidence pertaining to costs and expenses incurred pursuant to the project, for a minimum of 3 years after completion of the accounting for which such books, records, documents, or other evidence are required, to the extent and in such detail as will properly reflect total project costs, and in accordance with the standards for financial management systems set forth in the Uniform Administrative Requirements for Grants and Cooperative Agreements to State and Local Governments at 32 Code of Federal Regulations (CFR) Section 33.20;

m. Comply with all applicable Federal and State laws and regulations, including, but not limited to: Section 601 of the Civil Rights Act of 1964, Public Law 88-352 (42 U.S.C. 2000d) and Department of Defense Directive 5500.11 issued pursuant thereto; Army Regulation 600-7, entitled "Nondiscrimination on the Basis of Handicap in Programs and Activities Assisted or Conducted by the Department of the Army"; and all applicable Federal labor standards requirements including, but not limited to, 40 U.S.C. 3141- 3148 and 40 U.S.C. 3701 – 3708 (revising, codifying and enacting without substantial change the provisions of the Davis-Bacon Act (formerly 40 U.S.C. 276a *et seq.*), the Contract Work Hours and Safety Standards Act (formerly 40 U.S.C. 327 *et seq.*) and the Copeland Anti-Kickback Act (formerly 40 U.S.C. 276c *et seq.*);

n. Perform, or ensure performance of, any investigations for hazardous substances that are determined necessary to identify the existence and extent of any hazardous substances regulated under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), Public Law 96-510, as amended (42 U.S.C. 9601-9675), that may exist in, on, or under lands, easements, or rights-of-way that the Federal Government determines to be required for construction, operation, and maintenance of the project. However, for lands that the Federal Government determines to be subject to the navigation servitude, only the Federal Government shall perform such investigations unless the Federal Government provides the non-Federal sponsor with prior specific written direction, in which case the non-Federal sponsor shall perform such investigations in accordance with such written direction;

o. Assume, as between the Federal Government and the non-Federal sponsor, complete financial responsibility for all necessary cleanup and response costs of any hazardous substances regulated under CERCLA that are located in, on, or under lands, easements, or rights-of-way that the Federal Government determines to be required for construction, operation, and maintenance of the project;

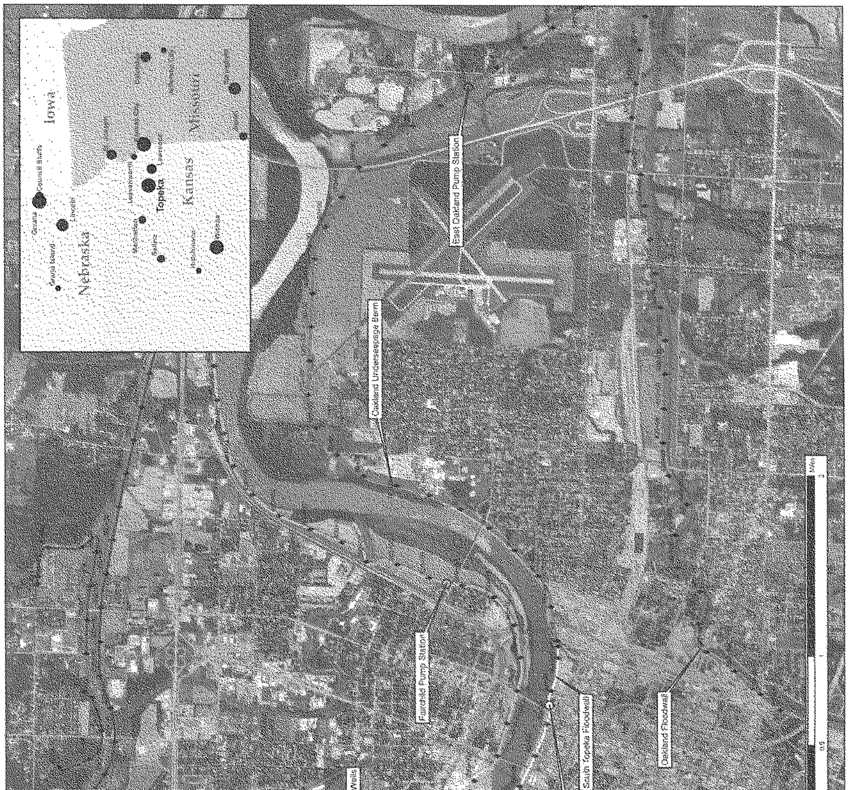
p. Agree, as between the Federal Government and the non-Federal sponsor, that the non-Federal sponsor shall be considered the operator of the project for the purpose of CERCLA liability, and to the maximum extent practicable, operate, maintain, repair, rehabilitate, and replace the project in a manner that will not cause liability to arise under CERCLA; and

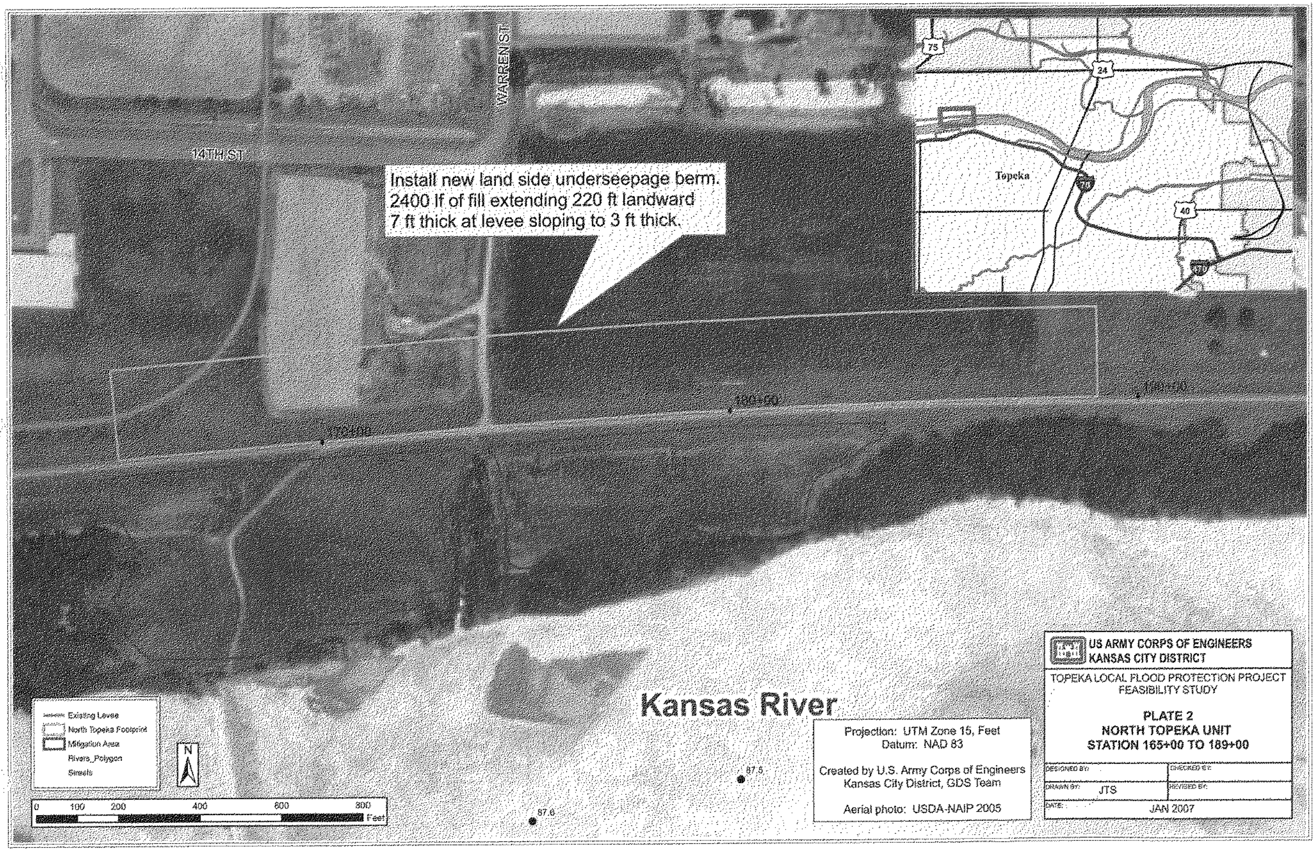
q. Comply with Section 221 of Public Law 91-611, Flood Control Act of 1970, as amended (42 U.S.C. 1962d-5b), and Section 103(j) of the Water Resources Development Act of 1986, Public Law 99-662, as amended (33 U.S.C. 2213(j)), which provides that the Secretary of the Army shall not commence the construction of any water resources project or separable element thereof, until each non-Federal interest has entered into a written agreement to furnish its required cooperation for the project or separable element.

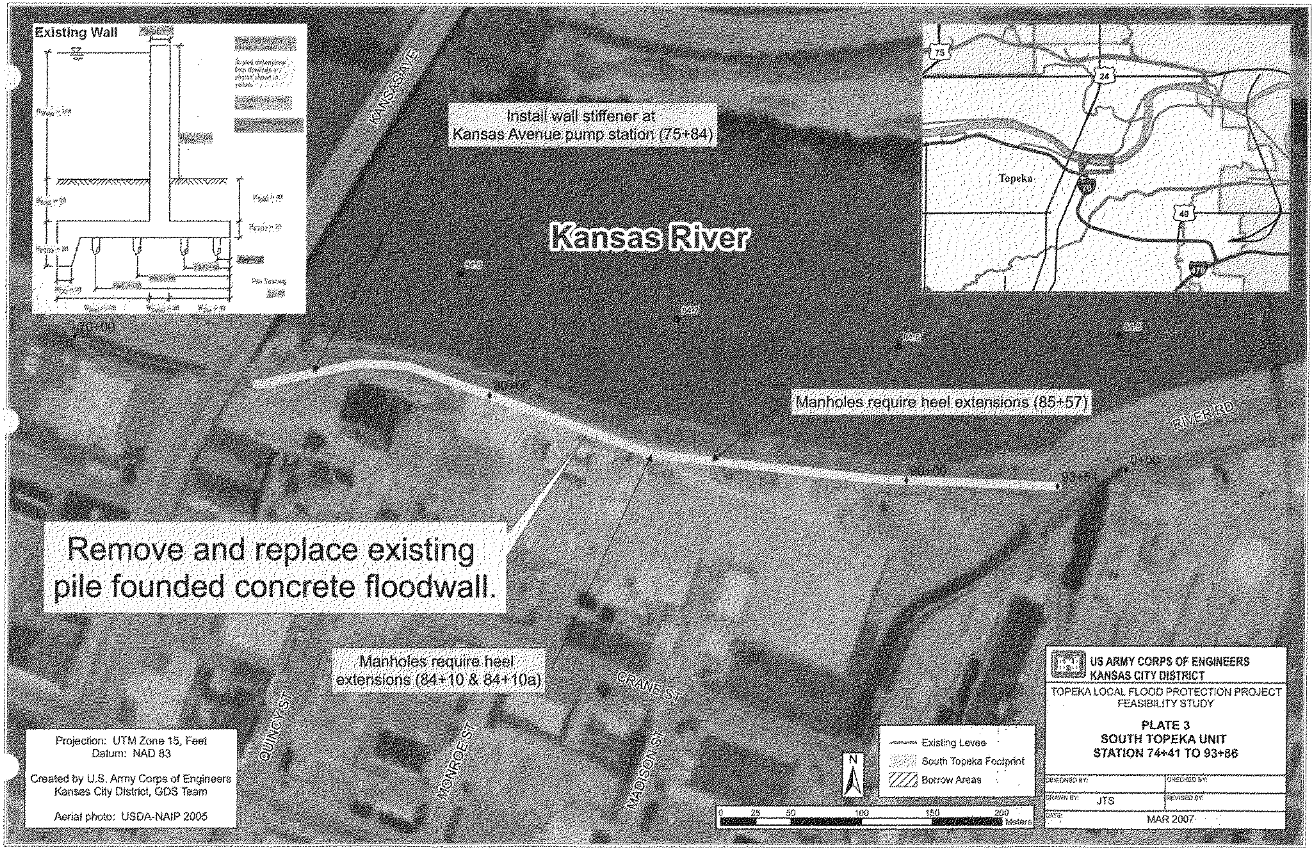
This recommendation is contingent upon such discretionary modifications as deemed necessary by the Chief of Engineers and funding requirements satisfactory to the Administration and Congress. The recommendations contained herein reflect the information available at the time and current Departmental policies governing formulation of individual projects. They do not reflect program and budgeting priorities inherent in the formulation of a national Civil Works construction program nor the perspective of higher review levels within the Executive Branch. Consequently, the recommendation may be modified prior to implementation. However, the project partner, the States, interested Federal agencies, and other parties will be advised of any modifications and will be afforded an opportunity to comment further.

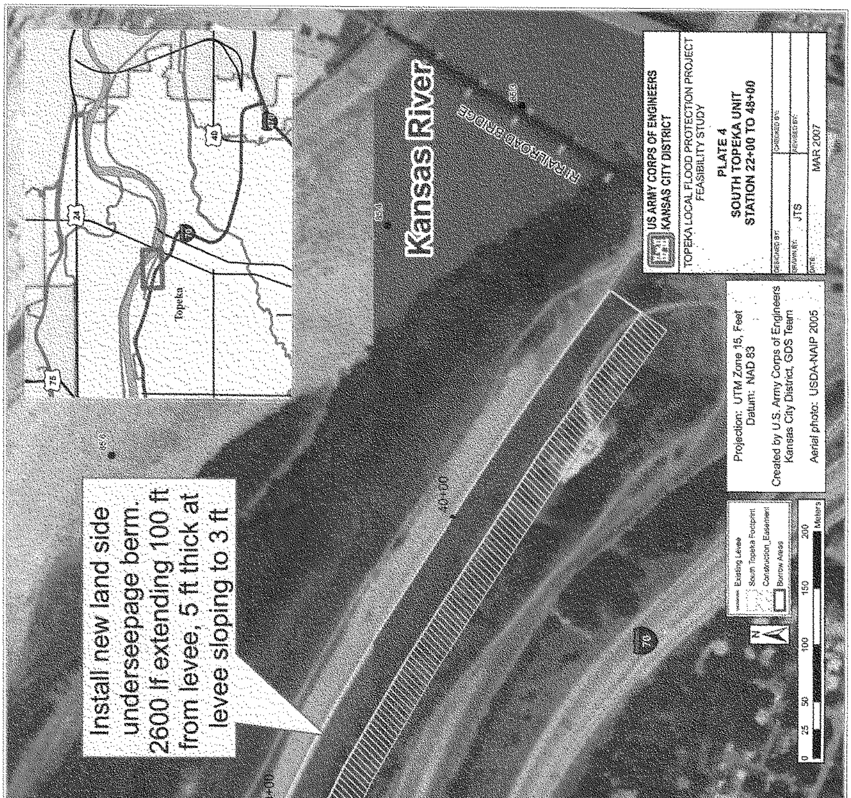
22 DEC 08

Roger A. Wilson, Jr. (date)
Colonel, Corps of Engineers
District Commander

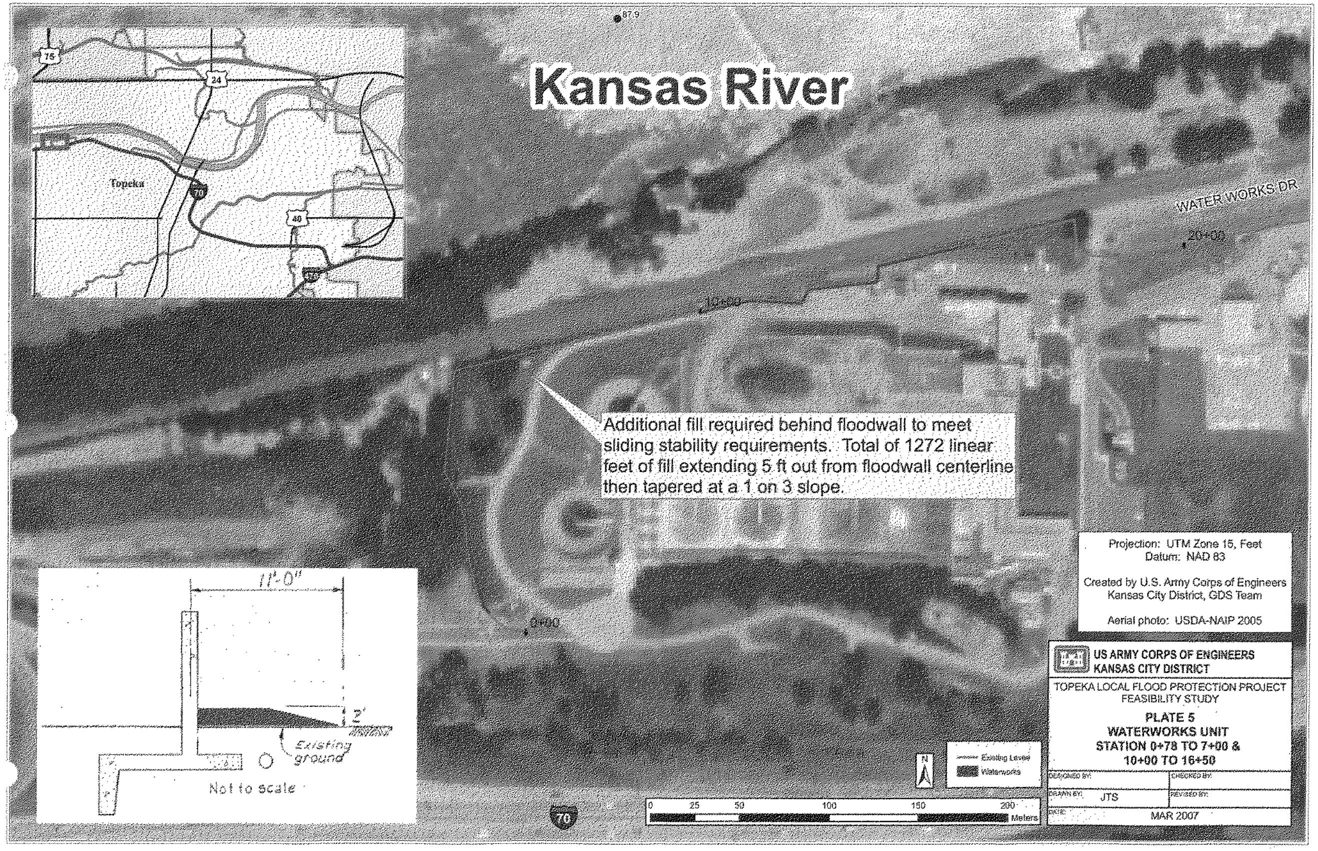

US ARMY CORPS OF ENGINEERS
KANSAS CITY DISTRICT
TOPEKA LOCAL FLOOD PROTECTION PROJECT
FEASIBILITY STUDY
PLATE 1
PROJECT OVERVIEW
JTS
JAN 2007
Levee Station
Levee Unit
Auburndale
North Topeka
Oakland
Soldier Creek
South Topeka
Waterworks
Mitigation Area
Borrow Area
North Topeka Underseepage Berm
Waterworks Floodwall
North Topeka Relief Wells
South Topeka Underseepage Berm
Kansas Avenue Pump Station
South Topeka Floodwall
Fairchild Pump Station
Oakland Floodwall
Oakland Underseepage Berm
East Oakland Pump Station
Nebraska
Iowa
Kansas
Missouri
Topeka

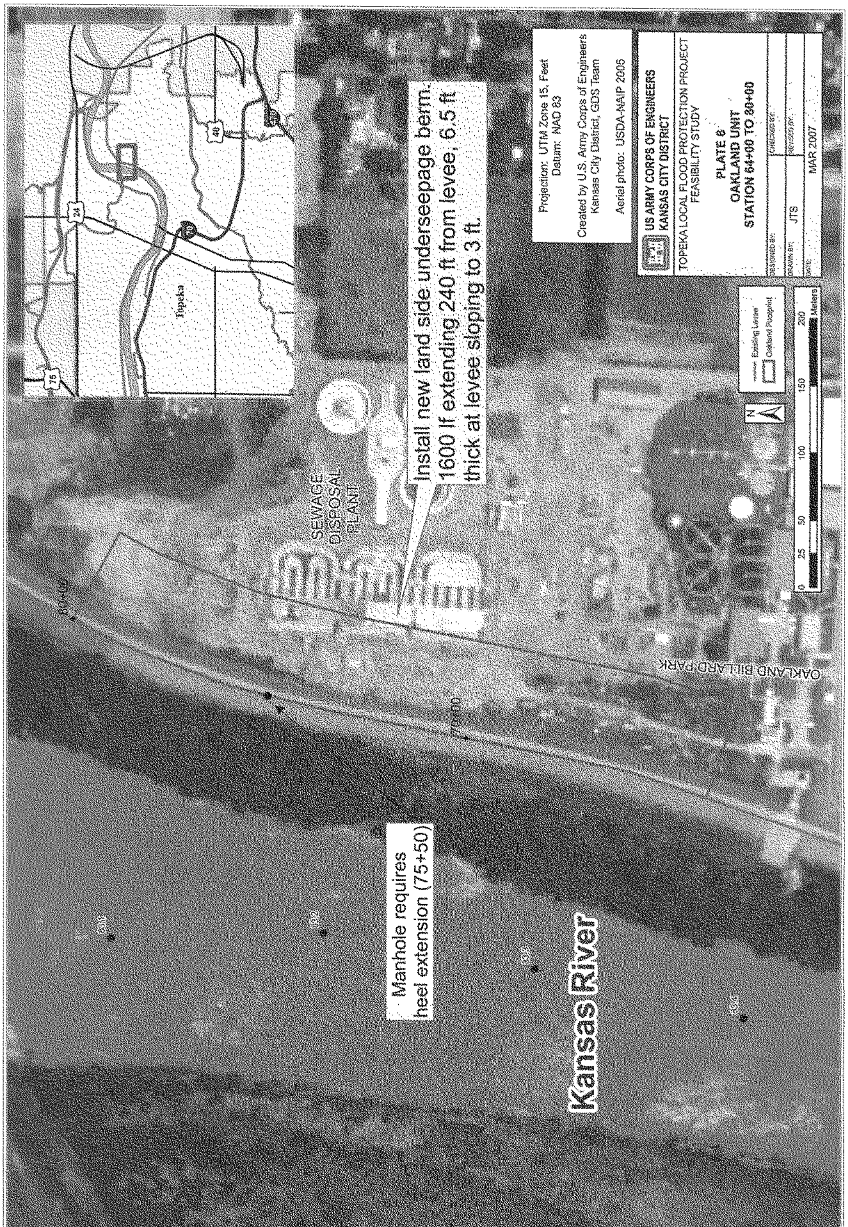

Install new land side underseepage berm.
2400 lf of fill extending 220 ft landward
7 ft thick at levee sloping to 3 ft thick.
14TH ST
WARREN ST
Topeka
75
24
40
Kansas River
87.5
87.6
Existing Levee
North Topeka Footprint
Mitigation Area
Rivers_Polygon
Streets
N
0 100 200 400 600 800 Feet
Projection: UTM Zone 15, Feet
Datum: NAD 83
Created by U.S. Army Corps of Engineers
Kansas City District, GDS Team
Aerial photo: USDA-NAIP 2005
US ARMY CORPS OF ENGINEERS
KANSAS CITY DISTRICT
TOPEKA LOCAL FLOOD PROTECTION PROJECT
FEASIBILITY STUDY
PLATE 2
NORTH TOPEKA UNIT
STATION 165+00 TO 189+00
DESIGNED BY:
CHECKED BY:
DRAWN BY: JTS
REVISED BY:
DATE: JAN 2007

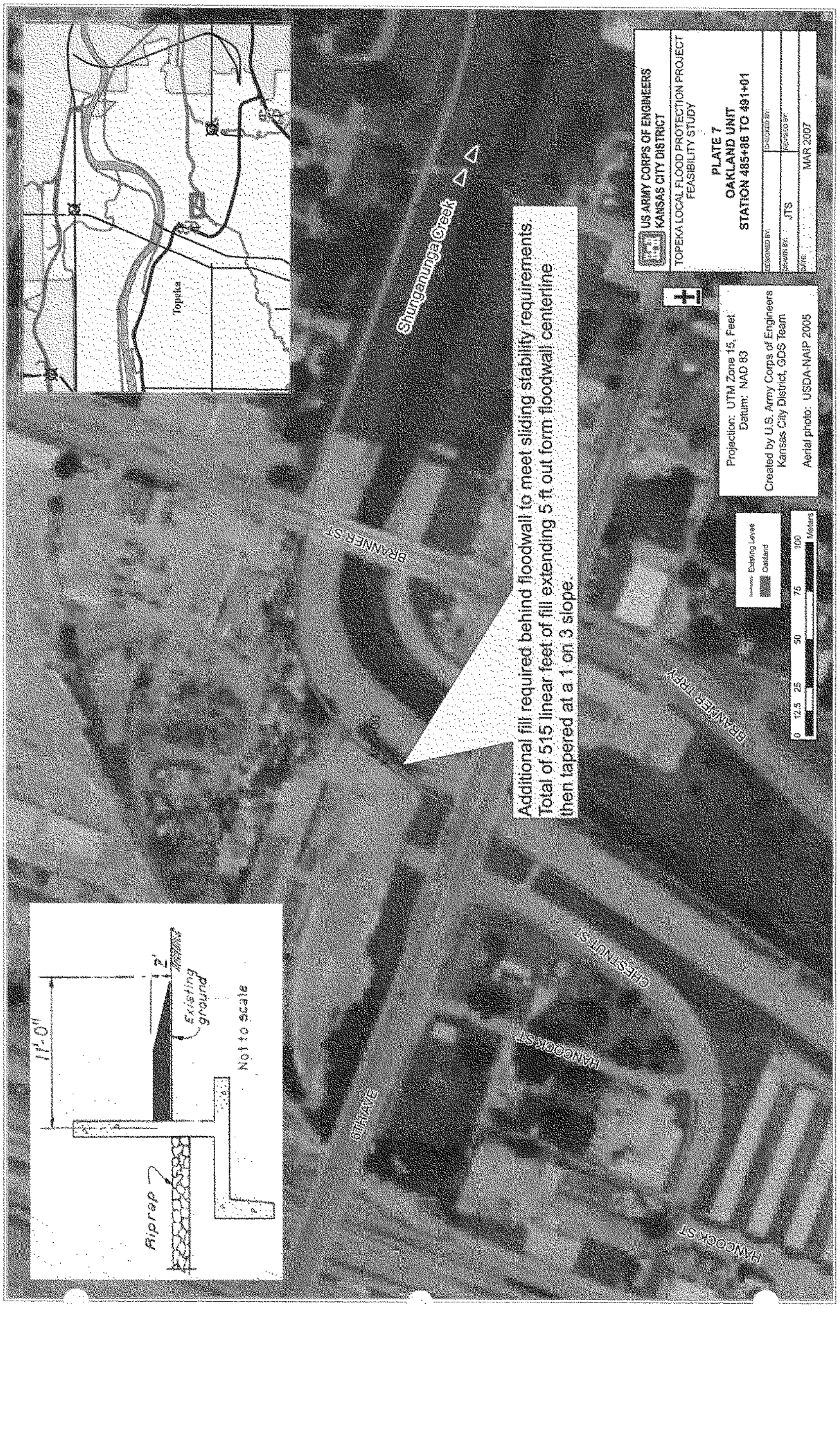

Existing Wall
Install wall stiffener at
Kansas Avenue pump station (75+84)
Kansas River
KANSAS AVE
Topeka
75
24
40
70+00
80+00
90+00
93+54
0+00
Manholes require heel extensions (85+57)
RIVER RD
Remove and replace existing
pile founded concrete floodwall.
Manholes require heel
extensions (84+10 & 84+10a)
CRANE ST
QUINCY ST
MONROE ST
MADISON ST
Projection: UTM Zone 15, Feet
Datum: NAD 83
Created by U.S. Army Corps of Engineers
Kansas City District, GDS Team
Aerial photo: USDA-NAIP 2005
Existing Levee
South Topeka Footprint
Borrow Areas
N
0
25
50
100
150
200
Meters
US ARMY CORPS OF ENGINEERS
KANSAS CITY DISTRICT
TOPEKA LOCAL FLOOD PROTECTION PROJECT
FEASIBILITY STUDY
PLATE 3
SOUTH TOPEKA UNIT
STATION 74+41 TO 93+86
DESIGNED BY:
CHECKED BY:
DRAWN BY: JTS
REVISED BY:
DATE: MAR 2007



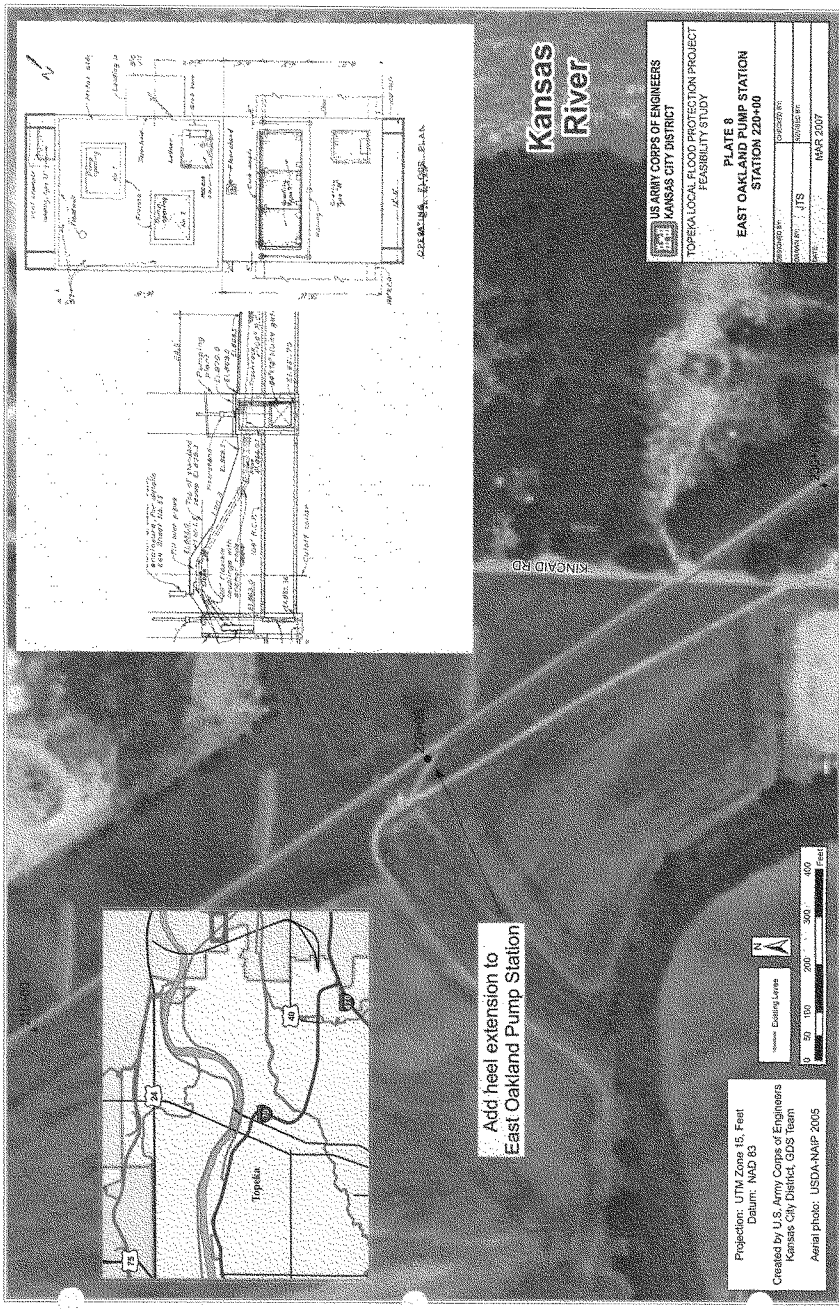
Manhole requires heel extension (16+07)
Construction easement extending 100 ft from new berm.
Install new land side underseepage berm. 2600 lf extending 100 ft from levee, 5 ft thick at levee sloping to 3 ft
RI RAILROAD
20+00
30+00
40+00
Kansas River
RI RAILROAD BRIDGE
Topeka
Existing Levee
South Topeka Footprint
Construction_Easement
Borrow Areas
0 25 50 100 150 200 Meters
Projection: UTM Zone 15, Feet
Datum: NAD 83
Created by U.S. Army Corps of Engineers
Kansas City District, GDS Team
Aerial photo: USDA-NAIP 2005
US ARMY CORPS OF ENGINEERS
KANSAS CITY DISTRICT
TOPEKA LOCAL FLOOD PROTECTION PROJECT
FEASIBILITY STUDY
PLATE 4
SOUTH TOPEKA UNIT
STATION 22+00 TO 48+00
JTS
MAR 2007

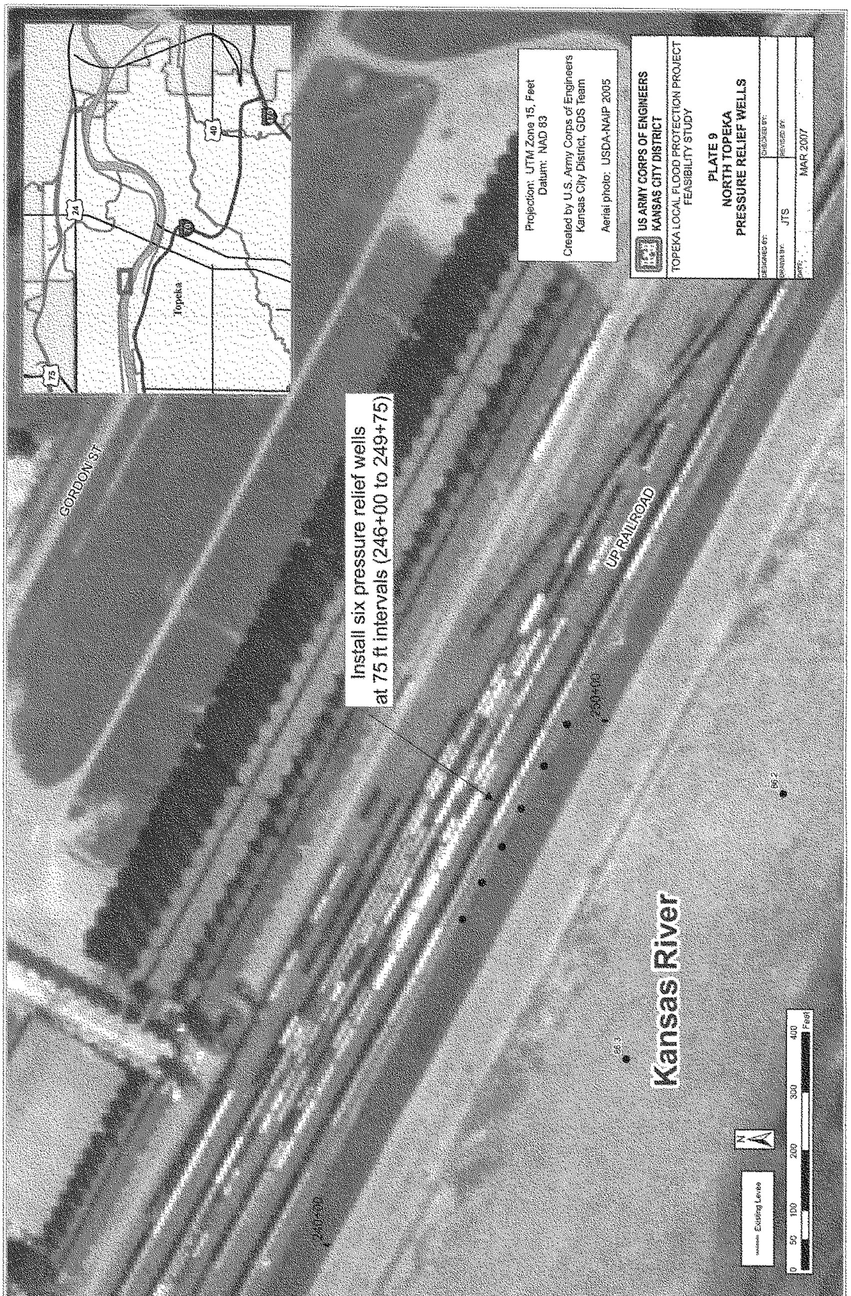

Kansas River
87.9
WATER WORKS DR
20+00
10+00
0+00
Topeka
Additional fill required behind floodwall to meet sliding stability requirements. Total of 1272 linear feet of fill extending 5 ft out from floodwall centerline then tapered at a 1 on 3 slope.
11'-0"
2'
Existing ground
Not to scale
Projection: UTM Zone 15, Feet
Datum: NAD 83
Created by U.S. Army Corps of Engineers
Kansas City District, GDS Team
Aerial photo: USDA-NAIP 2005
US ARMY CORPS OF ENGINEERS
KANSAS CITY DISTRICT
TOPEKA LOCAL FLOOD PROTECTION PROJECT
FEASIBILITY STUDY
PLATE 5
WATERWORKS UNIT
STATION 0+78 TO 7+00 &
10+00 TO 16+50
DESIGNED BY:
CHECKED BY:
DRAWN BY: JTS
REVISED BY:
DATE: MAR 2007
Existing Levee
Waterworks
0 25 50 100 150 200 Meters


Install new land side underseepage berm.
1600 lf extending 240 ft from levee, 6.5 ft
thick at levee sloping to 3 ft.
Manhole requires
heel extension (75+50)
Kansas River
SEWAGE
DISPOSAL
PLANT
OAKLAND BILLARD PARK
80+00
70+00
Topeka
Projection: UTM Zone 15, Feet
Datum: NAD 83
Created by U.S. Army Corps of Engineers
Kansas City District, GDS Team
Aerial photo: USDA-NAIP 2005
US ARMY CORPS OF ENGINEERS
KANSAS CITY DISTRICT
TOPEKA LOCAL FLOOD PROTECTION PROJECT
FEASIBILITY STUDY
PLATE 6
OAKLAND UNIT
STATION 64+00 TO 80+00
DESIGNED BY:
DRAWN BY: JTS
DATE: MAR 2007
CHECKED BY:
REVIEWED BY:
Existing Levee
Oakland Footprint
N
0 25 50 100 150 200 Meters

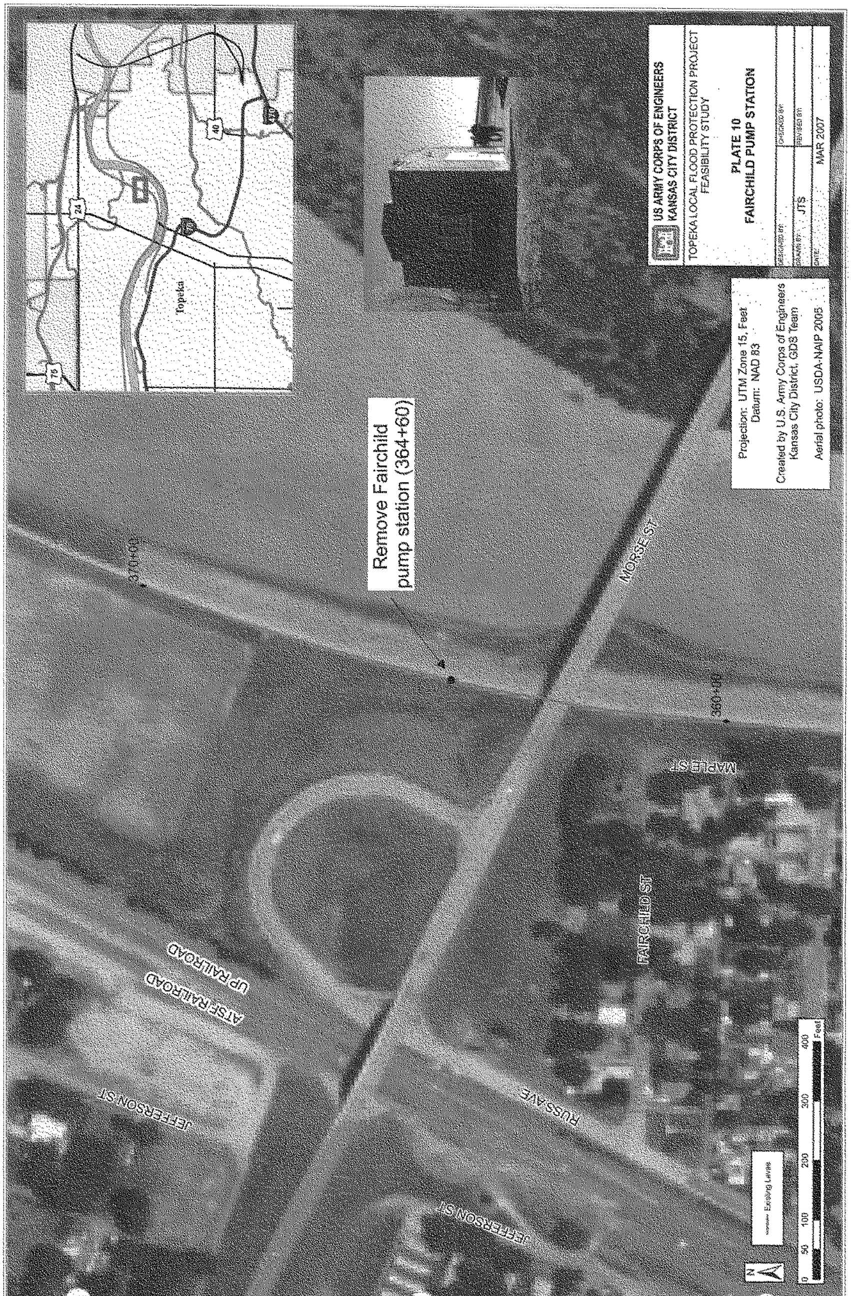


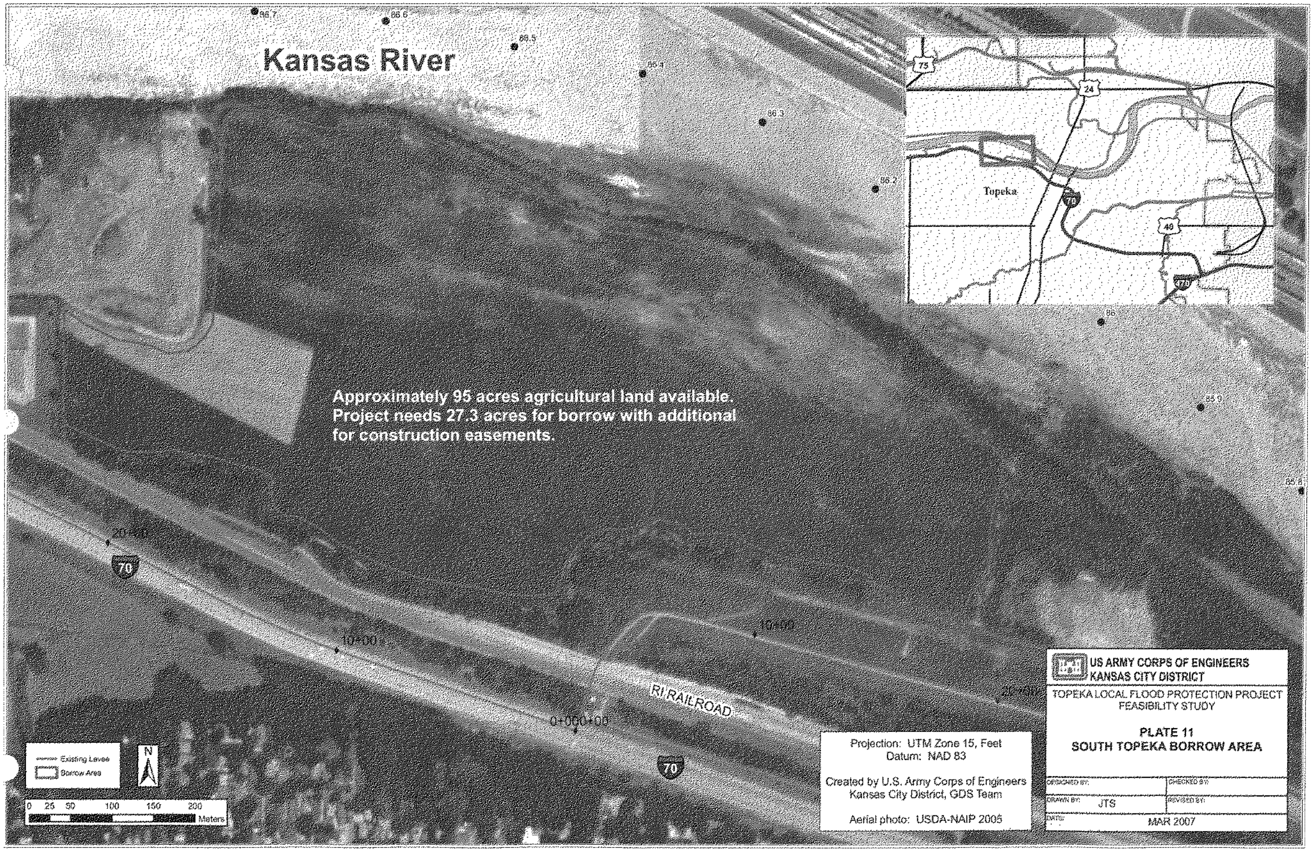
US ARMY CORPS OF ENGINEERS
KANSAS CITY DISTRICT
TOPEKA LOCAL FLOOD PROTECTION PROJECT
FEASIBILITY STUDY
PLATE 7
OAKLAND UNIT
STATION 485+86 TO 491+01
DESIGNED BY:
CHECKED BY:
DRAWN BY: JTS
REVISED BY:
DATE: MAR 2007
Projection: UTM Zone 15, Feet
Datum: NAD 83
Created by U.S. Army Corps of Engineers
Kansas City District, GDS Team
Aerial photo: USDA-NAIP 2005
Existing Levee
Oakland
0 12.5 25 50 75 100 Meters
Topeka
Shunganunga Creek
Additional fill required behind floodwall to meet sliding stability requirements.
Total of 515 linear feet of fill extending 5 ft out form floodwall centerline
then tapered at a 1 on 3 slope.
BRANNER ST
BRANNER TRFY
CHESTNUT ST
HANCOCK ST
6TH AVE
11'-0"
2'
Existing ground
Riprap
Not to scale

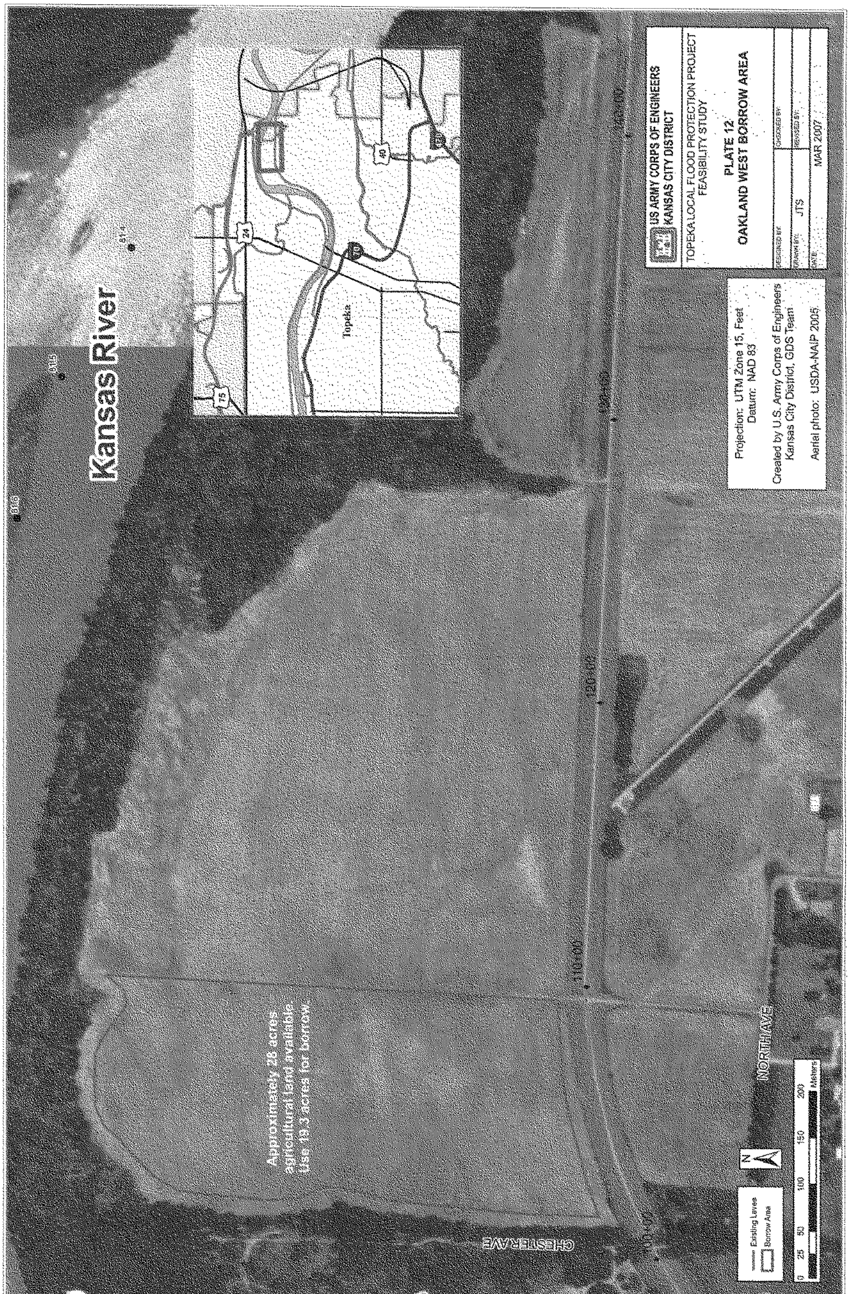

Kansas River
US ARMY CORPS OF ENGINEERS
KANSAS CITY DISTRICT
TOPEKA LOCAL FLOOD PROTECTION PROJECT
FEASIBILITY STUDY
PLATE 8
EAST OAKLAND PUMP STATION
STATION 220+00
JTS
MAR 2007
KINCAID RD
OPERATING FLOOR PLAN
Add heel extension to
East Oakland Pump Station
Existing Levee
Topeka
0 50 100 200 300 400 Feet
Projection: UTM Zone 15, Feet
Datum: NAD 83
Created by U.S. Army Corps of Engineers
Kansas City District, GDS Team
Aerial photo: USDA-NAIP 2005

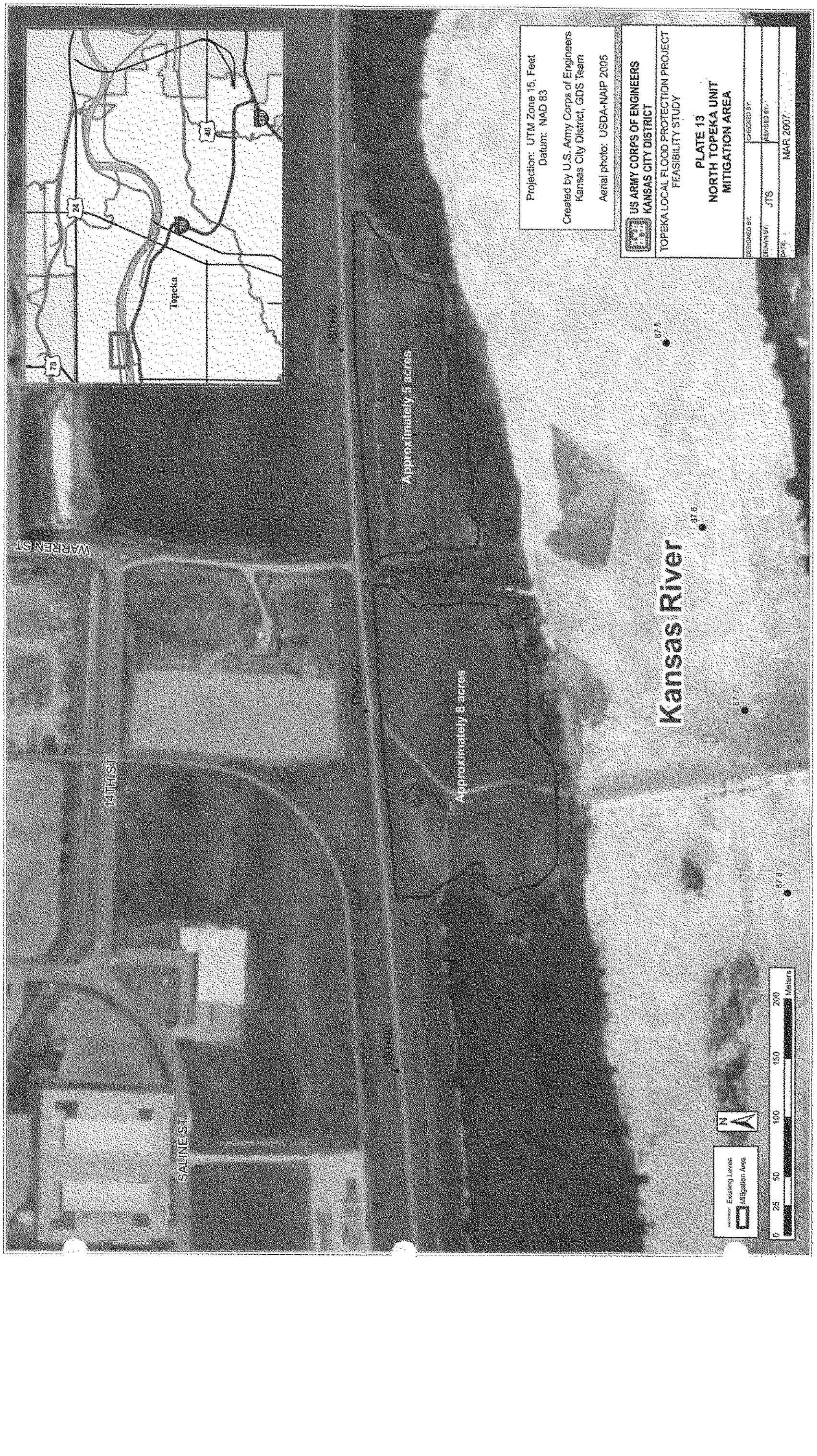


Install six pressure relief wells
at 75 ft intervals (246+00 to 249+75)
GORDON ST
UP RAILROAD
Kansas River
Topeka
Existing Levee
0 50 100 200 300 400 Feet
Projection: UTM Zone 15, Feet
Datum: NAD 83
Created by U.S. Army Corps of Engineers
Kansas City District, GDS Team
Aerial photo: USDA-NAIP 2005
US ARMY CORPS OF ENGINEERS
KANSAS CITY DISTRICT
TOPEKA LOCAL FLOOD PROTECTION PROJECT
FEASIBILITY STUDY
PLATE 9
NORTH TOPEKA
PRESSURE RELIEF WELLS
DESIGNED BY:
CHECKED BY:
DRAWN BY: JTS
REVISED BY:
DATE: MAR 2007


US ARMY CORPS OF ENGINEERS
KANSAS CITY DISTRICT
TOPEKA LOCAL FLOOD PROTECTION PROJECT
FEASIBILITY STUDY
PLATE 10
FAIRCHILD PUMP STATION
DRAWN BY: JTS
DATE: MAR 2007
Projection: UTM Zone 15, Feet
Datum: NAD 83
Created by U.S. Army Corps of Engineers
Kansas City District, GDS Team
Aerial photo: USDA-NAIP 2005
Remove Fairchild
pump station (364+60)
370+00
360+00
MORSE ST
MAPLE ST
FAIRCHILD ST
UP RAILROAD
ATSF RAILROAD
JEFFERSON ST
RUSS AVE
JEFFERSON ST
Existing Levee
0 50 100 200 300 400 Feet
N
Topeka
24
40
75


Kansas River
Approximately 95 acres agricultural land available.
Project needs 27.3 acres for borrow with additional
for construction easements.
RI RAILROAD
Topeka
Existing Levee
Borrow Area
0 25 50 100 150 200 Meters
Projection: UTM Zone 15, Feet
Datum: NAD 83
Created by U.S. Army Corps of Engineers
Kansas City District, GDS Team
Aerial photo: USDA-NAIP 2005
US ARMY CORPS OF ENGINEERS
KANSAS CITY DISTRICT
TOPEKA LOCAL FLOOD PROTECTION PROJECT
FEASIBILITY STUDY
PLATE 11
SOUTH TOPEKA BORROW AREA
DRAWN BY: JTS
DATE: MAR 2007


Kansas River
61.6
61.5
61.4
US ARMY CORPS OF ENGINEERS
KANSAS CITY DISTRICT
TOPEKA LOCAL FLOOD PROTECTION PROJECT
FEASIBILITY STUDY
PLATE 12
OAKLAND WEST BORROW AREA
DESIGNED BY:
CHECKED BY:
DRAWN BY: JTS
REVISED BY:
DATE: MAR 2007
Projection: UTM Zone 15, Feet
Datum: NAD 83
Created by U.S. Army Corps of Engineers
Kansas City District, GDS Team
Aerial photo: USDA-NAIP 2005
Topeka
100+00
110+00
120+00
130+00
140+00
Approximately 26 acres
agricultural land available
Use 19.3 acres for borrow.
NORTH AVE
CHESTER AVE
Existing Levee
Borrow Area
0 25 50 100 150 200 Meters
N


Projection: UTM Zone 15, Feet
Datum: NAD 83
Created by U.S. Army Corps of Engineers
Kansas City District, GDS Team
Aerial photo: USDA-NAIP 2005
US ARMY CORPS OF ENGINEERS
KANSAS CITY DISTRICT
TOPEKA LOCAL FLOOD PROTECTION PROJECT
FEASIBILITY STUDY
PLATE 13
NORTH TOPEKA UNIT
MITIGATION AREA
JTS
MAR 2007
Topeka
WARREN ST
14TH ST
SALINE ST
Approximately 5 acres
Approximately 8 acres
Kansas River
Existing Levee
Mitigation Area
Meters

US Army Corps
of Engineers
Kansas City District

U.S. Army Corps of Engineers-Kansas City District

Finding of No Significant Impact

CITY OF TOPEKA, FLOOD RISK MANAGEMENT PROJECT

SHAWNEE COUNTY, KANSAS

December 2008

DEPARTMENT OF THE ARMY
KANSAS CITY DISTRICT, CORPS OF ENGINEERS
700 FEDERAL BUILDING
KANSAS CITY, MISSOURI 64106-2896

Finding of No Significant Impact

CITY OF TOPEKA
FLOOD RISK MANAGEMENT PROJECT
TOPEKA, KANSAS

SUMMARY

The U.S. Army Corps of Engineers, Kansas City District (USACE), at the request and with the cooperation of the City of Topeka (local sponsor), proposes to provide flood risk management for the City of Topeka, Kansas. Specifically, this project will correct the existing geotechnical and structural weaknesses and increase the reliability of the flood risk management system for the City of Topeka. The Topeka flood risk management levee system is located in Shawnee County, Topeka, Kansas at the confluence of Soldier Creek and the Kansas River, and is a unit of the Kansas River Basin System. The levee units in Topeka that are proposed for modifications in this plan are: South Topeka Unit, Waterworks Unit, Oakland Unit, and North Topeka Unit. Proposed improvements include the installation of landside underseepage berms, heel extensions, fill behind floodwalls, new pressure relief wells, a wall stiffener on Kansas Avenue Pump Station, stability berms, removal of the Fairchild Pump Station, replacement of a section of the floodwall, and replacement of floodwall gatewells and sluice gates. The Auburndale and Soldier Creek units were studied for deficiencies in the early phase of the project. However, there were no deficiencies found; therefore, no work has been proposed for the Auburndale and Soldier Creek units. The authority for the study of this project is provided by Section 216 of the 1970 Flood Control Act.

PUBLIC INVOLVEMENT

A public meeting was held on 14 November 1996 at the Garfield Community Center in Topeka, Kansas. The purpose was to inform the public of the proposed study and to get feedback on the alternatives proposed in the study. Comments were addressed by USACE representatives and a record of these comments was included in the 1997 Reconnaissance Report. A second public meeting was conducted October 22, 2008 during the 30-day public review period of the Draft EA and Feasibility Report. The Draft Report was mailed to Federal and state agencies, local media, residents within the affected community and other interested parties. All comments received during the public review period were addressed. Comments were received during the public review period from the following entities: City of Topeka, Friends of the Kaw, North Topeka Drainage District, U.S. Fish & Wildlife Service, Kansas State Historical Society, Natural Resources Conservation Service, and Federal Aviation Administration. There were no comments that required reevaluation of the alternatives, identification of a new recommended plan, or a critical change to impact analysis. Copies of the comment letters and USACE responses can be found in the Appendix B of the Main Feasibility Report.

ALTERNATIVES

A total of four alternatives were evaluated in terms of individual and cumulative effects for the proposed project, which are Alternative 1-Recommended Plan, Alternative 2- Pressure Relief Wells, Alternative 3- Commercial Fill, Alternative 4- No-Action. These are addressed below.

Alternative 1- Recommended Plan: The Recommended Plan consists of the preferred alternatives for each levee unit and these are listed below. In addition, the Recommended Plan will require fill from two borrow areas. Fill will be obtained from two agricultural areas within the Oakland and South Topeka units. Approximately 19.3 acres will be excavated at the Oakland borrow site and 27.3 acres at the South Topeka borrow site.

Oakland Unit: A new earthen underseepage berm will be installed landward of the levee behind the water treatment plant. The berm will be placed along the toe of the levee for about 1,600 linear feet at a height of 6.5 feet, sloping to three feet thick at a distance of about 240 feet outward from the levee. At stations 75+50 and 220+00, heel extensions will be added to the manholes and to the East Oakland Pump Station to mitigate uplift pressures. Two feet of additional fill will be required behind the Shunganunga Creek floodwall to meet sliding stability requirements. About 388 cubic yards of fill will be used and will extend about five feet from the floodwall centerline and taper at a 1:3 slope.

North Topeka Unit: A new earthen underseepage berm will be installed landward of the levee from station 165+00 to 189+00. The berm will be placed along the levee toe for 2,400 linear feet. About 122,250 cubic yards of fill will be used for construction of the berm. New pressure relief wells will be installed along the levee for about 400 linear feet between stations 246+00 and 250+00. Six wells will be placed 75 feet apart and 75 feet deep. The existing Fairchild Pump Station will be removed. However, the below ground level structures will be left in place, filled with concrete-like material, and then covered with soil.

South Topeka Unit: A new earthen underseepage berm will be installed landward of the levee from station 22+00 to 48+00. The berm will be installed at the toe of the levee for about 2,200 linear feet. About 48,150 cubic yards of fill will be used for the construction of the berm. At station 74+41 to 93+86, the existing South Topeka floodwall will be removed and replaced. The new floodwall will be concrete and built along the existing wall alignment to the same length and height. Also, a working platform will be constructed on the bank of the river. This platform is not likely to extend into or impact the river itself. Access to this area will be from the landside through the first removed section of the existing wall. The existing gate wells and sluice gates will be replaced as part of the floodwall replacement. Three existing manholes will require heel extensions to mitigate uplift pressures. In addition, a wall stiffener at Kansas Avenue Pump Station will be installed to meet the required strength factor for safety.

Waterworks Unit: Approximately two feet of additional fill will be placed behind the floodwall to meet sliding stability requirements. About 1,272 linear feet of fill will be placed along the tow of the wall to five feet out from the floodwall centerline and tapered on a 1 to 3 slope. At stations 13+07 and 15+95, two feet of backfill will be placed behind the stop-log gap sidewalls to address sliding stability. A total of 958 cubic yards of fill will be used to meet sliding stability requirements.

Alternative 2 - Pressure Relief Wells: Under this alternative, the proposed actions will be the same as those described in the Recommended Plan, except pressure relief wells will be installed in place of the proposed underseepage berms on the North Topeka, South Topeka and Oakland Units. The relief wells will be placed landward and within the maintained right-of-way of the levee. The relief well system provides the reliability required with minor, negligible environmental impacts. With the use of pressure relief wells, the amount of borrow material required will be reduced. Both the Waterworks and the Oakland stability berms will be supplied by a single borrow cell. However, this alternative will be more expensive than the recommended plan due to its associated annual operation and maintenance costs.

Alternative 3 - Commercial Fill: Under this alternative, the proposed actions will be the same as those described in the Recommended Plan except under this alternative, borrow fill will obtained from a commercial source. Commercially obtained fill will likely come from permitted dredging operations in the Kansas River. The estimated amount of commercial fill needed is about 281,000 cubic yards. Several large dump trucks will be used to haul the fill from the commercial dredge site to the project area. This option was not selected as part of the recommended plan because there is a risk that this option may not be available at the time of construction. However, if the total amount of fill needed cannot be obtained from the proposed borrow sites at the time of project construction; then commercial fill will be obtained if available.

Alternative 4 - No-Action Alternative: Under the No-Action Alternative, the proposed project will not be constructed by the USACE. Existing weaknesses in the levees system would be allowed to continue and the risks to public safety and community infrastructure from potential flooding would remain.

SUMMARY OF ENVIRONMENTAL IMPACTS

The recommended plan has relatively minor impacts to the natural environment with overall positive benefits to the socio-economic environment. Impacts to the natural environment are minor because the project is located within a previously disturbed environment that is highly industrial and urbanized. The recommended plan would not result in any impacts to Federally-listed threatened or endangered species or their habitat. The proposed action would have no impact to sites listed on or eligible for inclusion on the National Register of Historic Places. Temporary, short-term construction impacts to natural and human environment would be related to noise, visual disturbance. The adverse impacts to the natural environment are minor and include the loss of about seven and one-half acres of woodland from the proposed construction of the underseepage berm at South Topeka unit. These impacts will be compensated through replanting and establishment of a natural area within a designated mitigation site. In addition, for borrow excavations from the two agricultural areas, appropriate measures will be taken to allow these areas to return to agricultural use after borrow and construction operations. For borrow operations, the top one foot of soil will be removed, stockpiled, and returned to the site after completion of excavation. In addition, excavation depths in agricultural areas will be kept to a minimum (four feet or less) to reduce impacts to field drainage and to allow farming operations to resume after construction is complete. Also, borrow cells will be excavated after the crops are harvested to avoid crop loss.

MITIGATION

Compensatory mitigation will include establishing a 15-acre planting regime within the South Topeka and North Topeka unit areas. Native tree and grass plantings will be implemented concurrently and/or following project construction. Additional mitigation measures will include the avoidance of construction activities in woodland areas during the migratory bird nesting season of April 1 to July 15. In addition, to minimize risk associated with HTRW contamination from proposed activities, any soil removed from a site associated with the levee work or borrow areas will be analyzed to ensure proper disposal.

CONCLUSION

Based on the environmental assessment, it has been determined that the Recommended Plan will not have any substantial adverse impacts on the natural and human environment. All practicable means to avoid and/or minimize adverse environmental effects have been incorporated into the Recommended Plan. Therefore, the Recommended Plan is the environmentally preferable alternative. Further, the USACE has determined that construction of the proposed project would not significantly impact the human environment and, therefore, an Environmental Impact Statement will not be prepared.

Date: 22 DEC 08

Roger A. Wilson, Jr.
Colonel, Corps of Engineers
District Commander

Environmental Assessment
City of Topeka
Flood Risk Management Study
Topeka, Kansas

December 2008

U.S. Army Corps of Engineers
Kansas City District
601 E 12th St.
Kansas City, Missouri 64106-2896

**CITY OF TOPEKA,
FLOOD RISK MANAGEMENT STUDY
ENVIRONMENTAL ASSESSEMENT
DECEMBER 2008**

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ENVIRONMENTAL ASSESSMENT

CITY OF TOPEKA,
FLOOD RISK MANAGEMENT STUDY

SHAWNEE COUNTY, KANSAS

1.0 INTRODUCTION

The U.S. Army Corps of Engineers (USACE), Kansas City District, has prepared this Environmental Assessment (EA) to evaluate the potential impacts associated with the recommended plan to provide flood risk management for the City of Topeka, Kansas. The Topeka Flood Risk Management Study is located at the confluence of Soldier Creek and the Kansas River, and is a unit of the Kansas River Basin System. The levee units in Topeka that are proposed for modifications in this plan are: South Topeka Unit, Waterworks Unit, Oakland Unit, and North Topeka Unit. The Auburndale and Soldier Creek units were studied for deficiencies in the early phase of the project. However, there were no deficiencies found; therefore, no work has been proposed for these units.

2.0 PURPOSE AND NEED FOR THE RECOMMENDED PLAN

The purpose of the recommended plan is to increase the reliability of the flood risk management system for the City of Topeka. The purpose of the recommended plan is to correct existing geotechnical and structural weaknesses and increase the reliability of the flood risk management system for the City of Topeka. The recommended plan is needed to reduce the risk to the local population from flooding due to levee failure and maintain the performance of the system as originally authorized and intended by Congress.

3.0 AUTHORITY FOR THE RECOMMENDED PLAN

This study is being conducted under the authority provided by Section 216 of the 1970 Flood Control Act. *(For more information, see the Feasibility Report page 3)*

4.0 PRIOR REPORTS

For information on prior reports, see the Feasibility Report.

5.0 PUBLIC INVOLVEMENT

A public meeting was held on 14 November 1996 at the Garfield Community Center in Topeka, Kansas. The purpose was to inform the public of the proposed study and to get feedback on the alternatives proposed in the study. Comments were addressed by USACE representatives and a record of these comments was included in the 1997 Reconnaissance Report. A second public meeting was conducted October 22, 2008 during the 30-day public review period of the Draft

EA and Feasibility Report. The Draft Report was mailed to Federal and state agencies, local media, residents within the affected community and other interested parties. All comments received during the public review period were addressed. There were no comments that required reevaluation of the alternatives, identification of a new recommended plan, or a critical change to impact analysis. On the Draft EA, one comment was received from the U.S. Fish and Wildlife Agency by letter dated, October 28, 2008. A copy of the USFWS letter and the USACE's response can be found in the Feasibility Report Appendix B.

6.0 LEVEE UNIT DESCRIPTIONS

For levee unit descriptions, see the Feasibility Report.

7.0 DESCRIPTION OF THE RECOMMENDED PLAN

The recommended plan consists of the preferred alternatives for each levee unit. The preferred alternatives are considered to have the highest net benefits, formulated to minimize negative environmental impacts, and designed to maximize cost-effectiveness. The recommended plan for each levee unit is listed below. Plate references in this Environmental Assessment, unless otherwise noted, are directed to the project maps found at the end of the Feasibility Report.

Oakland Unit

At station 64+00 to 80+00, a new earthen underseepage berm would be installed on the landward side of the levee behind the water treatment plant (Plate 6). The berm would be placed along the toe of the levee for about 1,600 linear feet at a height of 6.5 feet, sloping to three feet thick at a distance of about 240 feet outward from the levee. About 84,500 cubic yards of fill would be used.

At station 75+50, heel extensions would be added to the manholes by placing concrete on the existing foundation of the structure to increase its capacity to withstand uplift pressures

At station 220+00, heel extensions would be added to the East Oakland Pump Station to mitigate uplift pressures (Plate 8).

At station 485+86 to station 491+01, two feet of additional fill would be required behind the floodwall to meet sliding stability requirements (Plate 7). About 388 cubic yards of fill would be used and would extend about five feet out from the floodwall centerline and taper at a 1:3 slope.

North Topeka Unit

At station 165+00 to 189+00, a new earthen underseepage berm would be installed on the landward side of levee (Plate 2). The berm would be placed along the levee for 2,400 linear feet, seven feet thick at the levee toe sloping to three feet thick at a distance of 220 feet using 122,250 cubic yards of fill.

At station 246+00 to 250+00, new pressure relief wells would be installed along the levee for about 400 linear feet. About six wells would be placed 75 feet apart and 75 feet deep. The wells would be designed to drain to a central manhole using a buried header system. The total discharge of the system would be one cubic foot per second per well. The local sponsor will be required to pump the water down one foot below the existing ground level when the river is near the top of levee. A pad would be constructed on the slope for access. The North Topeka Railroad has a series of tracks just outside of the toe of the levee (about 100 feet from the levee). Temporary excavation for drilling access, a header pipe system and manhole installation would be done inside of the footprint.

At station 364+60, the existing Fairchild Pump Station (no longer used for flood risk management), would be removed (Plate 10). However, the below ground level structures (including the wet well and inlet/outlet pipes) would be left in place, filled with concrete-like material, and then covered with soil.

South Topeka Unit

At station 22+00 to 48+00, a new earthen underseepage berm would be installed on the landward side of the levee (Plate 4). The berm would be installed at the toe of the levee for about 2,200 linear feet, five feet thick at the levee toe sloping to three feet thick at a distance of 100 feet outward from the levee. About 48,150 cubic yards of fill would be used.

At station 74+41 to 93+86, the existing South Topeka floodwall would be removed and replaced (Plate 3). The existing floodwall is 1,944 linear feet of timber pile-founded concrete, about ten to 12 feet above ground and five to ten feet below grade. The existing wall is about one foot thick. The new floodwall would be concrete, and built along the existing wall alignment to the same length and height. About 3,322 cubic yards of concrete would be needed to construct the new floodwall and about 5,000 cubic yards of fill would be stockpiled on site to fill four floodwall monolith openings. The floodwall would be rebuilt in sections by demolishing and rebuilding one section at a time, driving foundation piles, and installing new pile caps. Also, a working platform would be constructed on the bank of the river. For the platform, material would be placed on the river side slope of the floodwall to provide an area wide enough for the placement of construction equipment. This platform is not likely to extend in or impact the river itself. Access to this area would be from the landside through the first removed section of the existing wall. After completion of the access/working area on the river side of the existing wall, removal of the remaining existing wall and construction of the new wall would be done from both sides of the wall. No more than four sections of the existing wall would be open at one time. The stockpiled fill would be used to close the sections as needed in case of flooding during construction.

The existing gate wells at stations 69+22, 75+62, 86+09, and 86+55, and the existing riverside sluice gates at stations 88+69 and 91+02 would be replaced as part of the floodwall replacement. At stations 16+07, 84+10, and 85+57 the existing manholes would require heel extensions to mitigate uplift pressures. At station 75+84, a wall stiffener at Kansas Avenue Pump Station would be installed to meet the required strength factor for safety (Plate 3).

Waterworks Unit

At stations 0+78 to 7+00 and 10+00 to 16+50, two feet of additional fill would be required behind the floodwall to meet sliding stability requirements (Plate 5). About 1,272 linear feet of fill would be placed five feet out from the floodwall centerline and tapered on a 1:3 slope.

At stations 13+07 and 15+95, two feet of backfill would be placed behind the stop-log gap sidewalls[1] to address sliding stability (Plate 5). A total of 958 cubic yards of fill would be used to meet sliding stability requirements.

Borrow Areas

Implementation of the preferred alternative would use borrow from locations close to the existing levee alignment to minimize haul distance costs and allow access to existing local haul routes. The use of conventional scrapers, front end loaders, backhoes and haul trucks would be more economical than dredging materials from the Kansas River. To minimize environmental impacts on floodplain terrestrial habitat, borrow material would come from two areas within the Oakland and South Topeka units.

Oakland West borrow area: This site would be used to provide material for the underseepage and stability berm in the Oakland Unit. The borrow site is on the river side of the levee between river miles 82.1 and 81.0 in Shawnee County, Kansas (Plate 12) and is currently used for row cropping. Soils in this area are primarily from the Eudora-Muir association. About 84,888 cubic yards of material is required for the proposed work. The area needed for borrow is about 19.3 acres. This would include two borrow cells 1,400 feet by 300 feet excavated three feet deep. A 100 foot buffer between each cell would be maintained to allow equipment movement and ensure foreshore stability. To avoid impacts to treed areas, the cells would be located at least 50 feet from the tree line. Also, cells would be located at least 100 feet from the existing levee and more than 400 feet from the Kansas River.

South Topeka borrow area: This site would be used to provide material for the proposed underseepage berms at South Topeka and North Topeka units and the floodwall stability berms in the Waterworks Unit. The proposed borrow area is located riverward of the levee between river miles 86.9 and 86.1 in Shawnee County, Kansas (Plate 11). The proposed area is currently

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1 Stop-log gaps are openings in the floodwall for roads, railroads tracks, gates, etc. and are so named because during a flood they are closed by stacking logs (railroad ties in most cases, aluminum "logs" in newer applications) in the opening. At each end of the opening is a groove in the wall that guides the placement of logs and holds them in place when the water rises. The section of the wall that contains the stop-log guide is referred to as the stop-log gap sidewall. The purpose of the stability berm behind these sections is to improve the structural factor of safety against sliding of the wall while under pressure from floodwaters.

used for row cropping. Soils in this area are primarily from the Eudora-Muir association. About 171, 344 cubic yards of material is required for the proposed work. The surface area needed for borrow is about 27.3 acres. It would have three borrow cells 1,000 feet by 400 feet excavated to four feet, each providing about 59,259 cubic yards of fill. Also, a 100 foot buffer between each cell would be maintained to allow equipment movement and insure foreshore stability. To avoid impacts to treed areas, the cells would be located at least 50 feet from the tree line. Also, cells would be located at least 500 feet from the existing levee and more than 300 feet from the Kansas River. These distances should prevent underseepage impacts and maintain bank stabilization.

Construction Schedule

Construction activities are expected to begin in 2010 and continue for a 3-year period thereafter.

Non-Government Land

The total project needs are 217 acres. Of this, 191 acres are for temporary construction easements, and 26 acres of sponsor-owned land used in perpetuity for the mitigation site.

Waste Disposal

The project construction would generate wastes from the removal of the floodwall and pump station. Anticipated wastes such as concrete and steel materials would be disposed at an existing commercial-land fill near the project area. Wastes generated from tree removal would be chipped and hauled offsite to a lumber mill or designated lumber stockyard.

8.0 ALTERNATIVES ORIGINALLY STUDIED BUT REMOVED FROM FURTHER CONSIDERATION

Several structural and non-structural alternatives were considered during the initial screening process, but were eliminated from further review because they did not meet the minimum technical criteria for the expected flood conditions. For a complete description of the structural and non-structural alternatives considered, but eliminated, see the Feasibility Report or Table 1 of Appendix A.

8.1 ALTERNATIVES CONSIDERED FURTHER

Pressure Relief Wells Alternative

Under this alternative, the proposed actions would be the same as those described in the recommended plan except pressure relief wells would be installed in place of proposed underseepage berms on the North Topeka, South Topeka and Oakland Units. With the use of pressure relief wells in place of berms, the amount of borrow material required for the

Waterworks and Oakland unit stability berms would be greatly reduced. Both the Waterworks and Oakland stability berms could be supplied by a single borrow cell. The cell at Waterworks would measure about 175 feet by 150 feet wide and 1 foot deep, and the cell at Oakland would measure about 105 feet by 100 feet wide and 1 foot deep.

Commercial Fill Alternative (All Units)

Under this alternative, the proposed actions would be the same as those described in the recommended plan except commercially obtained fill instead of borrow pits would be used. Commercially obtained fill would likely come from permitted dredging operations in the Kansas River. This could possibly provide a cost savings and minimize the environmental impact of borrow operations. At this time, only one commercial dredger is operating on the river in the Topeka area; and another is seeking a permit to operate a dredge in another reach east of Topeka. However, there is concern that these operators may not be able to provide the quantities necessary in addition to satisfying their existing commercial demands. The estimated amount of commercial fill needed is about 281,000 cubic yards.

No-Action Alternative (All Units)

Under the no-action alternative, the recommended plan would not be constructed by the Corps of Engineers.

9.0 ENVIRONMENTAL SETTING

General

The lower Kansas River basin includes three natural vegetation types: floodplain habitat consisting of cottonwood and willow trees (*Populus-Salix*), oak-hickory forest (*Quercus-Carya*) and bluestem prairie (*Andropogon-Panicum-Sorghastrum*). Typical dominant over story vegetation that may be found in the study area include American elm, American sycamore, eastern cottonwood, willow, beech, black walnut, and various oak species. Other plant species typically found in the area include maple, hackberry, hawthorn, honey locust, Osage orange, redbud, rough leaf dogwood, and slippery elm. Typical under story vegetation that may be found include reproduction of these species, with the ground layer containing species such as gooseberry, poison ivy, greenbrier, and prairie rose.

Climate

Topeka, Kansas has a typical continental climate. Characteristics of this climate are warm to hot summers, cold winters, moderate surface winds, and maximum precipitation in the warm season. In the winter months (December through February), the average daily temperature is 31.0 degrees Fahrenheit, the average daily minimum and maximum are 20.4 and 40.6 degrees

Fahrenheit, respectively. In the summer months (June through August), the average daily temperature is 76.8 degrees Fahrenheit. The average daily minimum and maximum temperatures are 65.1 and 87.3 degrees Fahrenheit. Precipitation is the heaviest from May through September when much of it falls during late evening or night time thunderstorms. The total average annual precipitation is 33 inches and the average annual snowfall is 21 inches.

Soils

The soils in the Topeka, Kansas area and floodplains of the surrounding streams are part of the Eudora-Muir soils association. The Eudora soils make up about 33 percent of this association; Muir soils, 25 percent; and minor soils, the remaining 42 percent. The Eudora soils occur mostly on intermediate levels in the valley and are above ordinary overflow of the Kansas River. Eudora soils are nearly level, well drained, light, and loamy. Their surface layer is grayish-brown silt loam about 12 inches thick. It is underlain by coarse loam or silt loam to about 42 inches. The material below this is stratified coarse silt loam to fine sand. Muir soils occupy intermediate and high levels of the river valley. They have a smooth surface and are nearly level and well drained. Their surface layer is dark-gray silt loam about 8 inches thick. The subsoil, about 54 inches thick, is silt loam to 20 inches and is silty clay loam below that depth. The rest of the association consists mainly of Kimo and Eudora soils that are closely intermingled with Sarpy and other soils. The Sarpy-Eudora complex consists of well-drained soils. These soils formed in medium-textured to moderately coarse textured alluvium and occur on the floodplain of the Kansas River. They experience occasional flooding, except in areas protected by the levee. Also, the soils survey for Shawnee County indicates that nearly all of this association outside of the municipal areas is used for cultivated crops. Corn, wheat, soybean, grain sorghum, and alfalfa are the primary crops.

Also, soils from river wash are typically found along the Kansas River. River wash soils consist of an unstable accumulation of sandy and silty alluvium. It occurs as sandbars and islands along the Kansas River and is only slightly above the riverbed. River wash is not suited to cultivated crops or pasture. Willows and cottonwoods are the native trees.

Floodplain Characteristics

Commercial, industrial, and residential developments are located in the floodplain of the study area behind the different levee units. Numerous city streets, county roadways, highways and railroads cross the floodplain. Also, the Philip Billard Airport, one water treatment plant, and two sewerage treatment plants are located in the floodplain.

10.0 AFFECTED ENVIRONMENT

The affected environments and resources described in this section are those recognized and required to be considered by various laws, executive orders, regulations, and other standards of national, state, or regional agencies and organizations; technical or scientific agencies; groups or individuals; and, the general public. The impacts of environmental resources addressed are summarized in Table 2 (Appendix A).

10.1 KANSAS RIVER AND ITS AQUATIC RESOURCES

Floodplain Description

The Kansas River is a major right-bank tributary of the Missouri River that begins at the confluence of the Republican River and Smoky Hill River near Junction City, Kansas. It flows 170.5 miles to its mouth in Kansas City, Kansas, where it joins the Missouri River at river mile 367.4 between the Fairfax-Jersey Creek and Central Industrial District Levee Units. The Kansas River basin above Topeka, Kansas, has 56,720 square miles of contributing and non-contributing surface area. Of this drainage, about 42,000 square miles are modified by existing reservoirs (Kansas Geological Survey, 1998). There are 16 Federal reservoirs within the basin that impact flow at Topeka. The project area is located within the Kansas River Middle Subbasin in Shawnee County, Kansas and the drainage area is about 500 square miles between Topeka and Wamego (KDHE, 2000). Solider Creek is the north bank tributary of the Kansas River at Topeka. Its basin is about 157 square miles and traverses southern Nemaha, Jackson and northern Shawnee counties flowing in a south-southeasterly direction. Shunganunga Creek flows northeasterly across the southern portion of the City of Topeka and joins the Kansas River about two miles east of the city. In addition, the Kansas River is listed on the Nationwide Rivers Inventory (NRI). The purposes of the inventory are several, including the identification of rivers which have potential to qualify for inclusion in the National Wild and Scenic Rivers System. The Kansas River was included in the inventory because of its outstanding scenic, recreational, fish, wildlife, and cultural values.

Water Quality

The designated uses for the Kansas River Middle Subbasin are Primary and Secondary Contact Recreation, Special Aquatic Life Support, Domestic Water Supply, Food Procurement, Irrigation, Industrial, Groundwater Recharge, and Livestock (Kansas Department of Health and the Environment, 2000). Water quality is monitored daily by the Kansas Department of Health and Environment (KDHE) at two sites along the Kansas River in Topeka, Station 258 at Topeka and Station 143 east of Topeka. The Kansas River Middle Subbasin is listed under Section 303(d) of the Clean Water Act as impaired waters by KDHE for not supporting Secondary Contact Recreation. Also, KDHE waste load modeling indicates impairment to aquatic life from elevated ammonia concentrations in the river at low flows. Historically, elevated ammonia concentrations in the river have been known to impact aquatic plants and animals, as well as affect primary and secondary recreation uses such as swimming and fishing. There are a number of National Pollution Discharge Elimination System permitted facilities along the river segment; however, only two discharge ammonia under their permits. Both permits are held by the City of Topeka (KDHE, 2000).

Aquatic Species

A list of typical fish species found in the project area can be obtained in the 2007 USFWS Coordination Act Report (Appendix C). The fisheries resources in the Middle Subbasin of the Kansas River are at their most sensitive during the spring spawning season, which is greatly influenced by flow releases from upstream reservoirs, especially Tuttle Creek Lake.

Future Conditions with Recommended Plan

No adverse impacts to aquatic resources or water quality are anticipated to occur from the implementation of the proposed plan. Construction activities for levee modifications would occur on the landward side of the levee, with the exception of riverward borrow construction areas. Replacement of the floodwall would occur along the existing alignment, and the floodwall platform is not anticipated to extend into or otherwise impact the river. Also, best management practices would be used to minimize the incidental fallback of material into the river during construction. Removal of the Fairchild Pump Station would not affect aquatic resources or water quality since the wet well and inlet/outlet pipes would not be removed.

Also, no adverse impacts to aquatic resources or water quality are anticipated to occur from soil borrowing activities. For all construction activities, best management practices would be used to minimize the introduction of fuel, petroleum products, or other deleterious material from entering into the waterway and adjacent resources. Such measures would include use of erosion control fences; storing equipment, solid waste, and petroleum products above the ordinary high water mark and away from areas prone to runoff; and requiring that all equipment be clean and free of leaks. Furthermore, all disturbed areas would be graded and seeded following construction. To prevent the spread of exotic and invasive species all equipment moved to and from the site would be thoroughly washed, and cleaned of any visible mud, seeds, plants, or animals.

Future Conditions with Use of Commercial Fill

This alternative is a modification to the Recommended Plan in which fill would be obtained from permitted dredging operations in the Kansas River. To address river bed degradation and other dredging-related impacts to the morphology and ecology of the river, the Corps implemented the Regulatory Plan for Commercial Dredging Activities on the Kansas River (1990). The Regulatory Plan contains restrictions that have been developed and implemented to limit the adverse impacts associated with commercial dredging activities on the Kansas River. The restrictions are intended to limit those impacts to a level which will have only minor effects on the morphology and ecology of the river and on public and private interests located in and along the river. No additional impacts are anticipated to occur from the use of commercial fill for levee berms. Fill will be deposited on dry land, more than 500 feet away from any water resource. To prevent fill from reaching water sources by wind or runoff, fill would be covered, stabilized or mulched, and silt fences would be used. With these management practices applied, the chances of the fill moving and reaching water resources is negligible.

Future Conditions with No-Action Alternative

Under the No-Action Alternative, there would be no modifications to the existing flood risk management system. However, in the absence of Federal action addressing levee improvements, a high water event could result in the release of a variety of industrial chemicals and substantially impact the natural and human environment within the project area. Levee failure could result in adverse impacts to water quality from increased levels of nutrient loading and wastes, including runoff of pollutants from industrial sources, petroleum products, and non-point sources of human and animal wastes.

Future Conditions with Relief well Alternative

Under this alternative, relief well systems would be installed in lieu of berms at the North Topeka, South Topeka and Oakland levee units. The risk of encountering groundwater contamination was evaluated in the 2007 HTRW assessment (Appendix H). Based on the assessment, there is a potential risk that soil contamination may be encountered in the North Topeka unit where a relief well is proposed. This is due to a railroad located in close proximity of the site. Therefore, the design of the relief well system would minimize soil disturbance to the greatest extent practical, and any soil that is removed from the site during construction would be tested to ensure proper disposal. However, the risk of groundwater contamination at the South Topeka and Oakland sites is considered low because there are no known contaminated sites located in close proximity of the sites. No substantial post-construction impacts to water resources or water quality are anticipated from the installation of relief wells.

10.2 WETLANDS

This resource is institutionally important because of the Clean Water Act of 1977, as amended and Executive Order 11990 of 1977 (Protection of Wetlands). Wetlands are important because they provide habitat for various species of plants, fish, and wildlife, serve as ground water recharge areas, provide storage areas for storm and flood waters, serve as natural water filtration areas, provide protection from wave action, erosion, and storm damage, and provide various consumptive and non-consumptive recreational opportunities. Wetlands are publicly important because of the high value the public places on the functions and values that wetlands provide.

No Impact to Wetlands Determination

The National Wetland Inventory database maps for the project area were consulted to determine wetland classifications within the project area. Also, Corps staff conducted wetland delineations on 13 October 2006. No wetlands were found within the proposed borrow areas on the riverward side of the levee or any other areas within the project footprint. The most likely areas to support wetlands are the riparian zones riverward of the levee where borrow material would be obtained. However, these areas did not meet the criteria for wetland classification; they contained either upland tree species, or agriculture, and they did not exhibit evidence of saturated or inundated soils.

10.3 PRIME AND UNIQUE FARMLAND

These resources are institutionally important because of the Food Security Act of 1985, as amended, and the Farmland Protection Policy Act of 1981. They are technically important because they provide habitat for open and forest-dwelling wildlife, and the provision or potential for provision of forest products and human and livestock food products. These resources are publicly important because of their present economic value or potential for future economic value.

Existing Conditions

There are many areas of cropland in close proximity to the project sites, including within some of the proposed borrow sites. The National Resource Conservation Service (NRCS) was consulted for a determination of prime farmlands within the project area (see Appendix B). Both the Oakland and South Topeka proposed borrow areas are considered prime farmland. However, the North Topeka agriculture area is not considered prime farmland. The major crops planted are corn and soybeans.

The NRCS defines three main categories of farmland: prime, unique, and farmland of statewide importance. These are primarily based on soil type and the historic use of the land for farming. Prime farmland is land that has the best combination of physical and chemical characteristics for producing food, feed, forage, fiber, and oilseed crops and is available for these uses. It must contain an adequate supply of moisture, acceptable acidity or alkalinity and sodium content, and few or no rocks. Also, it is not excessively erodible or saturated with water for long periods, and slopes between zero to eight percent. Unique farmland has a unique set of chemical and physical properties for producing certain high-value crops. Farmlands of statewide importance contain soils that do not meet the requirements for prime farmlands.

Future Conditions with the Recommended Plan

With the implementation of the recommended plan, beneficial impacts would consist of an increase in the reliability of the existing levee system that protects agriculture lands by reducing the risk of flood damage. Adverse impacts would include short term and minor impacts to three agriculture areas for obtaining borrow. Approximately 19.3 acres of the 98-acre Oakland site and 27.3 acres of 138-acre South Topeka site would be used for obtaining borrow. In addition, 12 acres of the North Topeka site would be disturbed from construction of the underseepage berm.

Prior to construction, the Corps will consider and discuss opportunities to restore the borrow areas in an environmentally acceptable manner with the land owners and the local sponsor, the community, and local resource agencies. Alternatively, the borrow areas can be returned to agricultural uses. If this is the preferred future condition, steps would be taken to minimize impacts and allow these areas to return to agricultural use after construction operations. Such measures would include preservation of the top layer of soil, which would be returned to the site, minimizing excavation depths to reduce impacts to the drainage of fields, and excavating after the harvest season to minimize impacts to crops.

Future Conditions with the Use of Commercial Fill

With this possible modification to the Recommended Plan, there would be no excavation required to obtain borrow fill, and disturbance of cropland would be limited to the construction of under seepage berm within the North Topeka unit. This disturbance would be short term and minor as farming operations would be allowed to return once construction is completed. Also, the beneficial impacts of this plan would be the same as those described under the recommended plan.

Future Conditions with the No-Action Alternative

Under the No-Action Alternative, there would be no modifications to the existing flood risk management system.

In the absence of Federal action addressing levee improvements, a high water event may result in inundation of agricultural lands for long periods of time causing loss of crops.

Future Conditions with the Relief well Alternative

Under this alternative, the amount of borrow material required would be substantially less than the amount required under the recommended plan; about 1,346 cubic yards for construction of stability berms in the Oakland and Waterworks units. The waterworks stability berm could be supplied by a single borrow cell 175 ft. by 150 ft. wide and one foot deep, and the Oakland stability berm could be supplied by a single borrow cell 105 ft. by 100 ft. wide and one foot deep. Therefore, the impacts on prime farmland areas would be minor and short term.

10.4 FOREST/WILDLIFE RESOURCES

This resource is institutionally important because of Section 906 of the Water Resources Development Act of 1986, and the Fish and Wildlife Coordination Act of 1958, as amended. Forest is technically important because it provides necessary habitat for a wide variety of species, it often provides a variety of wetland functions and values, is an important source of lumber and other commercial forest products, and provides various consumptive and non-consumptive recreational opportunities. Forest is also important because the general public highly values it for aesthetic, recreational, and commercial uses. Wildlife is technically important because they are a critical element of many valuable aquatic and terrestrial habitats; an indicator of the health of various aquatic and terrestrial habitats; and many species are important commercial resources. Wildlife is publicly important because of the high priority that the public places on their aesthetic, recreational, and commercial value.

Existing Conditions

Most of the forest and woodland in the study area has been greatly impacted by urban development. The impacts of the project to woodland and wildlife habitat within the project area are limited to the work within the South Topeka unit and construction of borrow areas.

The quality of the woodland within the South Topeka unit is considered moderate, and the age of the woodland stand is assumed to be about 30 years old. This woodland is part of the floodplain forest that extends along the Kansas River. The floodplain forest is considered the highest quality habitat in the Topeka area. A list of typical plant species found in the project area can be found in the mitigation plan (Appendix F).

Various wildlife species can be found using the riparian woodlands and grasslands along the banks of the Kansas River. These riparian areas provide food and cover for many wildlife species including various birds, mammals, reptiles, and amphibians. A list of typical species found in the project area can be found in the 2007 USFWS Coordination Act Report (Appendix C).

A community habitat suitability model for bottomland hardwoods (LDNR, 1994) was used to quantify net gains and losses of ecological value associated with future with project and future without project conditions, and the results are summarized in the mitigation plan (Appendix F).

Future Conditions with Recommended Plan

With implementation of the recommended plan, impacts to wildlife habitat would result from the removal of about seven and one-half acres of woodland for the construction of the underseepage berm at the South Topeka levee unit. Existing woodland habitat on either side of the impacted area would remain. Reducing the size of this woodland would result in a reduction in habitat quality and increase in competition among wildlife for available resources. In addition, during construction activities, wildlife species such as deer, and small mammals would most likely be temporarily displaced to adjacent woodlands and would be expected to return once project activities are completed. Wildlife species most likely at risk to be adversely impacted by the project action would include reptiles, amphibians and birds (USFWS, 2007). However, to minimize the impacts on migratory bird nesting, construction activities would be avoided in woodland areas during the nesting season from April 1 to July 15. In addition to offset the loss of this habitat, replacement of 15-acres of riparian habitat would be implemented. The results of the habitat model indicate a total of 15 acres of mitigation would provide enough compensation to offset the loss of 7.5 acres. The replacement habitat is expected to take up to 30 years to equal the value of the existing site. However, the production of soft mast and other edible seeds is expected to begin at about age ten.

In addition, any grassland areas disturbed from construction activities would be re-seeded following construction with rye, brome, fescue and then mulched. The entire mitigation plan can be found in Appendix F.

Future Conditions with Use of Commercial Fill

Impacts to woodlands would result from the removal of about seven and one-half acres of woodland for the construction of the underseepage berm at the South Topeka levee unit. Mitigation measures would be the same as those described under the recommended plan.

Future Conditions with No-Action Alternative

Under the No-Action Alternative, there would be no modifications to the existing flood risk management system; and the existing woodland is expected to continue to grow and reach full maturity by age 50, but would be subject to the potential risk of prolonged flooding due to levee failure. Vegetation that cannot tolerate prolonged flooding would experience anoxic stress and would die. Wildlife not adaptable to flooded conditions would be temporarily displaced until the water recedes.

Future Conditions with Relief well Alternative

With the installation of relief wells instead of the proposed underseepage berms, the amount of borrow material required would be less and impacts to woodland areas would be avoided. Therefore, there would be no mitigation needed, and impacts on wildlife habitat would be minor and limited to grass and cropland areas. Grassland areas disturbed from construction activities would be re-seeded following construction with rye, brome and fescue and mulch.

10.5 ENDANGERED OR THREATENED SPECIES

This resource is institutionally important because of the Endangered Species Act of 1973, as amended, and the Bald Eagle Protection Act of 1940. Endangered or threatened species are technically important because the status of such species provides an indication of the overall health of an ecosystem. These species are publicly important because of the desire of the public to protect them and their habitats.

Existing Conditions

There are three federally-listed species that may occur within the project area: bald eagle (*Haliaeetus leucoccephalis*), Least Tern (*Sterna antillarum*), and Piping Plover (*Charadrius melodus*). However, no impacts to federally-listed threatened and endangered species are anticipated to occur as a result of the project action. The USFWS concurred with our determination by letter on May 29, 2007.

State listed endangered species in Shawnee County were obtained from the Kansas Department of Wildlife and Parks (KDWP) website (Appendix D). They include the American burying beetle (*Nicrophours americanus*), Eskimo curlew (*Numenius borealis*), least tern, peregrine falcon (*Falco peregrinus*), silver chub (*macrhybopsis storeriana*), and whooping crane (*Grus americana*). State listed threatened species include the bald eagle, eastern spotted skunk (*Spilogale putorius*), piping plover, smooth earth snake (*Virginia valeriae*), snowy plover (*Charadrius alexandrinus*), sturgeon chub (*Macrhybopsis gelida*), and Topeka shiner (*Notropis Topeka*). No impacts to state-listed endangered or threatened species are anticipated to occur as a result of the project action. The KDWP concurred with our determination by letter on June 1, 2007.

Bald eagle. Also federally-listed, they typically are found roosting near reservoirs and large rivers in Kansas during the winter months. Known nesting areas include Perry Reservoir (northeast of Topeka), Clinton Reservoir (southeast of Topeka), and the Kansas River, with parents and young remaining in the area during the spring and summer months.

Least tern. Also federally-listed, they are summer residents in Kansas. Nesting birds have been recorded in six central and western Kansas counties, at Jeffery Energy Center, and along the Kansas River. Terns require barren areas near water such as saline flats in salt marshes, sand bars in river beds, and shores of large impoundments. A dependable food supply of small fish and aquatic crustaceans must be nearby. Least terns may occur accidentally or occasionally as transients anywhere in the state.

Piping plover. Also federally-listed, they are rare migrants through Kansas. They require sparsely vegetated shallow wetlands, open beaches and sandbars adjacent to or within streams and impoundments. Nesting has been recorded on sand bars along the Kansas River. Piping Plovers may occur occasionally anywhere in the state where suitable habitat is found.

Future Conditions with Recommended Plan

With implementation of the recommended plan, impacts to federally-listed species are not anticipated. This is because no work is proposed on the river itself that could affect habitat for piping plovers and least terns. Also, bald eagle habitat would be avoided; this includes any trees within 100 feet of the bank of the river which are over 50 feet in height and/or greater than 12 inches in diameter at breast height. The trees in the area proposed for removal are all within these parameters. In addition, no impacts to state-listed species are anticipated to occur from the proposed action.

Future Conditions with Use of Commercial Fill

If used, commercial fill would come from a preexisting site and/or from the Kansas River under the authority of the Corps Regulatory Program. To address river bed degradation and other dredging-related impacts, the Corps implemented the Regulatory Plan for Commercial Dredging Activities on the Kansas River (1990). The Regulatory Plan contains restrictions that have been developed and implemented to limit the adverse impacts associated with commercial dredging activities on the Kansas River. The restrictions are intended to limit those impacts to a level which will have only minor effects on threatened and endangered species and their habitat. No additional impacts are anticipated to occur from the use of commercial fill for levee berms.

Future Conditions with No-Action Alternative

Under the No-Action Alternative, there would be no modifications to the existing flood risk management system. In the absence of Federal action addressing levee improvements, a high water event could result in the release of a variety of industrial chemicals and substantially impact the natural and human environment within the project area. Levee failure would result in substantial impacts to a water quality, fisheries and wildlife, extensive property damage and potential loss of human life.

Future Conditions with Relief Well Alternative

With the installation of relief wells instead of the proposed underseepage berms, the amount of borrow material required would be less and impacts to woodlands would be avoided. Also, no work would be done on the river; therefore, there would be no impacts under this alternative.

10.6 CULTURAL RESOURCES

In compliance with National Historic Preservation Act, the Corps conducted a review of the National Register of Historic Places (NRHP), an appropriate records search at the Kansas State Historical Society, and a field reconnaissance of the project area. No NRHP properties are recorded in any of the proposed project locations or potential borrow areas. Also, the records search found no other archeological sites, historic structures, or shipwrecks recorded within any of these areas.

The field reconnaissance found that all of the areas have been severely disturbed by the existing levee construction or are located on recently accreted land and have little possibility of containing archeological sites or structures eligible for inclusion on the (NRHP). The Corps coordinated the results of the record search and reconnaissance with the Kansas State Historic Preservation Officer (SHPO) and recommended no further work for the project and that the project be allowed to proceed without further coordination with their office in letters dated June 13 and August 2, 2006. The SHPO concurred with these recommendations on July 5 and August 2006 respectively. The Corps also coordinated the project with affiliated Native American tribes thru the review of the EA during the 30-day public review period. If additional ground disturbing activities are needed for the project, further coordination with SHPO and Native American tribes would be required.

Also, in the unlikely event that archeological deposits or other cultural resources are encountered during construction, work in the area of discovery would cease. Before resuming, the inadvertent discoveries will be investigated and the findings coordinated with the appropriate SHPO and federally recognized Native American tribes.

Future Conditions with All Build Alternatives

No historic properties are recorded within the area of the proposed alternatives or borrow locations. These alternatives, all following the same alignment as the existing flood risk management system, were found to have a low potential for unrecorded archeological sites because they are located in areas severely disturbed by previous construction of the existing levee and are on accreted land. As a result of these disturbances, the Corps recommended no further investigations be conducted for any of the alternatives. The Kansas SHPO concurred with these recommendations.

Future Conditions with No-Action Alternative

The "No Action" alternative would result in no ground disturbances and would not have any effect on cultural resources.

10.7 VISUAL QUALITY

Existing Conditions

The Kansas River within the project area contains floodplain forest, sand bars, islands, and bluffs, which provide natural diversity to the river corridor landscapes. Cropland, grassland, and forested land are established in portions of the river's floodplains. Existing levees and flood risk management mechanisms that have been installed to prevent bank or levee erosion interrupt the natural character of the river systems. However, flood risk management features have been in place for many years and in many instances may blend in with the adjacent natural landscape.

Future Conditions with recommended plan

Impacts to aesthetics would primarily occur during construction activities. These would be temporary, minor and would only occur within the construction areas. Also, the levees would be seeded with grasses on completion of construction.

Future Conditions with Use of Commercial Fill

With this possible modification to the Recommended Plan, the adjacent road system could receive short term aesthetic impacts of haul material deposited on the established haul travel routes. Several large dump trucks would be needed to haul the fill from the commercial dredge site to the project area. To minimize impacts to roads, the haul routes would be those that are the shortest available at the time, and follow approved truck routes. In addition, the contractor would be required to immediately remove or clean these materials from the paved roads, streets and/or highway.

Future Conditions with No-Action Alternative

Under the No-Action Alternative, there would be no modifications to the existing flood risk management system. In the absence of Federal action addressing levee improvements, a high water event could result in widespread aesthetic impacts including deposits of debris, dead trees and property damage.

Future Conditions with Relief Well Alternative

With the installation of relief wells instead of the proposed underseepage berms, impacts to visual quality would consist of several manholes installed in the grassy areas along the levee. This would cause a small aesthetic impact during construction; however, these areas are not used as nature trails and are located along the levee right-of-way that is maintained for flood damage reduction. The addition of relief wells would only be a small addition to the existing flood risk management features. Once construction activities cease, areas around the relief wells would be re-seeded with grasses.

10.8 NOISE

Existing Conditions

This resource is institutionally important because of the Noise Control Act of 1972. The act establishes a national policy to promote an environment for all Americans free from noise that jeopardizes their health and welfare. A sound-level meter used to measure noise and the outputs are "decibels." For instance, a diesel truck at 50 feet produces a sound level of 85 decibels, a gas lawn mower at 3 feet produces a sound level of 95 decibels and normal speech at three feet is 65 decibels.

Existing sound levels throughout the Topeka metropolitan area are highly variable depending on location. Sound levels range from relatively loud noises associated with urban and industrial activities to very quiet rural environments. Noise sources within the project area include agricultural and industrial activities, traffic on roads, aircraft over-flights, and natural sounds such as wind through trees and water falling over rocks. It is highly unlikely that noise standards in the Topeka metropolitan area would be exceeded under existing conditions. In portions of the metropolitan area, especially near industrial areas, sound levels could occasionally exceed noise standards under certain conditions.

Ambient noise levels are generally dependent upon the level of urban development and associated activities conducted within a given area. Land uses within the project area consist of agricultural, residential, commercial, and industrial. The principal source of noise in the project area is from farming activities, motor vehicle traffic along major highways and in urban areas, industry, and to a lesser extent from railroad traffic.

Future Conditions with Recommended Plan

Project related impacts from noise would be from operation of construction related equipment and increased construction related traffic on area roads. During the 3-year design and construction period, every effort would be made to ensure the community is aware of the project and provides any suggestions to reduce construction noise. Also, source control, site noise emissions, and limited work hours will be used on the construction sites to minimize noise emissions. It is not anticipated that construction activities would increase noise levels beyond that typical of farming operations or area traffic in the vicinity. Therefore, noise impacts are not expected to be significant.

Future Conditions with Use of Commercial Fill

Construction activities would require using diesel-powered dump trucks on area roads. This would produce some noise during construction periods. However, it is not anticipated that construction activities would increase noise levels beyond that typical of farming operations or area traffic in the vicinity. Also, source control, site noise emissions, and work hours will be managed on the construction sites to minimize noise emissions.

Future Condition with No-Action Alternative

Under the No-Action Alternative, there would be no modifications to the existing flood risk management system. In the absence of Federal action addressing levee improvements, a high water event could result in unregulated and widespread noise from clean-up activities.

Future Conditions with Relief Well Alternative

With relief wells, impacts to noise would not be substantial and would be essentially the same as those described under the recommended plan.

10.9 AIR QUALITY

Existing Conditions

This resource is considered institutionally important because of the Clean Air Act of 1963, as amended. Air quality is technically important because of the status of regional ambient air quality in relation to the National Ambient Air Quality Standards (NAAQS). It is publicly important because of the desire for clean air expressed by virtually all citizens.

In accordance with the Clean Air Act, the U.S. Environmental Protection Agency set National Ambient Air Quality Standards (NAAQS) for pollutants considered harmful to the environment and public health. The six principal pollutants, also known as "criteria" pollutants, are: ozone, lead, particulate matter, carbon monoxide, nitrogen dioxide, and sulfur dioxide. The proposed project is located in Shawnee County, Kansas. Shawnee County and its surrounding counties are all in full attainment of all NAAQS. The surrounding counties in Kansas are rural and air emissions are not monitored.

Future Conditions with All Build Alternatives

With implementation of the recommended plan, minor, short-term impacts to air quality in the project area would result from construction activities. The air quality impacts would be localized and limited to those produced by heavy construction equipment and fugitive dust within the project area. The commercial-borrow source alternative would have a slight increase in emissions and dust on haul roads and areas of clearing and excavation, but is expected to be minor and short-term. The watering of road segments would be implemented to minimize the impact of dust and windblown particulate matter. Therefore, it is anticipated that implementation of the proposed action would conform to the National Ambient Air Quality Standards. Air quality impacts are not expected to be significant.

Future Conditions with No-Action Alternative

Under the No-Action Alternative, there would be no modifications to the existing flood risk management system. In the absence of a Federal action addressing levee improvements, a high water event could result in the release of a variety of dust, and other contaminants from clean-up activities. Air pollution from a levee failure could be widespread and generally uncontrolled relative to the minor, short term air quality impacts from the project action.

10.10 SOCIOECONOMICS

Demography

Future Conditions with the Recommended Plan

The geotechnical and structural improvements planned for the South Topeka, Oakland, and North Topeka levees in the recommended alternative would prevent adverse economic impacts, including flood damage (in all but the most catastrophic events) and high insurance premiums, to the protected neighborhoods. Flood-related building disincentives that could discourage new business start-ups and expansion of existing businesses, eventually resulting in population losses in these neighborhoods, would be prevented. Also, modest transitory population increases could occur in the study area in connection with project construction.

Future Conditions with the Use of Commercial Fill

The commercial fill alternative would involve the same geotechnical and structural repairs as in the recommended alternative. Therefore, essentially the same demographic impacts would be expected in this alternative as the recommended plan: preventing potential flood damage and investment disincentives resulting in eventual population loss, modest transitory population increases could occur in the study area in connection with project construction.

Future Conditions with the No Action Alternative

Failure to implement the recommended plan or commercial fill alternative would likely result in an increasing pattern of flood damage in the Oakland, South Topeka and North Topeka areas from the larger Kansas River flood events. This could result in Federal decertification of the levees at some point during the 50-year analysis period. Already struggling low and middle-income neighborhoods would be saddled with the additional burdens of continual catastrophic flood damage and threats to public safety, as well as the cost of higher flood insurance premiums and the economic stagnation caused by stricter building code requirements.

Substantial population losses in these areas would be all but certain in the long term. Also, a wider regional economic impact throughout the Topeka area would occur since many of the region's largest employers are behind the levees including Goodyear Tire, Payless Shoe Source, Burlington Northern Santa Fe Railroad, Hill's Pet Nutrition, Hallmark Cards, and Del Monte Foods. Any decisions by these companies to rule out expansion, reduce existing operations, or even relocate would result in substantial harm to the regional employment picture. Substantial job loss would eventually affect population levels both inside and outside the study area.

Future Conditions with the Relief Well Alternative

Under this alternative, the impacts would be the same as the recommended plan. Essentially the same demographic impacts would be expected in this alternative as the recommended plan: preventing potential flood damage and investment disincentives resulting in eventual population loss, modest transitory population increases could occur in the study area in connection with project construction.

Development and Economy

Past, Present, and Future

For information on future, past and present development trends, refer to Socioeconomics Appendix D, of the Feasibility Report.

Future Conditions with Recommended Plan

Restoring Topeka's levee system to the intended degree of flood risk management would benefit a large portion of the city's economic base. Large urban neighborhoods in North Topeka, Oakland, and South Topeka would avoid population loss associated with a pattern of severe flooding and would continue to create consumer demand for retail and service businesses. A number of large employers located in the floodplain would be able to continue operations and possibly expand, protecting jobs and the tax base, while additional companies might relocate to Topeka. The Topeka area's water supply and sewage treatment facilities would be protected from damage or disruption in most major Kansas River flood events.

Also, flood risk management would specifically benefit several prime areas for economic development in Oakland and North Topeka that are among the best industrial and commercial future development prospects in the region. Completion of the Oakland Expressway has opened up a new set of development possibilities for the Oakland area. Nearly 300 acres of undeveloped land near the intersection of the Oakland Expressway and Seward Avenue are available for industrial development, and nearly 400 acres of undeveloped land zoned for industrial and commercial uses lie within or adjacent to Billard Airport property.

In northwest Topeka, nearly 1,500 acres of undeveloped land are available for industrial or commercial uses near the intersection of U.S. Highways 24 and 75 and northwest of the intersection of Highway 75 and Lower Silver Lake Road. Much of this area will be somewhat more challenging to develop than the comparable areas in Oakland, but development is nevertheless likely during the 50-year period of analysis. Further development prospects in North Topeka are gradually taking shape near the Kansas Avenue and Topeka Boulevard bridges over Soldier Creek. All of these areas probably would have a healthy future in the event of continuing flood damage reduction.

Future Conditions with Use of Commercial Fill

The use of commercial fill for the repair and restoration of Topeka's levee system would result in the same economic impact as the recommended plan. A large portion of the city's economic base would benefit. Large urban neighborhoods in North Topeka, Oakland, and South Topeka would avoid population loss associated with a pattern of severe flooding and would continue to create consumer demand for retail and service businesses. A number of large employers located in the floodplain would be able to continue operations and possibly expand in some cases, protecting jobs and the tax base, while additional companies might relocate to Topeka. The Topeka area's water supply and sewage treatment facilities would be protected from damage or disruption in most major Kansas River flood events. Potential areas for development in Oakland and North Topeka would become more attractive.

Future Conditions with No Action Alternative

Continuing neglect of the deficiencies in the Topeka levee system eventually will result in catastrophic flood damage affecting large urban neighborhoods and industrial areas. Large employers in the floodplain areas might suffer severe damage or at least operational interruptions serious enough to cause them to scale back their operations at flood-prone locations, cancel expansion plans, and possibly relocate from the region. Some small business owners would be ruined by flood damage. Other business owners and residents would incur large premium increases for flood insurance. Insurance requirements would discourage new business development and the entry of large private employers. The Topeka region's water supply facility behind the Waterworks levee unit and sewage treatment facilities in the North Topeka and Oakland areas could be damaged and their operations interrupted periodically. Also, Topeka would lose opportunities for development since many of the region's most attractive developable parcels are located in Oakland and North Topeka.

Future Conditions with Relief Well Alternative

Under this alternative, the impacts would be the same as those described under the recommended plan.

Transportation

Existing Conditions

Transportation consists of roads and byways that are found within the proposed project. The major transportation routes through Topeka are Interstate Highways 70 and 335, and State

Highways 75 and 24. East-west highway access through the city is provided by Interstate Highway 70, which roughly parallels the Kansas River, while U.S. Highway 24 provides a secondary east-west route on the northern side of the area. The main north-south access route is U.S. Highway 75. Interstate Highway 335 runs from Topeka to the southwest, eventually joining Interstate Highway 35, the "NAFTA Highway."

Future Conditions with the Recommended Plan

With implementation of the recommended plan, there would be slight disruptions to traffic with construction equipment traveling to and from the project area. However, no roads are anticipated to be blocked or closed for extended periods of time. Most of the project area would be accessed from the levee road and should not interfere with the normal flow of traffic.

Future Conditions with the Use of Commercial Fill

Trucks hauling fill to the construction site may have temporary impacts to local roads, causing congestion, and possibly damage to the roads. Specifically, there is the potential that the roads or bridge would require early maintenance due to excessive wear and tear. This maintenance could include milling off the existing surface to eliminate potential rutting and surface irregularities, patching the road and base in failed areas, overlaying with asphalt, and then replacing the pavement striping.

Future Conditions with the No-Action Alternative

The No-Action alternative would involve no construction activity and no change in project operations. This alternative could pose a problem to transportation during a 100-year flood event. Area roads could be flooded, impairing evacuation and rescue of the local population. Roads also could be washed out and require reconstruction.

Future Conditions with the Relief Well Alternative

With the installation of relief wells instead of the proposed underseepage berms, impacts to transportation resources would not be substantial and would be the same as those described under the recommended plan.

11.0 HAZARDOUS, TOXIC, AND RADIOACTIVE WASTES

A Hazardous, Toxic, and Radioactive Waste (HTRW) assessment was completed as part of the Topeka, Kansas Reconnaissance Report (USACE, 1997), and a more recent assessment (USACE, 2007) of the potential HTRW resources was completed. The conclusions of the 2007 assessment are summarized below, and a complete write-up is included in Appendix I. It included a database search and site visit to identify areas of concern within 500 feet of either side of the levee. No sites registered in the database were reported on the National Priorities List, Comprehensive Environmental Response, Compensation, and Liability Information System, and Kansas Hazardous Waste Sites Report. Project impacts due to HTRW are not expected to be significant.

Conclusions and Recommendations

Overall, the environmental assessment found very little risk associated with HTRW contamination on proposed activities. However there were three areas where there was a potential HTRW or solid waste impact to the proposed work. The lateral limits of any contamination must be established to ensure that remediation measures are incorporated into the final construction plans.

South Topeka Unit, Station 74+41 to 93+86

There is a possibility that groundwater below a portion of this area is contaminated with chlorinated solvents. The potential for floodwall replacement activities to encounter contaminated groundwater will be investigated during the Pre-Construction Engineering and Design phase. The operation of new facilities will not result in the discharge of groundwater to the surface.

South Topeka Borrow Site

A former city dump was identified at the southwest corner of the proposed borrow area. The limits of the disposal cells are unknown so there may not be as much borrow area available as anticipated. Investigations are recommended to determine the nature of materials accepted and the lateral limits of the dump. Also, samples from the proposed borrow should be collected and analyzed to ensure material to be used on other sites is clean.

Oakland Borrow Site

A former city dump was identified at the southwest corner of the proposed borrow area. It was described as having debris from a 1968 tornado. The limits of the disposal cells are unknown so there may not be as much borrow area available as anticipated. Investigations to determine the nature of materials accepted and the lateral limits of the dump will be conducted prior to the start of construction. Also, samples from the proposed borrow would be collected and analyzed to ensure material to be used on other sites is clean.

Also, any soil removed from a site associated with the levee work will be analyzed to ensure proper disposal. In addition, any soils used to upgrade the levee system will be analyzed to ensure it is not contaminated. Both of these practices will ensure that contamination will not be inadvertently spread from one site to another.

12.0 ENVIRONMENTAL JUSTICE

The Executive Order on Environmental Justice (EO 12898) requires consideration of social equity issues, particularly any potential disproportionate impacts to minority and low-income groups. This is to ensure that issues such as cultural and dietary differences are taken into consideration to ensure that adequate risk is evaluated (EPA, 2004). Environmental Justice (EJ) means the fair treatment and meaningful involvement of all people regardless of race, income, or culture, in the developing, carrying-out, and enforcing of environmental laws, regulations, and policies. In addition, the Executive Order on the Protection of Children from Environmental Health risks and Safety risks (EO 13045) requires the consideration of disproportionate impacts to children. Children under age five and elderly populations above age 65 are considered to be sensitive populations that may experience disproportionate impacts from environmental stressors.

To determine any potential impacts of this project to the surrounding populations, present and potential environmental impacts were taken into consideration with regards to the current facility concentration and compliance history to determine disproportionate environmental burden. To determine any potential EJ areas and/or sensitive populations, the racial, income, and age composition of the individual census tracts within, and adjacent to the study area, were examined using 2000 census data.

Facility Concentration

Currently there is no regional threshold to determine an acceptable concentration of facilities. However, the EJ Program relies on looking at facility density within the study area compared to surrounding communities and the county it resides in. High facility concentration with potential additional environmental and/or human health burdens increases the risk or harm that may be shouldered by low-income and/or minority populations. Any facilities located in close proximity to sensitively populated areas of children and/or elderly age groups are also of concern.

The North Topeka area reports the highest concentration of active permitted facilities within the study area, while the Oakland area reports the lowest concentration.

Demographic Composition

Tables 3 thru 7, Appendix A, provide localized demographic data for the areas and zip codes of the project area that include: Auburndale, South Topeka, Oakland, North Topeka, and Soldier Creek Urban. EPA Region 7 uses a 25% or greater threshold in the identification of low-income and/or minority populated areas as an indicator for the potential for environmental justice concerns in conjunction with disproportionate environmental impacts. This threshold was determined through an economic and demographic analysis of the entire Region 7 area.

The South Topeka, Oakland, and North Topeka areas have the highest minority populations within the study area, and are represented by residents of African American and Hispanic or Latino heritage (Appendix A, Table 3). These areas also consistently had higher percentages of persons below the poverty level (Appendix A, Table 4). The core of Executive Order 12898 provides for the protection of both minority and low-income groups. Therefore, income and racial composition data from the 2000 Census were used to provide an overview of each levee unit in regards to their respective minority and income level composition. The Office of Management and Budget's Statistical Policy Directive 14 of the Census Bureau uses a set of money income thresholds that vary by family size and composition to determine who is poor. If a family's income is less than that family's threshold, then that family, and every individual in it, is considered poor.

Additional Environmental Justice Indicators

Additional environmental justice indicators such as education level, languages spoken, and percent children and elderly reveal trends about the socio-demographic aspects of a community that may be used to make generalizations about the population and the capacity of residents to cope with potential additional environmental stresses. The level of education and/or literacy rates for the adult population provides a critical measure of the likelihood and the ability of the community to know about and participate in public meetings, to comment on written proposals and to otherwise participate in the decision-making process. If tools used to encourage public participation are not tailored to local education rates, or perceived rates, the outreach process may be ineffectual (USEPA, 2004). Based on the educational attainment data of the percent of persons that earned high school diplomas or higher and college degree or higher, the areas of South Topeka, Oakland, and North Topeka have the lowest rates among all the study areas (Appendix A, Table 5).

Information on whether languages other than English are spoken among the population, and percentage distribution of these languages, is important in determining effective public participation processes. According to the U.S. Census Bureau (2000), the most common language spoken at home, by individuals age five and over, is English. Spanish is the second language other than English that is spoken in the South Topeka, Oakland, and North Topeka study areas (Appendix A, Table 6). Residents residing in the Oakland study area have the lowest English proficiency rate and the highest population of Hispanic or Latino ethnicity residents. Additionally, there are a small percentage of persons residing in the study areas that speak an Asian or Pacific Island language as the most common language spoken at home.

Children under age five and elderly populations above age 65 are considered to be sensitive populations that may experience disproportionate impacts from environmental stressors. The table below provides insight into a subpopulation that exists within the study area in comparison to County averages (Appendix A, Table 7). Generalizations conclude that the Oakland study area has the highest percent of children under age five and the Auburndale study area indicate the highest percent of residents age 65 and over.

Finding of No Disproportionate Impacts

Based on data obtained from EPA's Online Tracking Information System (OTIS) which contains detailed facility information, the study areas do not have a significant overburden concentration of permitted active and/or operating facilities that pose a disproportionate negative impact to the community. In addition, the facilities in the study areas do not have a disproportionate number permit violations. Although the project area does contain EJ populations such as minority and low-income groups, they would not be disproportionately impacted in a negative way; rather these groups would equally benefit from the reduced risk of flooding with the implementation of the project.

The levee modifications would be primarily constructed adjacent to and/or within industrial and agricultural areas, and are not anticipated to cause any disproportionate impacts to sensitive populations, but are anticipated to provide a safer living environment.

Public coordination of the project to the EJ communities within the affected area consisted of the following: The project was coordinated with EJ communities thru distribution of the project information to EJ contacts provided by EPA. Distribution of project information included notifications of the availability of information regarding the project, a project fact sheet, along with the project's website address, contact information for the project manager, an announcement of the public meeting that was held in Topeka, Kansas on October 22, 2008, and a media press release that was sent to local newspapers, radio stations in the Topeka and surrounding metropolitan area. No comments on the project were received from the EJ communities and contacts during the public involvement process. The public involvement process will continue to reach out and provide information to the communities affected by the proposed plan as implementation proceeds.

13.0 MITIGATION

The Topeka flood risk management project would impact about seven and one-half acres of a 25-acre woodland due to installation of an under seepage berm at the South Topeka unit. To offset the loss of this impact, a replacement of 15 acres of riparian woodlands is proposed. In addition to reduce impacts to nesting birds, no construction activities in woodland areas would occur during the migratory bird nesting season from April 1 to July 15. A detailed mitigation plan can be found in Appendix F.

14.0 CUMULATIVE IMPACTS

The proposed action consists of modifications to an existing levee system in the Topeka area. Cumulative impacts of the proposed action, consists of relatively minor adverse impacts to the natural environment and aesthetics, with overall positive benefits to the socio-economic environment based on an improved level of protection to the local infrastructure. The project action is not expected to induce development since this plan would result in modifications to an existing levee system. The proposed action would not involve a levee raise or additional levees, but would only correct existing geotechnical and structural weaknesses to increase the reliability of the flood risk management system for the City of Topeka. Implementation of the project would involve temporary impacts to prime farmland identified as borrow sources, aesthetics, wildlife resources, and human environment thru construction- related noise and minor traffic disruptions. Adverse impacts are limited to the loss of seven and one-half acres of woodland. Mitigation for this loss would include replacement of the seven and one-half acres with 15 acres of soft and hard mast producing trees and shrubs, native grasses and forbs. In addition, to reduce impacts to nesting birds no construction activities in woodland areas would occur during the migratory bird nesting season from April 1 to July 15.

The project induced impacts to agricultural areas are considered temporary because steps would be taken to allow these areas to return to agricultural use after borrow and construction operations. Such measures would include preservation of the top layer of soil, which would be returned to the site, minimizing excavation depths to reduce impacts to the drainage of fields, and excavating after the harvest season to minimize impacts to crops. In addition, no adverse direct or indirect impacts to aquatic resources or water quality are anticipated to occur from project construction activities. For all construction activities, Best Management Practices would be used to minimize the introduction of fuel, petroleum products, or other deleterious material from entering into the waterway and adjacent resources. Control measures would include use of erosion control fences; storing equipment, solid waste, and petroleum products above the ordinary high water mark and away from areas prone to runoff; and requiring that all equipment be clean and free of leaks. In addition, no disproportionate impacts to minorities and low-income groups, and sensitive populations are anticipated to occur from project-related activities.

Past actions such as the clearing of forest for timber and urban and industrial development, flood control, as well as the conversion of forest to agriculture have contributed to substantial adverse impacts to the Kansas River ecosystem. Loss of floodplains and wetlands to agriculture and development has caused loss of biodiversity (USFWS, 2000). In general, flood risk management reservoirs, dams and weirs have lead to ecological deterioration, increases in contamination, disruption of sediment transfer, and hindrances to fish passage to upstream reaches (Merritt and Cooper, 2000; Mant and Janes, 2006). Also, river bed degradation of the Kansas River has been attributed to commercial sand and gravel dredging (Simons et al.1984 and Kansas Geological Survey, 1998). However, in 1990 the Corps implemented a regulatory program for commercial dredging activities on the Kansas River, which consisted of dredging restrictions to minimize impacts and a monitoring program to assess the impacts of permitted dredging activities.

Other land changes have resulted from construction of levee systems and major changes in transportation over the past several decades (e.g. highway construction and improvements, bridge replacements and rehabilitations). Federal flood risk management involvement within the Kansas River levee units was initiated between the 1940's and the early 1950's, and again after the 1951 flood. The 1951 flood contributed to the support for building flood control reservoirs and improving levee systems throughout eastern Kansas. In Topeka, Federal flood risk management projects consisted of the construction of floodwalls, earthen levees, channel improvements and drainage structures for various levee units. Additional improvements to the levee system were completed in the late 1970s. Today, most of the project area is developed with residential, commercial and industrial development.

Future actions planned for the Topeka area over the next 20 years include major transportation projects (e.g. roads, bridges, transit services, paratransit services, bicycle facilities, and pedestrian facilities) and these actions may result in additional loss of woodland habitat.

In addition, the Kansas Department of Transportation is developing a long-range statewide transportation plan for various transportation improvements that include the Topeka area, which also could result in additional loss of existing woody areas.

The impacts resulting from proposed modifications to the existing levee system consist of minor and short term impacts on the human environment and include measures to compensate for the loss of woodland and restore grass and agriculture areas impacted from the project; as well as best management practices to avoid impacts to aquatic resources and water quality. Therefore, these project impacts are considered minor and insignificant when added to other past, present or future actions.

15.0 CONCLUSION

The purpose of the proposed action is to increase the reliability of the flood risk management system for the City of Topeka. During the study phase, issues of concern identified by Corps of Engineers' representatives were geotechnical and structural. The proposed modifications consist of installation of landside underseepage berms, heel extensions, fill behind floodwalls, new pressure relief wells, wall stiffener on Kansas Avenue Pump Station, stability berms, removal of Fairchild Pump Station, replacement of section of the floodwall, and replacements of floodwall gatewells and sluice gates.

This EA has assessed the environmental impacts of the recommended plan, and alternatives. The recommended plan represents the plan with the highest net economic benefits and has relatively minor impacts to the natural environment with overall positive benefits to the socio-economic environment. Impacts to the natural environment are minor because the project is located within a previously disturbed environment that is highly industrial and urbanized. The main impacts to the natural environment include the loss of about seven and one-half acres of woodland from the proposed construction of the underseepage berm at South Topeka unit. However, these impacts would be offset by replanting a total of 15 acres of woodland habitat within the South Topeka and North Topeka project areas. Additional mitigation measures would include the avoidance of construction activities in woodland areas during the migratory bird nesting season of April 1 to July 15. In addition, the environmental assessment found minimal risk associated with HTRW contamination from proposed activities. However, there were three areas where a potential HTRW or solid waste impact could occur. Therefore, any soil removed from a site associated with the levee work or borrow areas would be analyzed to ensure proper disposal. Based on the environmental assessment, it has been determined that the recommended plan would not have any substantial adverse impacts on the natural and human environment. All practicable means to avoid and/or minimize adverse environmental effects have been incorporated into the recommended plan. Impacts are temporary, and as mitigated, are not expected to be significant. Therefore, the recommended plan is the environmentally preferable alternative.

16.0 COORDINATION

Preparation of this EA and a draft Finding of No Significant Impact (FONSI) has been coordinated with appropriate Federal, state, and local agencies. Copies of the EA and Feasibility Report were sent to the below agencies, environmental groups, and other interested parties during the 30-day public review period. All comments received during the public review period were addressed. Comments were received during the public review period from the following entities: City of Topeka, Friends of the Kaw, North Topeka Drainage District, U.S. Fish & Wildlife Service, Kansas State Historical Society, Natural Resources Conservation Service, and Federal Aviation Administration. There were no comments that required reevaluation of the alternatives, identification of a new recommended plan, or a critical change to impact analysis. Copies of the comment letters and USACE responses can be found in the Appendix B of the Main Feasibility Report.

- U.S. Department of the Interior, Fish and Wildlife Service, Region 6
- U.S. Environmental Protection Agency, Region VII
- USDA, National Resource Conservation Service, Kansas State Conservationist
- Federal Aviation Administration
- Federal Railroad Administration
- U.S. Federal Highway Administration
- U.S. Coast Guard Marine
- U.S. Geological Survey
- National Park Service
- U.S. Federal Emergency Management Agency, Region VII
- Kansas Biological Survey
- Kansas Department of Wildlife and Parks
- Kansas Geological Survey
- Kansas State Historical Society
- Kansas Water Office
- Kansas Department of Transportation
- Kansas Department of Health and Environment
- Kansas Department of Agriculture
- Kansas State Conservation Commission
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17.0 COMPLIANCE WITH ENVIRONMENTAL LAWS AND REGULATIONS

Environmental compliance for the proposed action has been achieved. Coordination with the appropriate Federal and state agencies has been made in preparation of this EA.

The Endangered Species Act, Section 7, (USFWS) concluded on May 29, 2007, and (KDWP) on June 1, 2007 that the proposed action would not likely adversely affect any endangered or threatened species.

The National Historic Preservation Act, Section 106 concluded on August 25, 2006 for determination of No Affect on cultural resources. Coordination with tribal government was achieved during the 30-day public review period of the EA.

It was determined that the project action would not result in the placement of fill or dredged material in the waters of the U.S and wetlands; therefore, the Clean Water Act sections 401 and 404(b)(1) permits are not required for this project.

The Fish and Wildlife Coordination Act report (draft) was received on September 29, 2006, (final) was received on March 16, 2007.

The Clean Water Act, Section 402, National Pollution Discharge Elimination System (NPDES) permit would be obtained from the Kansas Department of Health and Environment during the design phase of the project as the plans and specifications for the project are completed.

Environmental Laws and Regulations Compliance	
Clean Air Act, as amended, 42 U.S. C. 7401-7671, et seq.	Full Compliance
Clean Water Act (Federal Water Pollution Control Act), 33 U.S.C. 1251, et seq.	Full Compliance
Coastal Zone Management Act, 16 U.S.C. 1451, et seq	Not Applicable
Endangered Species Act, 16 U.S.C. 1531, et seq.	Full Compliance
Estuary Protection Act, 16 U.S.C. 1221, et seq.	Not Applicable
Farmland Protection Policy Act, 7 U.S.C. 4201, et. seq.	Full Compliance
Federal Water Project Recreation Act, 16 U.S.C. 4601-12, et seq.	Not Applicable
Fish and Wildlife Coordination Act, 16 U.S.C. 661, et seq.	Full Compliance
Land and Water Conservation Act (16 U.S.C 4601-4 et seq	Not Applicable
Marine Protection, Research, and Sanctuaries Act 33 U.S.C. 1401, et seq	Not Applicable
National Environmental Policy Act, 42 U.S.C. 4321, et seq.	Full Compliance
National Historic Preservation Act of 1966, as amended, 16 U.S.C. 470a, et seq.	Full Compliance
Noise Control Act, 42 U.S.C. 4901-4918	Full Compliance
Rivers and Harbors Act, 33 U.S.C. 403, et seq.	Full Compliance
Watershed Protection and Flood Prevention Act, 16 U.S.C. 1001, et seq.	Full Compliance
Wild and Scenic River Act, 16 U.S.C. 1271, et seq.	Full Compliance

Protection & Enhancement of the Cultural Environment (Executive Order 11593)	Full Compliance
Floodplain Management (Executive Order 11988)	Full Compliance
Protection of Migratory Birds (Executive Order 13186)	Full Compliance
Protection of Wetlands (Executive Order 11990)	Full Compliance
Environmental Justice (Executive Order 12898)	Full Compliance

a. Full Compliance. Having met all requirements of the statute for the current stage of the project.
b. Not Applicable. No requirements for the statute required.

18.0 PREPARERS

This EA and the associated FONSI were prepared by Ms. Lekesha Reynolds (Biologist), with relevant sections prepared by Mr. Paul Speckin (HTRW); Mr. Timothy Meade (Cultural Resources); Mr. Alan Holland (Socio-Economics), and Mr. Eric Lynn (Project Manager). The address of the preparers is: U.S. Army Corps of Engineers, Kansas City, District; PM-PR, Room 843, 601 E. 12th St, Kansas City, MO 64106. In addition, the Environmental Justice section of this EA was prepared with the assistance of Ms. Debbie Bishop, an Environmental Justice Specialist of the U.S. Environmental Protection Agency, Region VII, Kansas City, Missouri.

19.0 REFERENCES

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Appendix A.

Tables

City of Topeka, Kansas
Flood Risk Management Study
Environmental Assessment

Table 1. Topeka, Kansas, Feasibility Study
Alternatives Matrix

Description of Problem by Levee Unit and Location	All Possible Alternative Corrective Measures Considered 1	2	3	4	5	Alternatives screening disscussion	Alternatives carried thru Environmental Analysis
North Topeka Unit, Station 364+60 Fairchild Pump Station Problem: Uplift	Operational changes	Heel Extension	Remove and replace	Remove and Dispose		Fairchild Pump Station out-dated and no longer used or maintained by sponsor. Recommend measure 4.	Remove and Dispose
North Topeka Unit, Station 246+00 to 250+00 Problem: Underseepage	Underseepage berm.	buried collector system.	Relief wells discharging to ground.	Relief wells discharging to manhole w/ temporary pumping.	Relief wells discharging to permanent pump station.	Insufficient area is available to install measure 1. Buried collector system is not as effective as relief wells in reducing underseepage pressures, and are more laborious and expensive. Uplift pressures are not high enough to allow for ground discharge. Pumping only required at times of high flow. Permanent pump station would increase construction cost and future O&M. Recommend measure 4.	Relief wells discharging to manhole w/ temporary pumping
North Topeka Unit, Station 165+00 to 189+00 Problem: Underseepage	Underseepage berm.	buried collector system.	Relief wells discharging to ground.	Relief wells discharging to manhole w/ temporary pumping.	Relief wells discharging to permanent pump station.	Sufficient open land is available to install measures 1, 2, and 3, but buried collector system is not as effective as relief wells in reducing underseepage pressures, and are more laborious and expensive. Uplift pressures are high enough to allow for ground discharge. Recommend either measures 1 or 3.	Underseepage berm and Relief wells
Oakland Unit, Station 220+00 East Oakland Pump Station Problem: Uplift	Operational changes	Heel Extension	Remove and Replace			Measure 1 will not provide sufficient uplift factor of safety. Measure 3 requires more labor and materials and is not more effective than measure 2. Recommend measure 2.	Heel Extension
Oakland Unit, Station 75+50 - Manhole Problem: Uplift	Heel Extension	Remove and Replace				Measure 1 will provide minimum uplift factor of safety. Measure 2 requires more labor and materials is not more effective than measure 2.	Heel Extension
Oakland Unit, Station 485+86 to 491+01 Problem: Sliding Stability	Stability berm	Foundation Mod				Measure 1 will provide minimum sliding stability factor of safety. Measure 2 provides the same effectiveness as measure 1, but is more expensive and complex.	Stability berm
Oakland Unit, Station 64+00 to 80+00 Problem: Underseepage	Underseepage berm.	buried collector system.	Relief wells discharging to ground.	Relief wells discharging to manhole w/ temporary pumping.	Relief wells discharging to permanent pump station.	Sufficient open land is available to install measures 1, 2, and 3. Buried collector system is not as effective as relief wells in reducing underseepage pressures, and are more laborious and expensive. Uplift pressures are high enough to allow ground discharge. Recommend either measures 1 or 3.	Underseepage berm and Relief wells
South Topeka Unit, Station 75+84 Kansas Avenue Pump Station Problem: Strength	Wall Stiffener	Remove and Replace	Remove and Dispose			Measure 1 will provide minimum strength factor of safety. Since the factor of safety can be obtained with measure 1, measures 2 and 3 are not preferred.	Wall stiffener
South Topeka Unit, Station 16+07 - Manhole Problem: Uplift	Heel Extension	Remove and Replace				Measure 1 will provide minimum uplift factor of safety. Measure 2 is more laborious and expensive.	Heel Extension
South Topeka Unit, Station 84+10 - Manhole Problem: Uplift	Heel Extension	Remove and Replace				Measure 1 will provide minimum uplift factor of safety. Measure 2 is more laborious and expensive.	Heel Extension
South Topeka Unit, Station 84+10a - Manhole Problem: Uplift	Heel Extension	Remove and Replace				Measure 1 will provide minimum uplift factor of safety. Measure 2 is more laborious and expensive.	Heel Extension
South Topeka Unit, Station 85+57 - Manhole Problem: Uplift	Heel Extension	Remove and Replace				Measure 1 will provide minimum uplift factor of safety. Measure 2 is more laborious and expensive.	Heel Extension
South Topeka Unit. Station 74+41 to 93+86 Problem: Floodwall foundation weakness	New wall on offset alignment	New wall on existing alignment and replace gate well and sluice gates currently on wall	Earthen Levee behind existing wall	Modify existing wall		Insufficient area is available to implement measures 1 and 3. Measure 4 would be difficult to install and maintain with the existing wall remaining in place. Recommend measure 2.	New floodwall on existing alignment
South Topeka Unit, Station 22+00 to 48+00 Problem: Underseepage	Underseepage berm.	buried collector system.	Relief wells discharging to ground.	Relief wells discharging to manhole w/ temporary pumping.	Relief wells discharging to permanent pump station.	Sufficient open land is available to install measures 1, 2 and 3, however measure 2 is not as effective as measure 3. Uplift pressures are high enough to allow for ground discharge. Recommend either measures 1 or 3.	Underseepage berm and Relief wells
Waterworks Unit, Station 0+78 to 7+00, 10+00 to 16+50 Problem: Sliding Stability	Stability berm	Foundation Mod	Wall replacement			Measure 1 will provide minimum sliding stability factor of safety. Measures 2 and 3 are more laborious and expensive than measure 1.	Stability berm
Waterworks Unit, Station 13+07 to 15+95 Problem: Sliding Stability	Stability berm	Foundation Mod	Wall replacement			Measure 1 will provide minimum sliding stability factor of safety. Measures 2 and 3 are more laborious and expensive than measure 1.	Stability berm

Table 2. Topeka, Kansas, Feasibility Study

Environmental Impacts Summary

Environmental Resources	Alternatives			
	Recommended Alternative	No-Action	Alternative Commercial Fill	Alternative Relief Wells
Aquatic/ Water Quality	No adverse impacts to aquatic resources or water quality would be anticipated from the *preferred alternative for the proposed levee* units within the project area	No action would result in catastrophic flood damage resulting in significant impacts to a water quality, fisheries and wildlife, extensive property damage and potential loss of human life	No adverse impacts to aquatic resources or water quality are anticipated to occur	No impacts on the existing groundwater or flowing conditions and no adverse impacts to aquatic resources or water quality are anticipated
Wetlands	No impacts to wetlands are anticipated	No impacts to wetlands are expected to occur under this alternative	No impacts to wetlands are expected to occur under this alternative	No impacts to wetlands are expected to occur under this alternative
Prime and Unique Farmlands	Two prime farmland sites would be impacted to obtain borrow fill Impacts are considered minor and short-term	No action would result in catastrophic flood damage resulting in significant impacts to a water quality, farmland, fisheries and wildlife, extensive property damage and potential loss of human life	Disturbance of prime farmland would be minor and limited to the construction of under seepage berm within the North Topeka unit	Disturbance of prime farmland areas would be minor and significantly less than those described under the recommended plan
Wildlife	Impacts to wildlife habitat would result from the permanent removal of approximately 7 5 acres of woodland for the construction of the underseepage berm at the South Topeka levee unit	No action would result in catastrophic flood damage resulting in significant impacts to a water quality, fisheries and wildlife, extensive property damage and potential loss of human life	Impacts to wildlife habitat would result from the removal of approximately nine acres of woodlands for the construction of the underseepage berm at the South Topeka levee unit	Widlife habitat within the project area would be avoided
Forest/Vegetation	Impacts to woodlands would result from the removal of approximately 7 5 acres of woodland for the construction of the underseepage berm at the South Topeka levee unit However, those impacts would be offset thru tree plantings and prairie establishement within a 15- acre area along the riverbank	No action would result in catastrophic flood damage resulting in significant impacts to a water quality, fisheries and wildlife, extensive property damage and potential loss of human life	Impacts to woodlands would result from the removal of approximately 7 5 acres of woodland for the construction of the underseepage berm at the South Topeka levee unit However, those impacts would be offset thru tree plantings and prairie establishement within a 15- acre area along the riverbank	Impacts to forest and vegetated resources within the project area would be avoided
Endangered and Threatened Species	No adverse impacts are anticipated	No action would result in catastrophic flood damage resulting in significant impacts to a water quality, fisheries and wildlife, extensive property damage and potential loss of human life	minor effects on threatened and endangered species and their habitat expected to occur associated with obtaining dredged material of the Kansas River	No impacts to the aquatic resources are expected to occur under this alternative
Cultural	No historic properties are recorded within the area of the proposed alternatives or borrow locations	No impacts to the aquatic resources are expected to occur under this alternative	No impacts to the aquatic resources are expected to occur under this alternative	No impacts to the aquatic resources are expected to occur under this alternative
Noise	Construction activities would not increase noise levels beyond that typical of farming operations or area traffic in the vicinity	No action would result in catastrophic flood damage resulting in unregulated and widespread noise from clean-up activities	Construction activities would not increase noise levels beyond that typical of farming operations or area traffic in the vicinity	Construction activities would not increase noise levels beyond that typical of farming operations or area traffic in the vicinity
Air Quality	Minor, localized, and short-term impacts to air quality in the project area would result from construction activities	No action would result in catastrophic flood damage resulting in the release of a variety of dust, and other contaminants from clean-up activities	Minor, localized and short-term impacts to air quality in the project area would result from construction activities	Minor, short-term impacts to air quality in the project area would result from construction activities
Visual Quality	Impacts would be temporary, minor and would only occur within the construction areas	No action would result in catastrophic flood damage resulting in widespread aesthetic impacts from deposits of debris, dead trees and property damage	Under this plan, the roads could receive short term aesthetic impacts of haul material deposited on the established haul travel routes, however, the contractor would be required to immediately remove or clean these materials	No significant impacts to this resource are anticipated
Demography	This plan would prevent adverse economic impacts, including flood damage (in all but the most catastrophic events) and high insurance premiums, to the protected neighborhoods	Failure to implement the recommended plan or commercial fill alternative would likely result in an increasing pattern of flood damage in the Oakland, South Topeka and North Topeka areas from large Kansas River events	This plan would prevent adverse economic impacts, including flood damage (in all but the most catastrophic events) and high insurance premiums, to the protected neighborhoods	This plan would prevent adverse economic impacts, including flood damage (in all but the most catastrophic events) and high insurance premiums, to the protected neighborhoods
Development and Economy	This plan would benefit a large portion of the city's economic base Specifically would porvide protection for several prime areas for economic development in Oakland and North Topeka that are among the best industrial and commercial future development prospects in the region	No action would result in catastrophic flood damage affecting large urban neighborhoods Large employers in the floodplain areas might suffer severe damage Some small business owners would be ruined by flood damage	This plan would benefit a large portion of the city's economic base Specifically would porvide protection for several prime areas for economic development in Oakland and North Topeka that are among the best industrial and commercial future development prospects in the region	This plan would benefit a large portion of the city's economic base Specifically would porvide protection for several prime areas for economic development in Oakland and North Topeka that are among the best industrial and commercial future development prospects in the region
Transportation	This plan would cause short-term, minor disruptions to traffic with the maneuvering of construction equipment to and from the project area	No action could pose a problem to transportation during a 100-year flood event Area roads could be flooded impairing evacuation and rescue of the local population	Trucks hauling fill material to the construction site may have temporary impacts to local roads, causing congestion, and possibly causing damage to the roads	This plan would cause slight disruptions to traffic with the maneuvering of construction equipment to and from the project area

Table 3: STUDY AREA SOCIOECONOMIC CHARACTERISTICS (RACE)

Based on 2000 Census

ANALYSIS AREA	White	Black or African American	American Indian and Alaska Native	Asian	Native Hawaiian and Other Pacific Islander	Some Other Race	Two or More Races	Hispanic or Latino (of any race)
State of Kansas	86.1%	5.7%	0.9%	1.7%	0.0%	3.4%	2.1%	7.0%
Shawnee County	82.9%	9.0%	1.2%	1.0%	0.0%	3.2%	2.7%	7.3%
Topeka MSA	82.9%	9.0%	1.2%	1.0%	0.0%	3.2%	2.7%	7.3%
City of Topeka	78.5%	11.7%	1.3%	1.1%	0.0%	4.1%	3.3%	8.9%
Silver Lake	96.8%	0.1%	0.7%	0.2%	0.1%	0.6%	1.5%	1.8%
AUBURNDALE								
Census Tract 21	79.3%	12.5%	1.4%	0.7%	0.1%	3.3%	2.7%	7.8%
Census Tract 21 - Block Group 4	91.0%	3.8%	0.9%	0.7%	0.0%	0.7%	2.8%	3.4%
Census Tract 21 - Block Group 5	90.1%	3.7%	1.9%	0.6%	0.0%	1.1%	2.6%	3.2%
Census Tract 22	92.4%	2.1%	0.6%	0.3%	0.0%	2.3%	2.3%	4.4%
Census Tract 22 - Block Group 1	89.1%	3.7%	1.3%	0.4%	0.0%	2.1%	3.5%	4.1%
Census Tract 22 - Block Group 3	90.4%	1.9%	0.7%	0.1%	0.0%	3.6%	3.3%	7.0%
Census Tract 41	91.6%	4.0%	0.7%	0.5%	0.0%	1.5%	1.7%	4.6%
Census Tract 41 - Block Group 1	89.4%	5.5%	1.0%	0.4%	0.0%	1.8%	2.0%	4.9%
Census Tract 41 - Block Group 2	93.7%	2.3%	0.8%	0.4%	0.0%	1.2%	1.6%	3.3%
SOUTH TOPEKA								
Census Tract 6	73.8%	11.6%	2.9%	0.5%	0.0%	5.5%	5.9%	12.7%
Census Tract 6 - Block Group 1	80.5%	5.1%	2.7%	0.4%	0.0%	5.7%	5.6%	11.6%
Census Tract 22	92.4%	2.1%	0.6%	0.3%	0.0%	2.3%	2.3%	4.4%
Census Tract 22 - Block Group 1	89.1%	3.7%	1.3%	0.4%	0.0%	2.1%	3.5%	4.1%
Census Tract 40	56.9%	26.1%	2.8%	1.0%	0.0%	9.4%	3.8%	18.8%
Census Tract 40 - Block Group 1	62.7%	8.8%	3.4%	0.0%	0.0%	21.7%	3.4%	34.6%
Census Tract 40 - Block Group 2	58.6%	28.8%	2.9%	1.7%	0.1%	5.5%	2.5%	16.5%
Census Tract 40 - Block Group 3	49.2%	34.8%	2.9%	0.8%	0.0%	8.0%	4.3%	15.3%
OAKLAND								
Census Tract 9	85.7%	2.1%	2.7%	0.3%	0.0%	6.6%	2.5%	12.8%
Census Tract 9 - Block Group 1	82.8%	1.9%	2.7%	0.2%	0.0%	7.9%	4.6%	16.1%
Census Tract 9 - Block Group 2	85.6%	1.8%	2.9%	0.1%	0.0%	6.6%	3.1%	13.1%
Census Tract 9 - Block Group 3	87.3%	1.5%	2.6%	0.8%	0.0%	5.0%	2.8%	10.4%
Census Tract 9 - Block Group 4	86.4%	3.1%	2.6%	0.3%	0.1%	7.0%	0.6%	12.3%
Census Tract 10	74.4%	2.0%	1.7%	0.2%	0.0%	17.0%	4.7%	34.5%
Census Tract 10 - Block Group 1	84.0%	2.1%	1.0%	0.0%	0.0%	8.3%	4.5%	22.6%
Census Tract 10 - Block Group 2	78.0%	1.9%	1.8%	0.6%	0.0%	14.7%	3.0%	25.9%
Census Tract 10 - Block Group 3	66.4%	0.5%	2.4%	0.0%	0.0%	24.8%	5.8%	52.9%
Census Tract 10 - Block Group 4	68.5%	2.8%	1.6%	0.2%	0.0%	21.2%	5.7%	40.6%
Census Tract 11	46.8%	20.4%	2.3%	0.0%	0.0%	23.6%	6.9%	40.8%
Census Tract 11 - Block Group 1	52.3%	23.4%	2.1%	0.0%	0.0%	16.7%	5.4%	28.6%
Census Tract 11 - Block Group 2	44.0%	19.0%	2.2%	0.1%	0.0%	25.6%	9.0%	41.5%
Census Tract 11 - Block Group 3	44.3%	18.9%	2.6%	0.0%	0.0%	27.9%	6.4%	51.1%
NORTH TOPEKA								
Census Tract 7	87.0%	6.3%	1.7%	0.3%	0.0%	1.5%	3.1%	5.3%
Census Tract 7 - Block Group 1	87.4%	5.9%	2.2%	0.0%	0.0%	1.4%	3.1%	4.3%
Census Tract 7 - Block Group 2	86.7%	6.5%	1.4%	0.5%	0.0%	1.6%	3.1%	5.8%
Census Tract 8	88.6%	3.4%	2.8%	0.4%	0.0%	1.6%	3.0%	5.3%
Census Tract 8 - Block Group 1	94.6%	1.2%	1.7%	0.2%	0.0%	0.4%	1.9%	3.1%
Census Tract 8 - Block Group 2	92.2%	2.9%	1.2%	0.0%	0.1%	1.1%	2.4%	3.3%
Census Tract 8 - Block Group 3	86.0%	4.2%	2.1%	1.2%	0.0%	2.5%	4.0%	8.3%
Census Tract 8 - Block Group 4	82.5%	5.1%	5.9%	0.2%	0.0%	2.5%	3.8%	6.4%
Census Tract 34	96.6%	0.6%	0.7%	0.3%	0.1%	0.5%	1.3%	2.4%
Census Tract 34 - Block Group 2	96.2%	1.0%	0.6%	0.4%	0.1%	0.6%	1.2%	2.2%
Census Tract 35	96.4%	0.3%	0.9%	0.3%	0.0%	0.8%	1.2%	2.0%
Census Tract 35 - Block Group 1	96.5%	0.6%	0.9%	0.2%	0.0%	0.9%	0.9%	1.5%
SOLDIER CREEK URBAN								
Census Tract 8	88.6%	3.4%	2.8%	0.4%	0.0%	1.6%	3.0%	5.3%
Census Tract 8 - Block Group 1	94.6%	1.2%	1.7%	0.2%	0.0%	0.4%	1.9%	3.1%
Census Tract 33.01	95.2%	0.8%	1.1%	0.3%	0.0%	1.5%	1.2%	5.0%
Census Tract 33.01 - Block Group 1	95.2%	0.8%	1.1%	0.3%	0.0%	1.5%	1.2%	5.0%
Census Tract 34	96.6%	0.6%	0.7%	0.3%	0.1%	0.5%	1.3%	2.4%
Census Tract 34 - Block Group 1	96.9%	0.3%	0.9%	0.3%	0.0%	0.4%	1.2%	2.6%
Census Tract 34 - Block Group 2	96.2%	1.0%	0.6%	0.4%	0.1%	0.6%	1.2%	2.2%
Census Tract 35	96.4%	0.3%	0.9%	0.3%	0.0%	0.8%	1.2%	2.0%
Census Tract 35 - Block Group 1	96.5%	0.6%	0.9%	0.2%	0.0%	0.9%	0.9%	1.5%

Table 4: STUDY AREA SOCIOECONOMIC CHARACTERISTICS (MINORITY&POVERTY)

Based on 2000 Census

ANALYSIS AREA	Black or African American	American Indian and Alaska Native	Asian	Native Hawaiian and Other Pacific Islander	Some Other Race	Two or More Races	Hispanic or Latino (of Any Race)	% Below Poverty in 1999
State of Kansas	5.7%	0.9%	1.7%	0.0%	3.4%	2.1%	7.0%	9.9%
Shawnee County	9.0%	1.2%	1.0%	0.0%	3.2%	2.7%	7.3%	9.6%
Topeka MSA	9.0%	1.2%	1.0%	0.0%	3.2%	2.7%	7.3%	9.6%
City of Topeka	11.7%	1.3%	1.1%	0.0%	4.1%	3.3%	8.9%	12.4%
Silver Lake	0.1%	0.7%	0.2%	0.1%	0.6%	1.5%	1.8%	4.2%
AUBURNDALE								
Census Tract 21	12.5%	1.4%	0.7%	0.1%	3.3%	2.7%	7.8%	6.7%
Census Tract 21 - Block Group 4	3.8%	0.9%	0.7%	0.0%	0.7%	2.8%	3.4%	1.7%
Census Tract 21 - Block Group 5	3.7%	1.9%	0.6%	0.0%	1.1%	2.6%	3.2%	5.8%
Census Tract 22	2.1%	0.6%	0.3%	0.0%	2.3%	2.3%	4.4%	6.4%
Census Tract 22 - Block Group 1	3.7%	1.3%	0.4%	0.0%	2.1%	3.5%	4.1%	10.3%
Census Tract 22 - Block Group 3	1.9%	0.7%	0.1%	0.0%	3.6%	3.3%	7.0%	9.6%
Census Tract 41	4.0%	0.7%	0.5%	0.0%	1.5%	1.7%	4.6%	6.5%
Census Tract 41 - Block Group 1	5.5%	1.0%	0.4%	0.0%	1.8%	2.0%	4.9%	5.7%
Census Tract 41 - Block Group 2	2.3%	0.8%	0.4%	0.0%	1.2%	1.6%	3.3%	3.2%
SOUTH TOPEKA								
Census Tract 6	11.6%	2.9%	0.5%	0.0%	5.5%	5.9%	12.7%	33.2%
Census Tract 6 - Block Group 1	5.1%	2.7%	0.4%	0.0%	5.7%	5.6%	11.6%	42.0%
Census Tract 22	2.1%	0.6%	0.3%	0.0%	2.3%	2.3%	4.4%	6.4%
Census Tract 22 - Block Group 1	3.7%	1.3%	0.4%	0.0%	2.1%	3.5%	4.1%	10.3%
Census Tract 40	26.1%	2.8%	1.0%	0.0%	9.4%	3.8%	18.8%	37.5%
Census Tract 40 - Block Group 1	8.8%	3.4%	0.0%	0.0%	21.7%	3.4%	34.6%	35.2%
Census Tract 40 - Block Group 2	28.8%	2.9%	1.7%	0.1%	5.5%	2.5%	16.5%	36.0%
Census Tract 40 - Block Group 3	34.8%	2.9%	0.8%	0.0%	8.0%	4.3%	15.3%	41.0%
OAKLAND								
Census Tract 9	2.1%	2.7%	0.3%	0.0%	6.6%	2.5%	12.8%	8.7%
Census Tract 9 - Block Group 1	1.9%	2.7%	0.2%	0.0%	7.9%	4.6%	16.1%	0.0%
Census Tract 9 - Block Group 2	1.8%	2.9%	0.1%	0.0%	6.6%	3.1%	13.1%	7.3%
Census Tract 9 - Block Group 3	1.5%	2.6%	0.8%	0.0%	5.0%	2.8%	10.4%	12.9%
Census Tract 9 - Block Group 4	3.1%	2.6%	0.3%	0.1%	7.0%	0.6%	12.3%	12.4%
Census Tract 10	2.0%	1.7%	0.2%	0.0%	17.0%	4.7%	34.5%	11.9%
Census Tract 10 - Block Group 1	2.1%	1.0%	0.0%	0.0%	8.3%	4.5%	22.6%	8.2%
Census Tract 10 - Block Group 2	1.9%	1.8%	0.6%	0.0%	14.7%	3.0%	25.9%	10.8%
Census Tract 10 - Block Group 3	0.5%	2.4%	0.0%	0.0%	24.8%	5.8%	52.9%	10.9%
Census Tract 10 - Block Group 4	2.8%	1.6%	0.2%	0.0%	21.2%	5.7%	40.6%	16.0%
Census Tract 11	20.4%	2.3%	0.0%	0.0%	23.6%	6.9%	40.8%	26.5%
Census Tract 11 - Block Group 1	23.4%	2.1%	0.0%	0.0%	16.7%	5.4%	28.6%	20.4%
Census Tract 11 - Block Group 2	19.0%	2.2%	0.1%	0.0%	25.6%	9.0%	41.5%	32.1%
Census Tract 11 - Block Group 3	18.9%	2.6%	0.0%	0.0%	27.9%	6.4%	51.1%	27.1%
NORTH TOPEKA								
Census Tract 7	6.3%	1.7%	0.3%	0.0%	1.5%	3.1%	5.3%	14.0%
Census Tract 7 - Block Group 1	5.9%	2.2%	0.0%	0.0%	1.4%	3.1%	4.3%	12.4%
Census Tract 7 - Block Group 2	6.5%	1.4%	0.5%	0.0%	1.6%	3.1%	5.8%	15.2%
Census Tract 8	3.4%	2.8%	0.4%	0.0%	1.6%	3.0%	5.3%	19.8%
Census Tract 8 - Block Group 1	1.2%	1.7%	0.2%	0.0%	0.4%	1.9%	3.1%	8.6%
Census Tract 8 - Block Group 2	2.9%	1.2%	0.0%	0.1%	1.1%	2.4%	3.3%	17.0%
Census Tract 8 - Block Group 3	4.2%	2.1%	1.2%	0.0%	2.5%	4.0%	8.3%	24.3%
Census Tract 8 - Block Group 4	5.1%	5.9%	0.2%	0.0%	2.5%	3.8%	6.4%	27.9%
Census Tract 34	0.6%	0.7%	0.3%	0.1%	0.5%	1.3%	2.4%	2.2%
Census Tract 34 - Block Group 2	1.0%	0.6%	0.4%	0.1%	0.6%	1.2%	2.2%	3.0%
Census Tract 35	0.3%	0.9%	0.3%	0.0%	0.8%	1.2%	2.0%	2.5%
Census Tract 35 - Block Group 1	0.6%	0.9%	0.2%	0.0%	0.9%	0.9%	1.5%	2.0%
SOLDIER CREEK URBAN								
Census Tract 8	3.4%	2.8%	0.4%	0.0%	1.6%	3.0%	5.3%	19.8%
Census Tract 8 - Block Group 1	1.2%	1.7%	0.2%	0.0%	0.4%	1.9%	3.1%	8.6%
Census Tract 33.01	0.8%	1.1%	0.3%	0.0%	1.5%	1.2%	5.0%	0.5%
Census Tract 33.01 - Block Group 1	0.8%	1.1%	0.3%	0.0%	1.5%	1.2%	5.0%	0.5%
Census Tract 34	0.6%	0.7%	0.3%	0.1%	0.5%	1.3%	2.4%	2.2%
Census Tract 34 - Block Group 1	0.3%	0.9%	0.3%	0.0%	0.4%	1.2%	2.6%	2.9%
Census Tract 34 - Block Group 2	1.0%	0.6%	0.4%	0.1%	0.6%	1.2%	2.2%	3.0%
Census Tract 35	0.3%	0.9%	0.3%	0.0%	0.8%	1.2%	2.0%	2.5%
Census Tract 35 - Block Group 1	0.6%	0.9%	0.2%	0.0%	0.9%	0.9%	1.5%	2.0%

Table 5: STUDY AREA SOCIOECONOMIC CHARACTERISTICS (EDUCATION)

Based on 2000 Census

ANALYSIS AREA	Percent High School Graduate or Higher	Percent Bachelor's Degree or Higher
State of Kansas	86.0%	25.8%
Shawnee County	88.1%	26.0%
Topeka MSA	88.1%	26.1%
City of Topeka	85.9%	25.3%
Silver Lake	92.5%	22.3%
AUBURNDALE		
Census Tract 21	87.0%	24.4%
Census Tract 21 - Block Group 4	86.4%	25.8%
Census Tract 21 - Block Group 5	96.1%	23.8%
Census Tract 22	88.9%	28.2%
Census Tract 22 - Block Group 1	93.0%	27.2%
Census Tract 22 - Block Group 3	81.3%	18.5%
Census Tract 41	89.3%	25.3%
Census Tract 41 - Block Group 1	86.8%	21.2%
Census Tract 41 - Block Group 2	94.5%	33.7%
SOUTH TOPEKA		
Census Tract 6	79.6%	12.0%
Census Tract 6 - Block Group 1	78.0%	5.3%
Census Tract 22	88.9%	28.2%
Census Tract 22 - Block Group 1	93.0%	27.2%
Census Tract 40	70.7%	6.7%
Census Tract 40 - Block Group 1	61.3%	8.1%
Census Tract 40 - Block Group 2	80.8%	4.7%
Census Tract 40 - Block Group 3	58.4%	4.0%
OAKLAND		
Census Tract 9	79.8%	7.2%
Census Tract 9 - Block Group 1	83.8%	9.4%
Census Tract 9 - Block Group 2	83.2%	9.3%
Census Tract 9 - Block Group 3	84.0%	5.2%
Census Tract 9 - Block Group 4	71.8%	5.4%
Census Tract 10	71.2%	6.6%
Census Tract 10 - Block Group 1	67.2%	10.2%
Census Tract 10 - Block Group 2	73.3%	5.4%
Census Tract 10 - Block Group 3	79.1%	5.2%
Census Tract 10 - Block Group 4	68.1%	5.1%
Census Tract 11	58.5%	4.7%
Census Tract 11 - Block Group 1	62.7%	5.7%
Census Tract 11 - Block Group 2	60.1%	4.5%
Census Tract 11 - Block Group 3	53.3%	4.1%
NORTH TOPEKA		
Census Tract 7	78.5%	5.9%
Census Tract 7 - Block Group 1	76.1%	7.0%
Census Tract 7 - Block Group 2	80.0%	5.2%
Census Tract 8	71.0%	5.9%
Census Tract 8 - Block Group 1	74.8%	9.3%
Census Tract 8 - Block Group 2	80.7%	5.0%
Census Tract 8 - Block Group 3	71.3%	7.9%
Census Tract 8 - Block Group 4	58.5%	2.0%
Census Tract 34	93.4%	23.6%
Census Tract 34 - Block Group 2	95.7%	24.8%
Census Tract 35	92.3%	20.2%
Census Tract 35 - Block Group 1	95.1%	23.5%
SOLDIER CREEK URBAN		
Census Tract 8	71.0%	5.9%
Census Tract 8 - Block Group 1	74.8%	9.3%
Census Tract 33.01	91.4%	16.8%
Census Tract 33.01 - Block Group 1	91.4%	16.8%
Census Tract 34	93.4%	23.6%
Census Tract 34 - Block Group 1	95.0%	26.1%
Census Tract 34 - Block Group 2	95.7%	24.8%
Census Tract 35	92.3%	20.2%
Census Tract 35 - Block Group 1	95.1%	23.5%

Table 6: STUDY AREA SOCIOECONOMIC CHARACTERISTICS (LANGUAGE)

Based on 2000 Census

ANALYSIS AREA	Language Spoken at Home: English Only	Speak English Less than "Very Well"
State of Kansas	91.3%	3.9%
Shawnee County	93.9%	2.4%
Topeka MSA	93.9%	2.4%
City of Topeka	93.0%	2.8%
Silver Lake	98.2%	0.3%
AUBURNDALE		
Census Tract 21	94.4%	2.4%
Census Tract 21 - Block Group 4	96.5%	1.0%
Census Tract 21 - Block Group 5	100.0%	0.0%
Census Tract 22	96.2%	2.3%
Census Tract 22 - Block Group 1	100.0%	0.0%
Census Tract 22 - Block Group 3	90.9%	6.4%
Census Tract 41	96.7%	0.9%
Census Tract 41 - Block Group 1	96.7%	0.9%
Census Tract 41 - Block Group 2	97.9%	1.0%
SOUTH TOPEKA		
Census Tract 6	97.5%	1.0%
Census Tract 6 - Block Group 1	98.7%	0.7%
Census Tract 22	96.2%	2.3%
Census Tract 22 - Block Group 1	100.0%	0.0%
Census Tract 40	83.6%	7.4%
Census Tract 40 - Block Group 1	66.2%	15.8%
Census Tract 40 - Block Group 2	90.9%	3.4%
Census Tract 40 - Block Group 3	93.5%	3.0%
OAKLAND		
Census Tract 9	96.2%	1.4%
Census Tract 9 - Block Group 1	98.5%	0.0%
Census Tract 9 - Block Group 2	94.5%	2.2%
Census Tract 9 - Block Group 3	97.7%	1.1%
Census Tract 9 - Block Group 4	95.6%	1.6%
Census Tract 10	82.8%	7.5%
Census Tract 10 - Block Group 1	84.2%	7.3%
Census Tract 10 - Block Group 2	81.6%	10.2%
Census Tract 10 - Block Group 3	78.1%	11.0%
Census Tract 10 - Block Group 4	85.8%	3.3%
Census Tract 11	68.8%	19.2%
Census Tract 11 - Block Group 1	85.7%	11.5%
Census Tract 11 - Block Group 2	67.2%	16.4%
Census Tract 11 - Block Group 3	55.5%	27.8%
NORTH TOPEKA		
Census Tract 7	94.0%	1.7%
Census Tract 7 - Block Group 1	90.7%	3.0%
Census Tract 7 - Block Group 2	96.1%	0.9%
Census Tract 8	95.5%	2.0%
Census Tract 8 - Block Group 1	96.7%	2.0%
Census Tract 8 - Block Group 2	98.6%	0.0%
Census Tract 8 - Block Group 3	94.8%	2.8%
Census Tract 8 - Block Group 4	92.4%	3.1%
Census Tract 34	97.0%	1.0%
Census Tract 34 - Block Group 2	97.5%	0.7%
Census Tract 35	96.8%	0.9%
Census Tract 35 - Block Group 1	95.4%	1.5%
SOLDIER CREEK URBAN		
Census Tract 8	95.5%	2.0%
Census Tract 8 - Block Group 1	96.7%	2.0%
Census Tract 33.01	97.8%	0.9%
Census Tract 33.01 - Block Group 1	97.8%	0.9%
Census Tract 34	97.0%	1.0%
Census Tract 34 - Block Group 1	95.6%	2.1%
Census Tract 34 - Block Group 2	97.5%	0.7%
Census Tract 35	96.8%	0.9%
Census Tract 35 - Block Group 1	95.4%	1.5%

Table 7: STUDY AREA SOCIOECONOMIC CHARACTERISTICS (AGE)
Based on 2000 Census

ANALYSIS AREA	Median Age	% Under 5	% Under 18	% 65 and Over
State of Kansas	35.3	7.0%	26.5%	13.2%
Shawnee County	37.2	6.8%	25.2%	13.7%
Topeka MSA	37.1	6.8%	25.3%	13.7%
City of Topeka	36.4	7.1%	24.3%	15.0%
Silver Lake	37.1	5.9%	28.3%	10.8%
AUBURNDALE				
Census Tract 21	34.3	7.0%	23.3%	14.9%
Census Tract 21 - Block Group 4	36.4	6.4%	19.6%	16.2%
Census Tract 21 - Block Group 5	36.7	6.1%	22.1%	12.8%
Census Tract 22	39.4	7.9%	25.2%	16.7%
Census Tract 22 - Block Group 1	36.1	6.3%	26.5%	11.5%
Census Tract 22 - Block Group 3	39.1	7.7%	21.4%	15.7%
Census Tract 41	37.0	6.6%	18.4%	19.3%
Census Tract 41 - Block Group 1	40.2	5.3%	12.7%	26.7%
Census Tract 41 - Block Group 2	35.1	6.6%	21.7%	13.9%
SOUTH TOPEKA				
Census Tract 6	30.5	9.3%	29.5%	8.4%
Census Tract 6 - Block Group 1	30.6	9.9%	29.6%	9.8%
Census Tract 22	39.4	7.9%	25.2%	16.7%
Census Tract 22 - Block Group 1	36.1	6.3%	26.5%	11.5%
Census Tract 40	34.8	9.0%	21.5%	11.7%
Census Tract 40 - Block Group 1	32.7	7.2%	25.5%	11.2%
Census Tract 40 - Block Group 2	33.4	1.9%	12.9%	6.4%
Census Tract 40 - Block Group 3	34.8	9.0%	28.2%	14.6%
OAKLAND				
Census Tract 9	35.7	7.0%	26.1%	14.6%
Census Tract 9 - Block Group 1	31.1	9.8%	30.1%	12.9%
Census Tract 9 - Block Group 2	32.1	8.5%	26.8%	12.2%
Census Tract 9 - Block Group 3	37.4	6.1%	24.3%	16.6%
Census Tract 9 - Block Group 4	41.4	4.8%	24.3%	17.6%
Census Tract 10	39.6	6.7%	24.7%	16.6%
Census Tract 10 - Block Group 1	43.7	5.7%	20.2%	21.4%
Census Tract 10 - Block Group 2	34.4	7.3%	26.6%	14.0%
Census Tract 10 - Block Group 3	38.2	6.8%	24.0%	20.5%
Census Tract 10 - Block Group 4	36.8	9.0%	25.8%	16.2%
Census Tract 11	28.5	10.1%	34.2%	10.6%
Census Tract 11 - Block Group 1	30.3	10.2%	32.7%	14.7%
Census Tract 11 - Block Group 2	28.4	11.1%	34.5%	9.1%
Census Tract 11 - Block Group 3	28.6	9.7%	34.0%	8.7%
NORTH TOPEKA				
Census Tract 7	32.0	7.7%	31.3%	11.5%
Census Tract 7 - Block Group 1	35.1	7.7%	27.1%	15.9%
Census Tract 7 - Block Group 2	29.3	6.7%	32.6%	9.8%
Census Tract 8	38.2	7.4%	23.8%	13.4%
Census Tract 8 - Block Group 1	35.7	7.0%	24.5%	10.6%
Census Tract 8 - Block Group 2	40.2	6.7%	21.7%	17.6%
Census Tract 8 - Block Group 3	40.6	6.3%	24.1%	14.5%
Census Tract 8 - Block Group 4	37.8	8.1%	23.6%	13.5%
Census Tract 34	39.8	6.0%	26.4%	10.4%
Census Tract 34 - Block Group 2	38.7	6.5%	27.4%	7.2%
Census Tract 35	37.4	6.2%	29.5%	11.2%
Census Tract 35 - Block Group 1	39.0	5.1%	29.5%	9.3%
SOLDIER CREEK URBAN				
Census Tract 8	38.2	7.4%	23.8%	13.4%
Census Tract 8 - Block Group 1	35.7	7.0%	24.5%	10.6%
Census Tract 33.01	40.9	6.0%	25.4%	13.8%
Census Tract 33.01 - Block Group 1	40.9	6.0%	25.4%	13.8%
Census Tract 34	39.8	6.0%	26.4%	10.4%
Census Tract 34 - Block Group 1	41.7	6.1%	24.5%	14.9%
Census Tract 34 - Block Group 2	38.7	6.5%	27.4%	7.2%
Census Tract 35	37.4	6.2%	29.5%	11.2%
Census Tract 35 - Block Group 1	39.0	5.1%	29.5%	9.3%

Appendix B.

Agency Coordination Letters

City of Topeka, Kansas
Flood Risk Management Study
Environmental Assessment

United States Department of Agriculture

NRCS

Natural Resources Conservation Service
3231 Southwest Van Buren Street, Suite 2
Topeka, Kansas 66611-2291

Phone: 785-267-5721
FAX: 785-266-8293
www.ks.nrcs.usda.gov

October 17, 2006

Ms. Lekesha Reynolds
U.S. Army Corps of Engineers
PM-PR, Room 846
601 E 12th St
Kansas City, Missouri 64106

Ref: Letter and map of October 13, 2006, requesting wetland and CRP locations for possible levee work in Topeka, Kansas.

Dear Ms. Reynolds,

A review of the proposed work area has been made. The current procedure is that we do not have "wetland mapped areas" as such. What we have now is "certified wetlands" as a result of individual landowners requesting a wetland determination on agricultural land. In those cases a sight visit and analysis to made to determine if wetlands exist. No requests have been made by landowners in the proposed areas indicated on the map. So we would have no information as to the wetland status.

A few other items related to wetlands. The Natural Resources Conservation Service through a MOA with your agency determines wetland issues as long as the landuse is agricultural. This kind of work would change its' status to "non-ag" of which then your agency would make the determination. The areas indicated may also be under your agency's jurisdiction due to it's proximity to "The Waters of The U.S.. And finally, there are a few areas of impounded water that may also have wetland considerations.

On the item of the Conservation Reserve Program (CRP) areas. The Farm Service Agency (FSA) in our same building is the agency that manages enrolled land in the CRP. I reviewed the map with Mark Nieman, CED, with FSA and he indicated there was no current land enrolled at the locations indicated in the CRP.

If you have any questions feel free to give me a call.

Sincerely,

Dennis J. Brinkman
DISTRICT CONSERVATIONIST

NRCS
United States Department of Agriculture
Natural Resources Conservation Service
1125 Westport Drive
Manhattan, Kansas 66502-2860

"A Partner in Conservation Since 1935"

Phone: 785-776-5182
FAX: 785-539-7983
www.ks.nrcs.usda.gov

August 28, 2006

Lekesha Reynolds
U.S. Army Corps of Engineers, PM-PR
601 E. 12th Street, Room 843
Kansas City, Missouri 64106

Re: Topeka, Kansas Levees Project.

Dear Ms. Reynolds:

Thank you for the opportunity to review the improvement project the Corps levees along the Kansas River in Topeka, Kansas.

Attached to this letter is form AD-1006, which in indicates the Farmland Conversion Impact Ratings for the four sites where borrow material is proposed to be taken from. As for any other environmental issues for which the Natural Resources Conservation Service is responsible for evaluating, I see no negative concerns at this point in time.

If I can be of further assistance, please let me know.

Sincerely,

Alan R. Boerger
Resource Conservationist

Cc: Lynn Thurlow, Soil Conservationist, NRCS, Salina, Kansas.
Dennis Brinkman, District Conservationist, NRCS, Topeka, Kansas.
Ken Hoffman, ASTC(FO), NRCS, Manhattan, Kansas.

U.S. Department of Agriculture

FARMLAND CONVERSION IMPACT RATING

PART I (To be completed by Federal Agency)	Date Of Land Evaluation Request: August 15, 2006
Name Of Project: Topeka Levees	Federal Agency Involved: U.S.A.C.E Kansas District
Proposed Land Use: Borrow areas for fill	County And State: Shawnee County, KS
PART II (To be completed by NRCS)	Date Request Received By NRCS: 8/22/06

Does the site contain prime, unique, statewide or local important farmland? (If no, the FPPA does not apply -- do not complete additional parts of this form).	Yes ☑ No ☐	Acres Irrigated: 7,900	Average Farm Size: 276 Ac.
Major Crop(s): Corn - Soybeans	Farmable Land In Govt. Jurisdiction Acres: 111,900 % 31.5	Amount Of Farmland As Defined in FPPA Acres: 154,600 % 43.5	
Name Of Land Evaluation System Used: LESA	Name Of Local Site Assessment System: --	Date Land Evaluation Returned By NRCS: 8/28/06	

PART III (To be completed by Federal Agency)	Maximum Points	Site A	Site B	Site C	Site D
A. Total Acres To Be Converted Directly		43.0	98.0	138.0	364.0
B. Total Acres To Be Converted Indirectly					
C. Total Acres In Site		0.0 43.0	0.0 98.0	0.0 138.0	0.0 364.0
PART IV (To be completed by NRCS) Land Evaluation Information					
A. Total Acres Prime And Unique Farmland		6.0	55.0	41.0	0
B. Total Acres Statewide And Local Important Farmland		37.0	43.0	97.0	364.0
C. Percentage Of Farmland In County Or Local Govt. Unit To Be Converted		<1	<1	<1	<1
D. Percentage Of Farmland In Govt. Jurisdiction With Same Or Higher Relative Value		78	43	78	100
PART V (To be completed by NRCS) Land Evaluation Criterion Relative Value Of Farmland To Be Converted (Scale of 0 to 100 Points)		0 14	0 56	0 33	0 0
PART VI (To be completed by Federal Agency) Site Assessment Criteria (These criteria are explained in 7 CFR 658.5(b)	Maximum Points				
1. Area In Nonurban Use	15	7	13	14	5
2. Perimeter In Nonurban Use	15	9	6	0	8
3. Percent Of Site Being Farmed	20	5	0	20	0
4. Protection Provided By State And Local Government	20	0	0	0	0
5. Distance From Urban Builtup Area	15	5	5	5	5
6. Distance To Urban Support Services	15	0	0	0	0
7. Size Of Present Farm Unit Compared To Average	10	0	0	0	0
8. Creation Of Nonfarmable Farmland	10	0	0	0	0
9. Availability Of Farm Support Services	5	0	0	1	0
10. On-Farm Investments	20	2	0	5	0
11. Effects Of Conversion On Farm Support Services	10	1	1	5	0
12. Compatibility With Existing Agricultural Use	10	0	0	0	0
TOTAL SITE ASSESSMENT POINTS	160	0 29	0 25	0 50	0 18
PART VII (To be completed by Federal Agency)					
Relative Value Of Farmland (From Part V)	100	0 14	0 56	0 33	0 0
Total Site Assessment (From Part VI above or a local site assessment)	160	0 29	0 25	0 50	0 18
TOTAL POINTS (Total of above 2 lines)	260	0 43	0 81	0 83	0 18

Site Selected:	Date Of Selection	Was A Local Site Assessment Used? Yes ☐ No ☐

Reason For Selection:

(See instructions on reverse side) Form AD-1006 (10-83)

This form was electronically produced by National Production Services Staff

Reynolds, Lekesha W NWK

From: Davis, Nate [nated@wp.state.ks.us]
Sent: Friday, June 01, 2007 2:08 PM
To: Reynolds, Lekesha W NWK
Subject: Topeka Flood Damage Reduction Project

KDWP Track: 20070264 CO: SN Ref: D1.1103
upgrades to levee system surrounding Topeka

Ms. Reynolds,

Impacts to state-listed species should not be significant; however, we recommend mitigation of the 7 acres of woodlands that will be impacted along the South Topeka Unit. Please feel free to contact our office for recommendations on where & how to implement effective mitigation.

Thank you,

Nate Davis
Ecologist;KDWP,Environmental Services Section;512 SE 25th Ave,Pratt,KS 67124
620.672.0795 (O)620.450.8311 (C),nated@wp.state.ks.us
http://www.kdwp.state.ks.us/news/other_services/threatened_and_endangered_species

Reynolds, Lekesha W NWK

om:	Susan_Blackford@fws.gov
nt:	Tuesday, May 29, 2007 1:20 PM
o:	Reynolds, Lekesha W NWK
Cc:	Mike_LeValley@fws.gov; Susan_Blackford@fws.gov
Subject:	Re: T& E coord. For Topeka FR Prj
Attachments:	USFWS coord. T_E species.doc

USFWS coord. T_E species.doc (...

To: Lekesha Reynolds, Corps of Engineers, Kansas City District
From: Susan Blackford, U.S. Fish and Wildlife Service
Date: May 29, 2007

In accordance with section 7(c) of the Endangered Species Act (16 U.S.C. 1531 et seq.), and based on the information presented to the Service to date, we agree with your determination that there should be no adverse impacts to Federally listed threatened and endangered species from the Topeka Flood Damage Reduction Study (previously called the Topeka Local Flood Protection Project).

Susan Blackford
U.S. Fish and Wildlife Service
2609 Anderson Ave.
Manhattan, KS 66502
785-539-3474 ext. 102
Susan_Blackford@fws.gov

"Reynolds, Lekesha W NWK" <Lekesha.W.Reynolds@nwk02.usace.army.mil>

05/18/2007 08:52 AM

To <mike_LeValley@fws.gov>

cc <susan_blackford@fws.gov>

Subject T& E coord. For Topeka FR Prj

Hi Mike

Please see the attached memo. The map was too large to email. Susan has a hardcopy map. If not I can mail more.
If you have any questions, please call me.

Please respond as soon as possible, but no later than May 31st.

hanks,

Lekesha W. Reynolds
Corps of Engineers

KSR&C No. 06-07-001

KANSAS

Kansas State Historical Society
Jennie Chinn, *Executive Director*

KATHLEEN SEBELIUS, GOVERNOR

August 25, 2006

Timothy Meade
Cultural Resource Manager
Kansas City District, Corps of Engineers
700 Federal Building
Kansas City, Missouri 64106-2896

RE: Possible Borrow Locations
Levee Construction Along the Kansas River
Shawnee County

Dear Mr. Meade:

In accordance with 36 CFR 800, the Kansas State Historic Preservation Office has examined its cultural resources files and has reviewed your letter (dated August 2, 2006) describing plans for borrow areas associated with improvements to the levee system in Topeka and North Topeka in Shawnee and Jefferson Counties. The proposed borrow areas are all situated between the existing levees and the Kansas River. This area has little potential for archeological sites and as you have pointed out, has been subjected to considerable recent disturbance. We therefore concur with the conclusion that use of the proposed borrow areas during the levee construction project will have no effect on historic properties as defined in 36 CFR 800. This office has no objection to use of the proposed borrow areas.

Any changes to the project, which include additional ground disturbing activities, will need to be reviewed by this office prior to beginning construction. If construction work uncovers buried archeological materials, work should cease in the area of the discovery and this office should be notified immediately.

This information is provided at your request to assist you in identifying historic properties, as specified in 36 CFR 800 for Section 106 consultation procedures. If you have questions or need additional information regarding these comments, please contact Tim Weston at 785-272-8681 (ext. 214).

Sincerely,

Jennie Chinn, Executive Director and
State Historic Preservation Officer

Timothy Weston

Patrick Zollner
Deputy SHPO

6425 SW Sixth Avenue • Topeka, KS 66615-1099
Phone 785-272-8681 Ext. 205 • Fax 785-272-8682 • Email jchinn@kshs.org • TTY 785-272-8683
www.kshs.org

Appendix C.

U.S. Fish and Wildlife Service Coordination Act Report

City of Topeka, Kansas
Flood Risk Management Study
Environmental Assessment

United States Department of the Interior

FISH AND WILDLIFE SERVICE
Kansas Ecological Services Office
2609 Anderson Avenue
Manhattan, Kansas 66503-6172

March 16, 2007

Dr. Christopher White
U.S. Army Corps of Engineers, Kansas City District
Rm 843, PM-PR
601 E. 12th Street
Kansas City, MO 64106

Dear Dr. White:

Enclosed is our Final Fish and Wildlife Coordination Act Report for the Topeka Local Flood Protection Project (Topeka, Kansas). This FCAR was prepared in accordance with provisions of the Fish and Wildlife Coordination Act (16 U.S.C. 661 et seq.). It constitutes the report of the Secretary of the Interior on the project within the meaning of Section 2 (b) of this Act.

This report is intended to accompany the U.S. Army, Corps of Engineers Environmental Assessment on the proposed project.

Please note the following changes in the FCAR from the Draft CAR.

* Recommendations 2 and 4 have been modified.

* Recommendation 9 has been added.

*A short discussion of the woodland and native vegetation impacts at the South Topeka Unit underseepage berm and the proposed mitigation areas has been added to the Executive Summary and Introduction sections.

*Expanded the discussion of the importance of native vegetation in the Terrestrial Resources Section (page 6).

*The Fish and Wildlife Resources With the Project has been modified to reflect the new recommendation #9 (page 21).

*The Invasive Species Best Management Practice recommendation has been modified. This is located under the Mitigation Discussion Section (page 23).

We are also transmitting a copy of this Final report to the Kansas Department of Wildlife and Parks for review and have requested a letter of concurrence if they generally agree with our report. We will forward their letter of concurrence upon receipt for incorporation within our report as an appendix.

If you have any questions concerning this final report, please contact Ms. Susan Blackford, of my staff, at 785 539-3474 ext. 102.

Sincerely,

Michael J. LeValley
Field Supervisor

Enclosure

MJL/shb

FINAL FISH AND WILDLIFE COORDINATION ACT REPORT FOR THE TOPEKA, KANSAS LOCAL FLOOD PROTECTION PROJECT

PREPARED FOR THE

The Kansas City District
U.S. Army Corps of Engineers
Kansas City, Missouri

Prepared by

U.S. Fish and Wildlife Service
Kansas Ecological Services Field Office
Manhattan, Kansas
March, 2007

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LIST OF FIGURES

EXECUTIVE SUMMARY

The Kansas River flood of 1993 caused flood damage to industrial and other properties inside the Topeka, Kansas Local Flood Protection Project (Topeka LFPP) levees due to internal runoff and seepage. The existing levees and other flood protection works provide protection for about the 100-year event. The proposed improvements consist of land side underseepage berms, manhole foundation heel extensions, fill behind floodwalls, new pressure relief wells, gatewells, sluice gates, and floodwall replacements. The Fairchild Pump Station will be abandoned in place. As part of the abandonment, the Corps will remove the above grade structure and fill the below-grade structure and outlet lines with flowable fill. The Madison Street Pump Station will be removed and replaced. No concerns were identified in the Soldier Creek or Auburndale Units. The South Topeka Unit underseepage berm potentially would have the greatest impacts. The work for this unit will impact approximately 5 acres of woodland habitat landward of the levee for construction of the underseepage berm. This loss of woodland habitat is proposed to be mitigated at the borrow/mitigation area west of the North Topeka Unit which would restore approximately 10 acres of cropland and bare ground to a woodland riparian area with native trees, shrubs, and grasses.

Riparian vegetation is the only significant resource anticipated to be impacted by the proposed flood control work. The few, remaining areas of native vegetation represent valuable wildlife habitat. There are many areas of cropland in close proximity to the project sites, including within some of the proposed borrow sites. Areas of native vegetation should be avoided if possible or mitigated.

RECOMMENDATIONS

1. Riparian and wetland habitats should be avoided to the maximum extent practicable when selecting borrow sites for the proposed levee improvements. Compensatory mitigation should be undertaken for unavoidable impacts. Since channelization, levee construction and floodplain development have already resulted in dramatic loss of riparian and wetland habitats in the Kansas River basin within the project area, the Corps should focus on bare or cropland areas for borrow.

2. Levees and levee easements should be seeded with native, warm-season grasses such as buffalo grass (*Buchloe dactyloides*). Buffalo grass is a drought tolerant, perennial, native, turf grass that reaches a height of 8 – 10 inches.

3. The Corps should create wetland mitigation habitat to compensate for the loss of wetland acreage from construction of the projects in accordance with the FWS Region 6 Wetland Mitigation Guidelines, generally at a minimum of 1.5:1 ratio for emergent wetland and at a 2:1 ratio for forested wetland. If farmed wetland is directly impacted by borrow activities it should be mitigated at a 1.0 to1.0 ratio.

4. Removal of woodlands and other native vegetation should be avoided where possible. If avoidance if not possible a mitigation plan should be developed in coordination with the U.S. Fish and Wildlife Service (Service), Environmental Protection Agency (EPA), and the Kansas Department of Wildlife and Parks (KDWP). Woody vegetation and native grasses should be replaced by establishing two acres of native vegetation for every acre impacted.

5. Best Management Practices to prevent the transport of invasive species to or from the construction sites should be included as an integral component of the project.

6. Establish native vegetation riverward of levee segments where riparian woodlands are sparse or nonexistent or where invasive species, e.g. reed canary grass, have become established.

7. All disturbed areas should be immediately planted with native vegetation following construction to prevent erosion and the establishment of invasive species.

8. The potential use of borrow sites for wetland and aquatic habitat enhancement and public recreation should be investigated with the project sponsors and borrow site owners. The City of Topeka is interested in developing a greenway and public access to the Kansas River within the project limits.

9. If possible, establish mitigation areas prior to the onset of impacts from the project to lessen the impacts to wildlife from habitat loss.

INTRODUCTION

This Final Fish and Wildlife Coordination Act Report (FCAR) is submitted pursuant to the Fish and Wildlife Coordination Act (16 U.S.C. 661 et seq.), and the fiscal year 2005 Scope-of-Work Agreement between the U.S. Fish and Wildlife Service (Service) and the U.S. Army Corps of Engineers, Kansas City District (Corps) for the City of Topeka Local Flood Protection Project, Shawnee County, Kansas (LFPP). The FCAR is designed to accompany and is to be incorporated into the Corps' Environmental Assessment on the proposed project. The Service has previously provided a draft Planning Aid Letter (PAL) dated August 29, 1997, a final PAL dated September 4, 1997, and an update to the final PAL dated December 15, 2005.

This study was authorized under authority of Section 205 of the Flood Control Act of 1948, as amended.

Following the flood of 1951, that caused approximately $34,000,000 in damages, an extensive array of eight principal units were built to protect Topeka against future floods. Construction features include some 41.6 miles of levees, over 1,000 feet of flood wall, riprap of levees, five separate systems of relief wells, 17.1 miles of modified channels, 11 pumping plants to take care of interior drainage and relief well discharge, four railroad bridges, and major alterations to two Kansas River railway bridges. Construction of project features required extensive alteration of Topeka's' existing street and highway bridges. The cost of constructing all complete units of the Topeka LFPP was about $21,175,000 Federal and $10,383,000 non-Federal. In addition to the local protection project, the city is now protected by an array of upstream Federal flood control reservoirs on tributaries to the Kansas River Basin. Projects that have come on-line since 1951 include Tuttle Creek Reservoir, Milford Reservoir, Wilson Reservoir, and Glen Elder Reservoir.

The present identified flood problems that surfaced after the flood of 1993 include flood damage to industrial and other properties and damage inside the levees caused by internal runoff and seepage. The existing levees and other flood protection works provide protection for about the 100-year event.

Issues identified in the Topeka LFPP consist of geotechnical and structural concerns. Geotechnical concerns are related to underseepage beneath the levee which may occur during high flow events. If underseepage is allowed to surface on the land side uncontrolled during a flood, it can create a failure of the levee foundation by piping. Underseepage pressures can be countered using either underseepage berms (additional soil placed on the ground surface) to prevent flow to the surface, or by pressure relief wells that provide a controlled path for the underseepage. Berms are usually the preferred method based on lower installation cost and maintenance needs, but require more real estate for installation and borrow areas. In locations where real estate is not available, relief wells can be installed.

Structural concerns are generally related either to uplift pressures or stability weaknesses. Similar to underseepage, uplift pressures are caused by high water on one side of the levee and can severely affect those underground structures located near the levee. This includes manholes, pump stations, and drainage structures (gatewells, sluice gates, and pipes). The easiest method to counter uplift pressures is by installing heel extensions to the structure in question, which is essentially the pouring of a concrete collar around the base of the structure. This may require extensive excavation around the structure. If the structure cannot be sufficiently modified to counteract the pressures, it would need to be replaced, or if no longer a necessary part of the protection system, abandoned.

Stability concerns have been identified at several of the concrete floodwall and closure gap structures. The direct pressure of high water on one side of the structure during a flood may cause either sliding, overturning, or breaking of the structure. The primary method to counter this concern is the installation of a stability berm on the land side of the structure to provide additional support. Structures that cannot be corrected using stability berms require replacement.

No new levees have been proposed for this project. The proposed improvements consist of land side underseepage berms, manhole foundation heel extensions, fill behind floodwalls, new pressure relief wells, and gatewell, sluice gate, and floodwall replacements. The Fairchild Pump Station will be abandoned in place, with removal of the above grade structure and filling of the below-grade structure and outlet lines with flowable fill. The Madison Street Pump Station will be removed and replaced. No concerns were identified in the Soldier Creek or Auburndale Units. The Corps has estimated the amount of needed borrow to be in excess of 281,000 cubic yards.

The South Topeka Unit underseepage berm potentially would have the greatest impacts. The work for this unit will impact approximately 5 acres of woodland habitat landward of the levee for construction of the underseepage berm. This loss of woodland habitat is proposed to be mitigated at the borrow/mitigation area west of the North Topeka Unit which would restore approximately 10 acres of cropland and bare ground to a woodland riparian area with native trees, shrubs, and grasses.

Most of the borrow will be used to construct underseepage and stability berms. Work concerning manholes, pump stations, and floodwalls will occur in previously disturbed areas and, for the most part, urbanized areas and will require little, if any borrow. The only alternatives identified by the Corps for the project is the source of borrow. The alternatives consist of 1) the use of up to four possible borrow areas in close proximity to levee areas which will need borrow or 2) the use of commercially obtained borrow.

DESCRIPTION OF THE STUDY AREA

The project is located in Topeka, Shawnee County, Kansas, in the northeastern part of the State. The project area encompasses levees on both sides of the Kansas River beginning just east of the sewage treatment plant to the western edge of Topeka near North Highway 75 (approximate River Miles 77.6 to 88.6) (Figure 1).

Topeka is the State Capitol with a US Census 2000 estimated population of 122,377 (Retrieved September 7, 2006 from http://topeka.areaconnect.com/statistics.htm). Topeka is located on the banks of the Kansas River about 84 miles above the junction with the Missouri River. The total drainage area of the Kansas River basin above Topeka is approximately 56,720 square miles. Mean annual discharge is approximately 5,871 cfs. The river flows west to east through the center of the city. Although much of the City south of the river is above flood heights, important railroad and industrial developments, the municipal water works, a sewage treatment plant, and the municipal airport are located on the 3,300-acre flood plain along the south bank of the river. Shunganunga Creek and its tributary Deer Creek are the primary tributaries draining south and southwestern Topeka. Shunganunga Creek enters the Kansas River just to the east of Philip Billard Airport. The north Topeka area, consisting of approximately 5,100 acres, includes business, residential, industrial, and specialized farm developments. Three tributaries enter the Kansas River within this area. They are Soldier, Halfday, and Indian Creeks.

The levees were built close to the Kansas River constricting its floodplain and limiting the amount of riparian habitat. In many areas the levees were built near the top of the banks of the river. At one of the narrowest points near downtown Topeka, the area between the levees on opposite sides of the Kansas River is less than one-half mile wide. The areas between the river and levees contain much of the remaining available wildlife habitat in the project area. The proposed borrow areas are located between the levees and the river as close as possible to the work sites. The Corps is proposing four borrow areas labeled as Waterworks/North Topeka borrow area, South Topeka borrow area, East Oakland and West Oakland borrow area. As an alternative, the Corps is also evaluating the use of commercially obtained borrow in which the source may be from river dredging.

The Soil Survey, Shawnee County, Kansas (USDA 1970) identifies the primary soil associations of the project area as the Eudora-Muir, Martin-Sogn, and Pawnee-Shelby-Morrill associations. Most of the proposed borrow areas occur in the Eudora-Muir association which is deep, well-drained or moderately well drained soils that have a clay or clay loam subsoil on benches in the Kansas River Valley. The other two soil associations are described in the same manner except they are found on uplands.

Terrestrial Resources

Most of the vegetation in the study area has been greatly impacted by urban development and agricultural land clearing. The major land use of the project area is urban, with cropland being the second major land use (Figure 2). There are a few small patches of native prairie in or near the project area and pockets of riparian woodlands. The area between the levees, which includes the Kansas River, contains much of the remaining wildlife habitat. The remaining areas of native vegetation provide vital habitat for local wildlife, and migrating songbirds. The lack of native vegetation is a limiting factor for the populations of these species. As the establishment of native vegetation may take years, or even decades for woodlands, the removal of existing areas may cause further declines in the numbers of individuals and the numbers of species that are dependent on these areas. Mitigating the loss of these areas at a 2:1 ratio offers some compensation for the temporal loss of habitat and allows space for planting an a greater number of trees than were removed in acknowledgment that many of those planted will not survive to maturity.

The Kansas River provides important habitat for wildlife in an area in which the primary landcover types are urban and agricultural. The river provides waterfowl and shorebird resting feeding, and staging areas during migration. In spring and summer, sandbars and islands provide protected feeding and potential nesting sites for Canada geese and shorebirds. Stream banks provide habitat for bank swallows, belted kingfishers, beaver, and muskrat. Many riparian areas are sparsely vegetated with "weedy" annuals or mowed grass.

In a few areas the riparian vegetation is more robust consisting of native tree species like cottonwood, willow, sycamore, American elm, and maple, along with grasses, shrubs, and herbaceous species. These riparian areas provide food and cover for many neotropical migrant birds, and wintering habitat for the bald eagle. Currently, riparian woodlands in the project area consist mainly of small pockets of trees riverward of the levees.

The riparian woodland that remains along the Kansas River is the highest quality habitat in the Topeka area. It offers the greatest vegetative diversity and degree of interspersion with other habitat types, which is important to many wildlife species. Additionally, riparian woodlands are important for preventing streambank erosion; intercepting sediments and pollutants before entering streams; providing shade and leaf detritus to the stream; and providing recreational opportunities through fishing, nature study, and wildlife observation.

White-tail deer, raccoons, and other wildlife also use riparian habitats. Linear corridors of habitat, such as that found along the Kansas River, allow animals to disperse throughout their ranges, preventing genetic isolation and allowing the reestablishment of populations in areas, like Topeka, where wildlife may have been eliminated in the past.

As indicated previously, Soldier and Shunganunga creek have been channelized and contained within a levee system within north and south Topeka respectively. The new channels were cut through agricultural fields and the raw earth of the new levee banks and stream channel were planted to grasses. There are a few individual trees on the banks of the stream but no area remains that would qualify as riparian woodland.

Reptiles, amphibians and birds are the local wildlife most likely to be impacted from the project with most of the impacts due to the taking of borrow.

Thompson and Ely (1989) report that 424 bird species have been recorded in Kansas. The state's central location is an important contributing factor to this large species count, containing both eastern deciduous forest and the central grasslands and it is on a major flyway. Kansas is also a wintering area for far-northern birds, as well as a breeding area for typically southern species. Our major rivers funnel in stragglers from the Rocky Mountains. Many migratory songbird species are dependent on woodlands, and especially riparian woodlands, for food, shelter, and raising of young. As a prairie state, bird species dependent on grasslands are predominant in Kansas. However, as a group, grassland birds are declining at a faster rate than any other group of birds in North America.

Reptiles and amphibians found in Shawnee County include the tiger salamander, plains spadefoot, American toad, Woodhouse's toad, Blanchard's cricket frog, western chorus frog, gray treefrog, plains leopard frog, bullfrog, plains narrowmouth toad, common snapping turtle, ornate box turtle, western painted turtle, red-eared slider, midland smooth softshell turtle, western spiny softshell turtle, ground skink, five-lined skink, great plains skink, prairie skink, prairie-lined racerunner, western worm snake, prairie ringneck snake, rough green snake, eastern yellowbelly racer, black rat snake, bullsnake, prairie kingsnake, common kingsnake, milk snake, red-sided garter snake, lined snake, Texas brown snake, Graham's crayfish snake, northern water snake, copperhead, massasauga, and timber rattlesnake.

Aquatic Resources

Aquatic resources of the area consist of the Kansas River and the north or left bank tributary stream Soldier Creek and the right bank tributary Shunganunga Creek to the south. The quality of these streams varies according to a number of factors.

Ninety-nine species of fish inhabit the Kansas River basin of which at least 19 are probably introduced, non-native species. The distribution and abundance of most species have changed markedly in this century in response to reservoir construction and land use changes. Cross and Collins (1995) state that species found in the lower Kansas River and within the immediate area of Topeka are gizzard shad, bigmouth buffalo, black buffalo, shorthead redhorse, channel and flathead catfish, freshwater drum, longnose gar, shortnose gar, river carpsucker, silver chub, speckled chub, emerald shiner, red shiner, sand shiner, goldeye, plains minnow and common carp (an introduced species), shovelnose sturgeon, American eel, speckled chub, western silvery minnow, sturgeon chub, creek chub, blue sucker, green sunfish, orangespot sunfish, largemouth bass, white crappie, and orangethroat darter. A Kansas State University fish survey of the Kansas River between River Miles 75 and 79 found most of the above fish. The dominant species found during the survey were river carpsucker, red shiner, sand shiner, and western mosquitofish. In addition, the survey found two species, the blue sucker and the quillback, that are listed as State of Kansas Species in Need of Conservation (SINC) (Craig Paukert, pers. comm., September 25, 2006).

In a 1977 report, Kansas River Basin, Kansas, Preliminary Stream Survey, by the Kansas Forestry, Fish and Game Commission, angler utilization from approximately Junction City to Kansas City was 29,909 angler days per year. With increasing population during the last 20 years within the river corridor from Junction City to Kansas City, recreation and angler days have, no doubt, also increased.

The proposed flood control improvements will take place within a reach of the Kansas River identified by the Kansas Water Authority in the 1992 State Water Plan, as suitable for development, management, and promotion for its recreational opportunities. The river that divides Topeka, however, is under utilized by the resident population. This may be due, in part to a lack of adequate access or development of park lands riverward of the flood control levee system. Several boat launching facilities and fisherman-access sites have been constructed along the Kansas River in recent years. One access site, named the Topeka Seward Avenue Kaw River Access, has been developed in the project area. Boating use of the river through the Topeka area is problematic due to the hazard presented by the Topeka Low Head Dam. Portage around this hazard is difficult.

Soldier Creek, a north bank tributary, joins the Kansas River at Topeka. The narrow watershed of approximately 157 square miles, traverses southern Nemaha, Jackson, and northern Shawnee Counties flowing in a south-southeasterly direction. Approximately one half of the present Pottawatomie Indian Reservation lies in the lower Soldier Creek Basin.

The mainstem of Soldier Creek has been extensively altered in the lower reach for flood control purposes. An extensive array of levees, channelization and other stream alteration work has been completed but stream degradation caused by these stream alterations has persisted. The channel degradation, which includes both widening and deepening of the stream channel through erosion, has slowly moved upstream endangering roads, bridges, and railroads and destroying much of the remaining stream-side vegetation. In response to the degradation, grade control structures have been installed, to help slow down and perhaps stop the severe erosion, scouring, silting, and water quality degradation that has occurred.

Shunganunga Creek originates approximately 2.5 miles west of Sherwood Lake. From Sherwood Lake it flows northeasterly across the city of Topeka, and joins the Kansas River about 2.25 miles east of the city. West of Topeka, the banks are heavily wooded with mature trees and mixed shrubs. From 15th street east, the channelized banks are devoid of trees, but include a fair cover of mixed weeds and grasses. Land use of this watershed is estimated to be 95% urban development. The remaining five percent is cultivated to primarily milo and soybeans. Urbanization and channelization have made most of the area inaccessible or unattractive for fishing.

Soldier and Shunganunga Creek have been classified as moderate fishery resource (Value Class III) by the Kansas Department of Wildlife and Parks, (formerly the Kansas Fish and Game Commission). There are several important game fish present in these streams including catfish, crappie, and walleye. Due to channelization, these streams have shallow water, steep mud banks, and very little diversity within the city limits. In this lower reach most fishing is confined to backwater areas of the Kansas River at the mouth of each stream. In its upper reach Soldier Creek still supports specialized species including stoneroller, bluntnose minnow, sand shiner, and slender madtom.

Wetlands

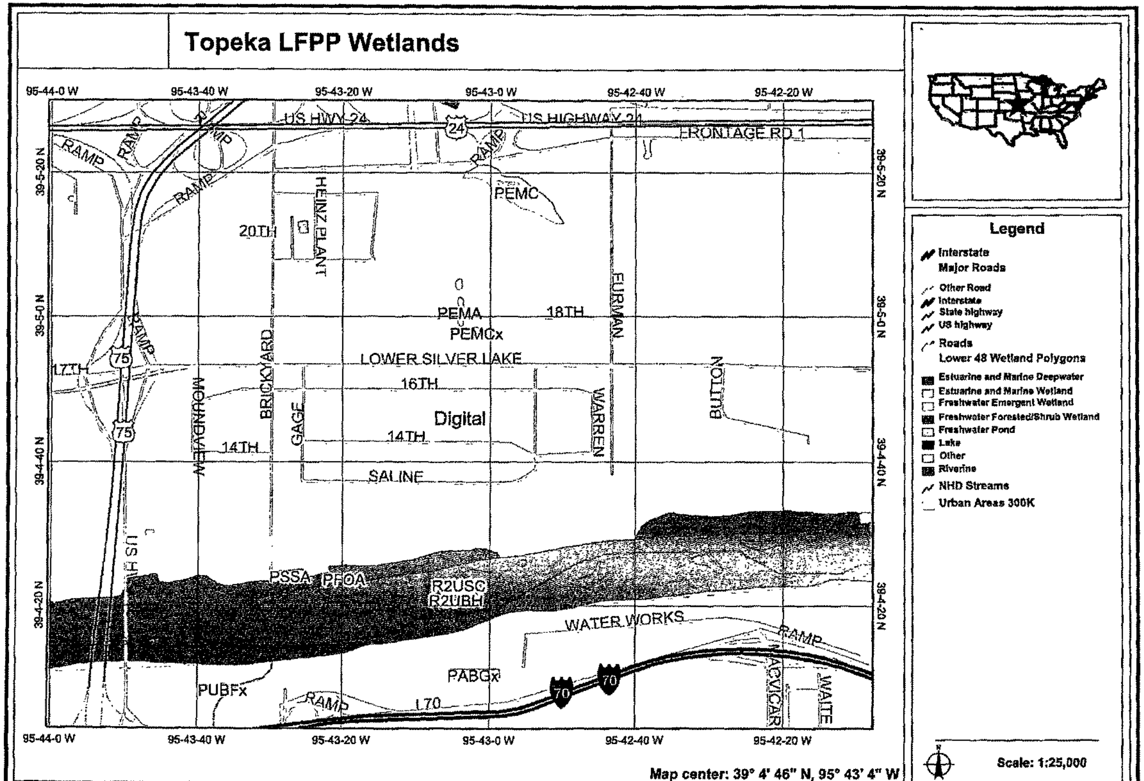
Wetlands on the Kansas River floodplain in close proximity to Topeka are small and contain water seasonally. During drier years most wetlands are farmed. Therefore, vegetation diversity is relatively low and consists mostly of annual species such as smartweed and foxtail barley. These wetlands are important for the production of invertebrates and serve as habitat for amphibians. When not cropped, they provide habitat for cottontail rabbit, ring-neck pheasant, and many non-game animals. Wetlands are present in the cut-off remnants of the old Soldier Creek and Shunganunga Creek channels. These wetlands consist of narrow linear habitats with prairie cordgrass, smartweed, switchgrass, and cattails in the wettest areas. Remnants of the riparian woodlands that covered their banks also persist in a few areas, particularly the old channel of Shunganunga Creek on the Billard Airport grounds and at the mouth of the old Soldier Creek where it enters the Kansas River.

The National Wetland Inventory database indicates the existence of wetlands within the project area (Figures 3 – 8). Wetland impacts should be mitigated in accordance with the FWS Region 6, Wetland Mitigation Guidelines presented in the Mitigation Discussion section.

Federal Threatened and Endangered Species

Section 7 of the Endangered Species Act, 87 Stat. 884, as amended, requires Federal Agencies to ask the Secretary of the Interior, acting through the U.S. Fish and Wildlife Service, whether any listed or proposed endangered species may be present in the area of each Federal construction project. If the project may effect listed species, the Corps of Engineers should initiate formal Section 7 consultation with this office. If there will be no effect, or if the Fish and Wildlife Service concurs in writing that there will be beneficial effects, further consultation is not necessary.

There are three federally-listed species that may occur within the project area. The bald eagle (*Haliaeetus leucoccephalis*), federally-listed as threatened, frequents reservoirs and large rivers in Kansas during the winter months. Perry Reservoir (northeast of Topeka), Clinton Reservoir (southeast of Topeka), and the Kansas River also have nesting pairs of bald eagles, with parents and young remaining in the area throughout the spring and summer months. Eagles use large trees and snags in close proximity to water. If any trees at least 50 feet tall and/or 24 inches diameter at breast height (dbh) or 10 or more trees greater than 12 inches dbh are to be removed riverside of the levees, consultation with the Service may be required pursuant to section 7 of the Endangered Species Act (16 U.S.C. 1531 et seq.).



This map is a user generated static output from an Internet mapping site and is for general reference only. Data layers that appear on this map may or may not be accurate, current, or otherwise reliable. THIS MAP IS NOT TO BE USED FOR NAVIGATION.

Figure 3. Map includes the Waterworks Unit, North Topeka Unit, and the Waterworks-North Topeka Borrow/Mitigation Area

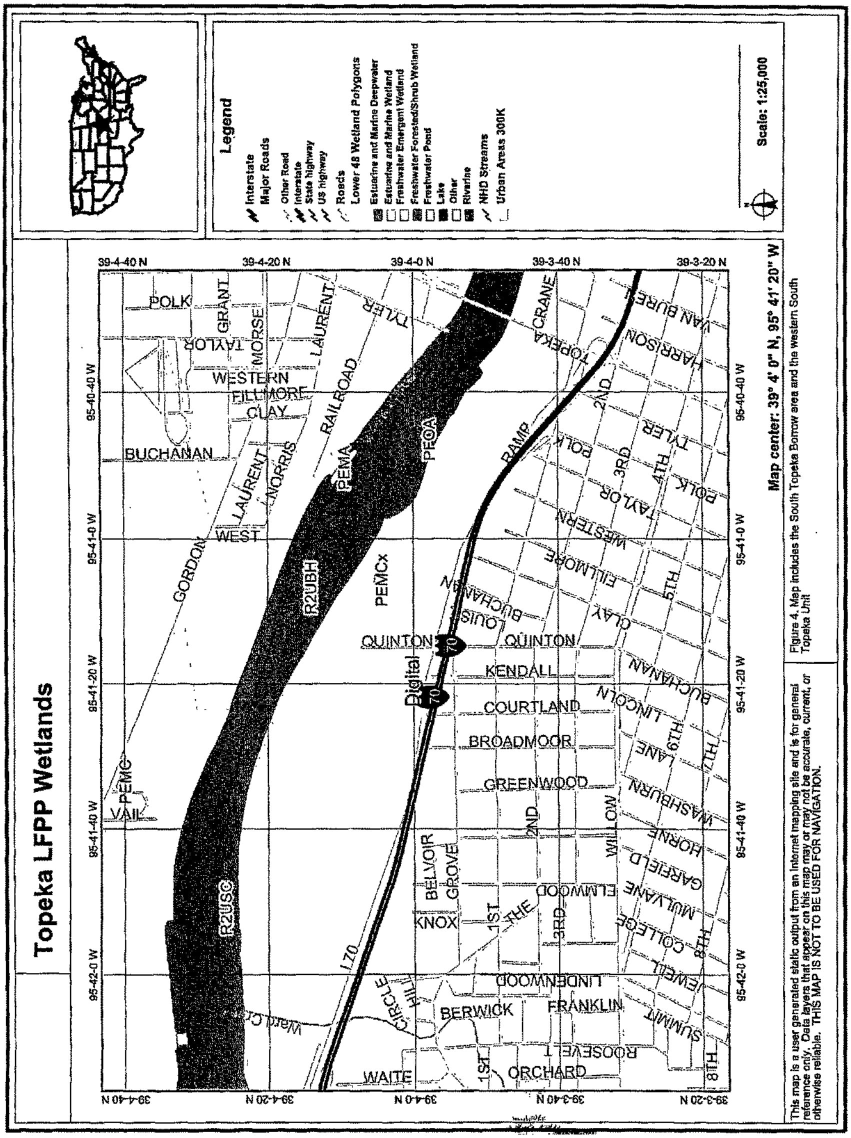


Figure 4. Map includes the South Topeka Borrow area and the western South Topeka Unit

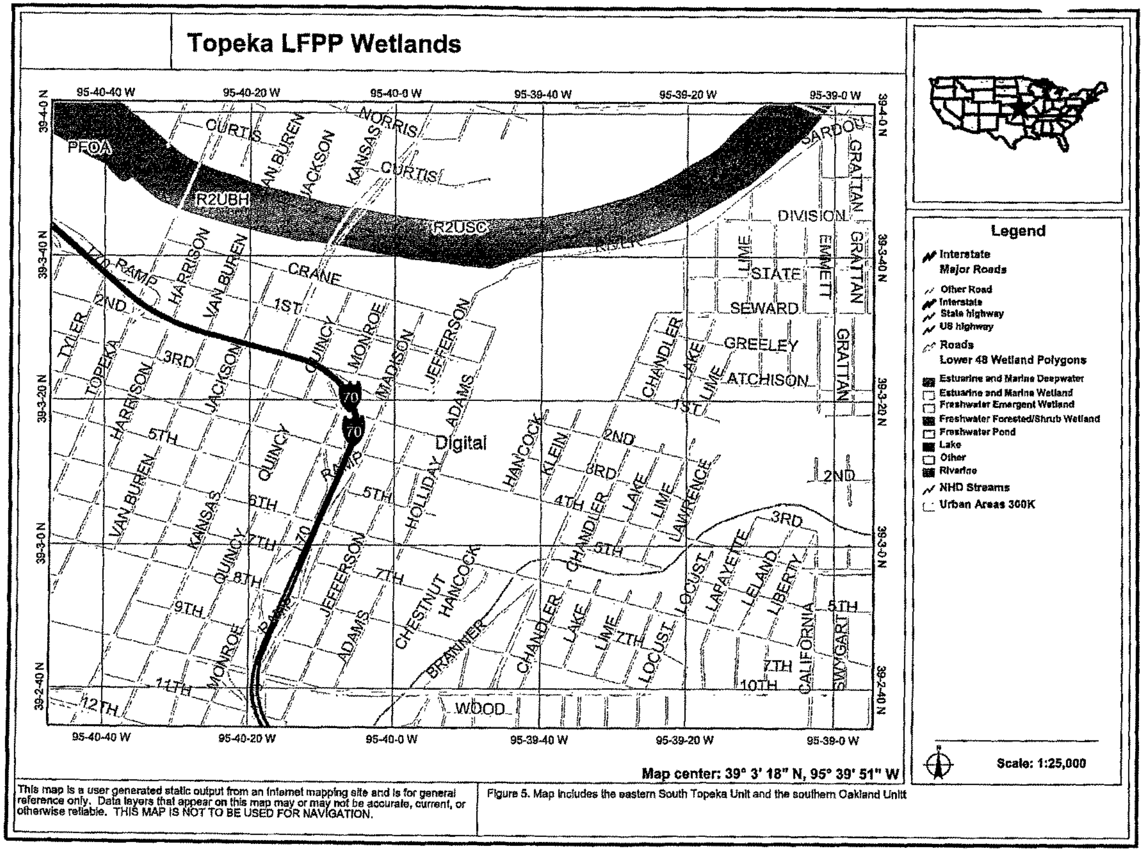


Figure 5. Map includes the eastern South Topeka Unit and the southern Oakland Unit

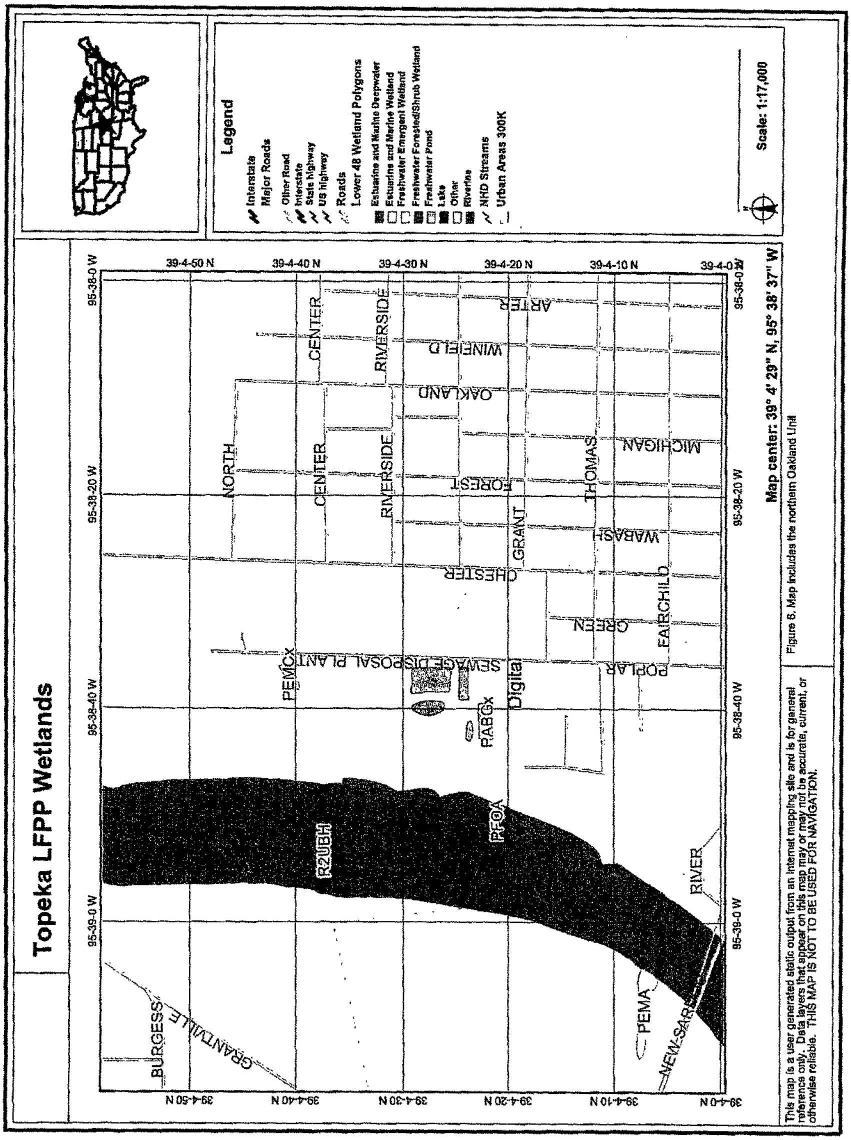
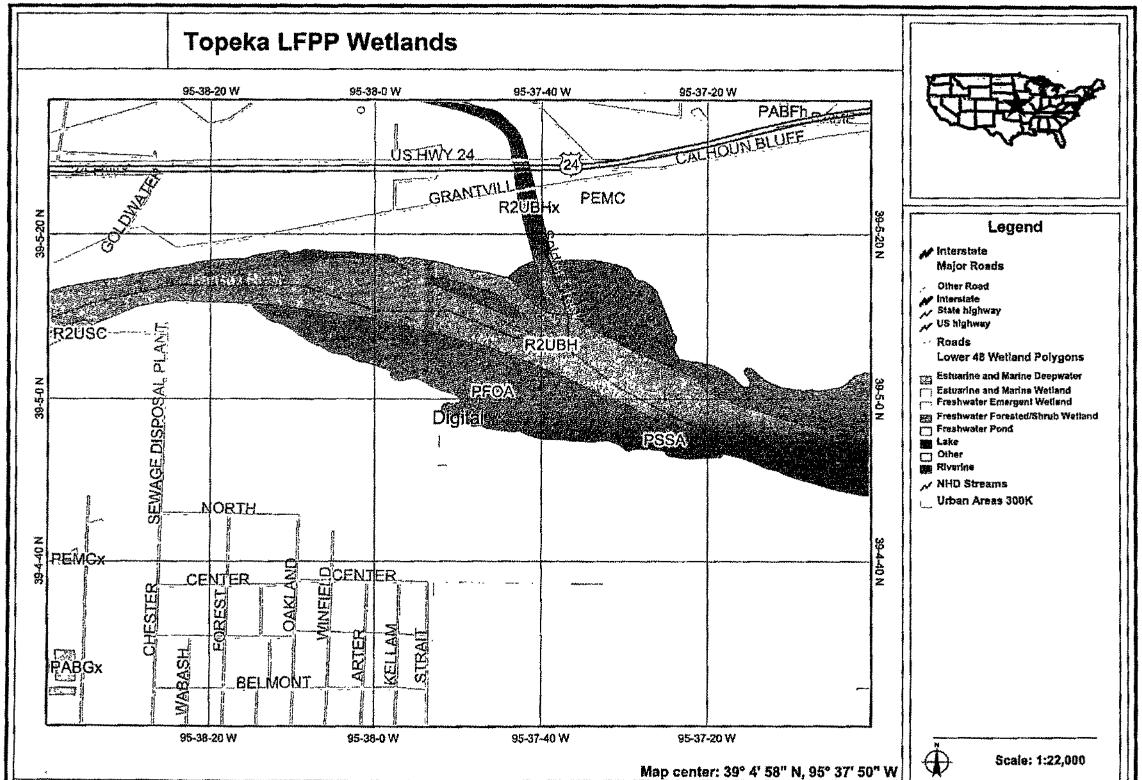


Figure 6. Map includes the northern Oakland Unit



This map is a user generated static output from an Internet mapping site and is for general reference only. Data layers that appear on this map may or may not be accurate, current, or otherwise reliable. THIS MAP IS NOT TO BE USED FOR NAVIGATION.

Figure 7. Map includes the western Oakland Borrow Area

In addition, if any project activity appears likely to harass or disturb any bald eagle observed at or near any construction site, this office should be notified prior to commencement of the activity, so that an assessment may be made of the potential for adverse impacts. An activity which harasses a bald eagle or any listed species and disrupts its normal breeding, feeding, or sheltering activities to the extent that harm or injury results is a prohibited taking under the Endangered Species Act.

The high flows on the Kansas River in July 1993 and in May 1995 caused many new high elevation sandbars on the Kansas River. This flood-induced habitat was attractive to piping plovers (*Charadrius melodus*), federally-listed as threatened, and least terns (*Sterna antillarum*), federally-listed as endangered. The first documented nesting of least terns and piping plovers was in 1996 and 1997, respectively (Busby 1997). This was the first nesting of piping plover ever recorded in Kansas and the first time least terns were known to nest along the Kansas River. Since 1998, nesting locations of these two bird species have been monitored throughout the breeding season to determine productivity of the species (Boyd 2005).

Our office has worked closely with the Kansas City District Corps of Engineers (Corps) to monitor nesting tern and plover colonies on the Kansas River. We are involved in water release decisions made by the Corps in an attempt to avoid direct take of active nests. Beginning in 1997, the Service's Kansas Field Office staff has conducted boat surveys of the upper Kansas River, searching for tern and plover nesting colonies. Currently, the tern and plover nests nearest to the Topeka LFPP area are at Kansas River Miles 109 and 65. However, suitable habitat exists in the Kansas River within the Topeka LFPP area.

The State of Kansas lists several species as threatened or endangered as occurring in Shawnee County that are also Federally-listed species. These include the American burying beetle, Eskimo curlew, whooping crane and Topeka shiner. While these species may occur in Shawnee County, suitable habitat for them is not present in the project area and therefore they have not been included in this Section.

Migratory Bird Treaty Act

Under the Migratory Bird Treaty Act (MBTA), construction activities in prairies, wetlands, stream, and woodland habitats, including the removal of upland borrow, and those that occur on bridges (e.g., which may affect swallow nests on bridge girders) that would otherwise result in the taking of migratory birds, eggs, young, and/or active nests should be avoided. Although the provisions of the MBTA are applicable year-round, most migratory bird nesting activity in Kansas occurs during the period of April 1 to July 15, although some migratory birds are known to nest outside this period. If the proposed project may result in the take of nesting migratory birds, the Service recommends a field survey during the nesting season of the affected habitats and structures to determine the presence of active nests. Our office should be contacted immediately for further guidance if a field survey identifies the existence of one or more active bird nests that cannot be avoided temporally or spatially by the planned activities.

State Listed Species

Kansas State Law (K.S.A. 32-504, 32-507: effective May 1, 1981) requires persons undertaking or sponsoring publicly funded or State or Federally Assisted action which is likely to impact endangered or threatened wildlife habitat where they are likely to occur, to obtain a project action permit from the Secretary of the Kansas Department of Wildlife and Parks (KDWP) prior to initiation of such action. In addition to the federally-listed threatened and endangered species, the State lists additional species that may be of concern within the project areas.

The KDWP maintains a list of State listed threatened and endangered species and species in need of conservation (SINC). The following list of species was retrieved September 22, 2006 from http://www.kdwp.state.ks.us/news/content/pdf/7035. As these lists are periodically updated, the Corps should contact KDWP directly for the most current information at Environmental Services Section, 512 SE 25th Ave, Pratt KS 67124-8174.

State-listed endangered species in Shawnee County include American burying beetle (*Nicrophorus americanus*), Eskimo curlew (*Numenius borealis*), least tern (*Sterna antillarum*), peregrine falcon (*Falco peregrinus*), silver chub (*Macrhybopsis storeriana*), and whooping crane (*Grus americana*).

State listed threatened species in Shawnee County includes bald eagle (*Haliaeetus leucocephalus*), eastern spotted skunk (*Spilogale putorius*), piping plover (*Charadrius melodus*), smooth earth snake (*Virginia valeriae*), snowy plover (*Charadrius alexandrinus*), sturgeon chub (*Macrhybopsis gelida*), and Topeka shiner (*Notropis topeka*). In addition, the State has designated critical habitat for the bald eagle along the Kansas River corridor and for the sturgeon chub in the Kansas River (Jim Hays, pers. comm.. Sept. 25, 2007).

SINC species listed for Shawnee County include black tern (*Chlidonias niger*), bobolink (*Dolichonyx oryzinvorus*), Cerulean warbler (*Dendroica cerulean*), golden eagle (*Aquila chrysaetos*), Henslow's sparrow (*Ammodramus henslowii*), plains minnow (*Hybognathus placitus*), short-eared owl (*Asio flammeus*), southern bog lemming (*Synaptomys cooperi*), southern flying squirrel (*Glaucomys volans*), tadpole madtom (*Noturus gyrinus*), timber rattlesnake (*Crotalus horridus*), whip-poor-will (*Camprimulgus vociferous*), and yellow-throated warbler (*Dendroica dominica*).

EVALUATION OF ALTERNATIVES CONSIDERED

Previous alternatives considered included 1-foot incremental heightening of the existing levee system at five of the eight levee units located along portions of the Kansas River and Soldier Creek. The units that were considered for levee improvements were the North Topeka, Oakland, Soldier Creek Diversion, South Topeka, and Waterworks. Levee height was proposed to be increased 1, 2, 3, 4, or 5 feet maximum with a corresponding widening of the levee base to accommodate the increase in height. The levee raises would have been accomplished on the landward-side whenever possible to maintain the present floodway cross-section.

The levee raise alternatives have not been brought forward and under the current proposal no new levees have been proposed for this project. The proposed improvements consist of land side underseepage berms, manhole foundation heel extensions, fill behind floodwalls, new pressure relief wells, and gatewell, sluice gate, and floodwall replacements. The Fairchild Pump Station will be abandoned in place, with removal of the above grade structure and filling of the below-grade structure and outlet lines with flowable fill. The Madison Street Pump Station will be removed and replaced. No concerns were identified in the Soldier Creek or Auburndale Units. The Corps has estimated the amount of needed borrow to be in excess of 281,000 cubic yards (cy).

The following is a list of the specific modifications proposed for the Topeka Levee system by unit and location.

Oakland Unit

- Station 64+00 to 80+00, install new land side underseepage berm. 6.5 feet of fill, 240 ft. wide, 70,000 cubic yards (cy) material.
- Station 75+50. Manhole requires foundation heel extensions to mitigate uplift pressures.
- Station 220+00. East Oakland Pump Station requires heel extensions to mitigate uplift pressures.
- Station 489+50. 2 ft. of additional fill required behind floodwall to meet sliding stability requirements.
- Station 489+81. 2 ft. of additional fill required behind floodwall to meet sliding stability requirements.

North Topeka Unit

- Approximately Station 165+00 to 189+00, install new land side underseepage berm. 7 feet of fill, 220 feet wide, 140,000 cy material
- Station 246+00 to 250+00 install new pressure relief wells. Need 6 wells spaced at 75 feet, each a length of 75 feet. The wells are to drain to a central manhole using a buried header system; the total discharge of the system is to be 1 cfs per well or 6 cfs total (2700 GPM). The drainage district will be required to pump the water down 1 foot below existing ground when the river is near the top of levee. A pad should be constructed on the slope for access. The railroad has a series of tracks just outside of the toe of the levee. Work may need to be done

inside of the footprint (temporary excavation for drilling access, header pipe system and manhole installation).

- Station 364+60. Fairchild Pump Station to be abandoned in place. Fill below-grade structure and outlet lines with flowable fill. Remove above-grade structure.

South Topeka Unit

- Approximately Station 22+00 to 48+00, install new land side underseepage berm. 5 feet of fill 100 feet wide, 71,000 cy material.

- Station 74+41 to 93+86. Remove and replace existing pile founded concrete floodwall.

- Station 69+22. Gatewell to be replaced as part of floodwall replacement.
- Station 75+62. Gatewell to be replaced as part of floodwall replacement.
- Station 86+09. Gatewell to be replaced as part of floodwall replacement.
- Station 86+55. Gatewell to be replaced as part of floodwall replacement.

- Station 16+07. Manhole requires heel extensions to mitigate uplift pressures.
- Station 84+10. Manhole requires heel extensions to mitigate uplift pressures.
- Station 84+10a. Manhole requires heel extensions to mitigate uplift pressures.
- Station 85+57. Manhole requires heel extensions to mitigate uplift pressures.

- Station 88+69. Riverside sluice gate to be replaced along with floodwall.
- Station 91+02. Riverside sluice gate to be replaced along with floodwall.

- Station 75+84. Install wall stiffener at Kansas Avenue Pump Station to meet required strength factor of safety.

- Station 86+00. Remove and replace Madison Street Pump Station.

Waterworks Unit

- Stations 0+78 to 7+00 and 10+00 to 16+50. 2 ft. of additional fill required behind floodwall to meet sliding stability requirements. Total of 1,272 linear feet of fill extending 5 feet out from floodwall centerline then tapered at a 1 on 3 slope.

- Stations 13+07 and 15+95. 2 ft. of backfill behind stoplog gap sidewalls to address sliding stability.

There are no concerns identified in the Soldier Creek or Auburndale Units.

The only alternatives under consideration concern the source of borrow. The Corps is considering the use of borrow from several sites riverward of the levees that would be in close proximity to the work sites or alternatively to use commercially obtained borrow.

If the Corps uses commercially obtained borrow it may likely come from permitted dredging operations in the Kansas River. Dredging for sand and gravel has been permitted on the Kansas River and in the recent past dredging operations were active near the project area. To address river bed degradation and other dredging-related impacts to the morphology and ecology of the river and impacts to other public and private interests the Corps implemented the Regulatory Plan for Commercial Dredging Activities on the Kansas River (1990). The Plan mandates that the maximum allowable reduction in the surface elevations of the riverbed is 2 feet for each reach of the river at which time it is termed a "dredged-out reach". At that point the dredging operation must move out of that particular river reach. Due to river bed degradation only one commercial dredger is still operating on the river in the Topeka area although another is seeking a permit to operate a dredge in another reach east of Topeka (Joshua Marx, COE, pers. comm.).

FISH AND WILDLIFE RESOURCES WITHOUT THE PROJECT

Much of the land in the project areas has been converted to urban uses and cropland. Existing wildlife habitat is scarce and generally low quality due to habitat fragmentation and replacement of native vegetation with non-native or low quality vegetation. We do not anticipate much change in land use, and therefore impacts to fish and wildlife resources, if the project does not occur.

FISH AND WILDLIFE RESOURCES WITH THE PROJECT

Grassland strips occurring on and adjacent to the levee and the toe would be temporarily impacted during construction grading, sloping, and grubbing for the seepage and stability berms. Impacts would be temporary but would cease to provide habitat to existing wildlife during project construction and for approximately two to three years after project completion or until the grassland vegetation is well established.

Riparian vegetation is the only significant resource anticipated to be impacted by the proposed flood control work. The few, remaining areas of native vegetation represent valuable wildlife habitat. Areas of native vegetation should be avoided. There are many areas of cropland in close proximity to the project sites, including within some of the proposed borrow sites. Work in the riparian areas area will displace wildlife that currently use the area due to disturbances from noise, dust, human activity, machinery and destruction of habitat. Depending on construction timing, this displacement could result in serious consequences to wildlife such as loss of reproduction and possible death of individual animals from accidents (crossing roads and unknown hazards in new areas), starvation, competition for other areas, etc. There is little refuge habitat in close proximity to the project area and available habitat is presumably at carrying capacity which further reduces the likelihood of wildlife surviving the displacement and intensifies the competition for the limited habitat available. Although the temporal displacement may be relatively short, the repercussions could be long-term. Impacts to migrating songbirds are of particular concern. Existing wildlife travel corridors linking the borrow areas and other areas of suitable floodplain upstream and downstream of the borrow area should be maintained during project construction. Establishment of mitigation areas prior to the onset of project construction would lessen the impacts to wildlife from habitat loss.

Construction activities would cause temporary, short-term impacts to fish and wildlife from noise, dust, and the presence of workers and machinery. Runoff from construction areas, access roads, staging areas and unprotected fills could degrade water quality inside the levee system. Accidental spills of fuels, lubricants, hydraulic fluids, and other petrochemicals would be harmful to aquatic life.

Remaining wetlands in the project area are few and relatively small. Impacts to these wetlands should be avoided. In addition, the removal of fill from cropland areas has the potential to cause the loss of farmed wetland. Farmed wetland should be delineated within the borrow site and should be avoided if possible. If an unavoidable loss is incurred, the quantity and quality of the farmed wetland will determine the amount of compensation necessary to offset project losses. The wetland mitigation plan would be developed in coordination with the Corps, EPA, and KDWP. This plan should include site locations, time frames, construction plans, a monitoring plan, progress reports, and standards of success. This plan should be a condition of any permit issued for the project. Borrow operations could be used to create wetlands or aquatic habitats. The potential for borrow sites to be designed to enhance habitat should be initiated with the project sponsors and borrow site owners. The completed plan should be implemented regardless of whether impacted wetlands are classified as jurisdictional for purposes of the Clean Water Act.

MITIGATION DISCUSSION

The Service has established a mitigation policy used as guidance in determining resource categories and recommending mitigation (46 FR: 7644-7663).

We have determined that most of the wildlife habitat that would be affected by the raising of existing levees (levee footprints and easements) is in Resource Category No. 4 (habitats of medium to low value). For this category, loss of habitat value should be minimized.

Forested wetland and riparian woodland are consistent with Resource category No. 2 that is, habitats are of high value that are relatively scarce or becoming scarce on a national or regional basis. Forested wetlands have been found to support significantly higher abundance and diversity of bird species compared to upland forests (Brinson 1981).

Losses attributed to the project would require in-kind mitigation (replacement of habitat value lost with equal habitat values of the same kind of habitat as those eliminated). The cost of mitigating habitat losses should be included as a project cost. Mitigation for impacts to these areas should be included in the mitigation plan developed in cooperation with the Service, EPA, and KDWP.

The National Wetland Inventory (NWI) database indicates that wetlands exist within the project area. A jurisdictional wetland determination will be necessary if levee alignments or borrow areas directly impact wetlands. The quantity and quality of existing wetlands will determine the amount of compensation necessary to offset project losses. A wetland mitigation plan would be developed in coordination with the Corps, Service, EPA, and KDWP. This plan would include site locations, time frames, construction plans, a monitoring plan, progress reports, and standards of success. This plan would be a condition of any Section 404 permit issued for the project. The plan should be implemented regardless of the regulatory nature of the wetland. Impacts to farmed wetlands should be mitigated at a minimum 1:1 ratio. Minimum replacement ratios for compensatory wetland mitigation should be based on the following guidelines:

U.S. Fish and Wildlife Service, Region 6
Wetland Mitigation Policy Guidance (8/97)
Recommended Minimum Replacement Ratios

Mitigation Type	Ratio	Type of Wetland Being Mitigated
Advance Creation	1.5:1	forested, scrub-shrub
	1:1	emergent
Concurrent Creation	2:1	forested, scrub-shrub
	1.5:1	emergent
Advance Restoration	1.5:1	forested, scrub-shrub
	1:1	emergent
Concurrent Restoration	2:1	forested, scrub-shrub
	1.5:1	emergent
Advance Enhancement	3:1	forested, scrub-shrub
	2:1	emergent
Concurrent Enhancement	4:1	forested, scrub-shrub
	3:1	emergent

Whenever possible, we recommend upland trees within the construction right-of-way remain undisturbed. While the trees may be young now, they are closer to a mature and more valuable stage than newly established tress.

Trees at least 50 feet tall and /or 24-inches dbh riverside of the levees should be avoided. Removal of these trees may adversely affect the habitat of the bald eagle.

Under the Migratory Bird Treaty Act (MBTA), construction activities in prairies, wetlands, stream and woodland habitats, including the removal of upland borrow, and those that occur on bridges (e.g., which may affect swallow nests on bridge girders) that would otherwise result in the taking of migratory birds, eggs, young, and/or active nests should be avoided. To minimize impacts to birds protected under the MBTA, construction areas should be surveyed for the presence of nesting birds during the general migratory bird nesting season of March through August. Disturbance of nesting areas should be avoided until nesting is completed.

Vegetation clearing and construction related soil disturbances can cause sediment-laden runoff to enter waterways. To minimize impacts associated with erosion, contractors should employ silt curtains, coffer dams, dikes, straw bales or other suitable erosion control measures adjacent to floodplain water bodies or tributaries affected by the project. Construction related petrochemical spills can also negatively impact fish and wildlife resources. Therefore, measures should be implemented prior to construction to minimize the likelihood of petrochemical spills.

Invasive species have been identified as a major factor in the decline of native flora and fauna and their ecosystems. Invasive species of particular concern in Kansas include the zebra mussel (*Dreissena polymorpha*), Eurasian watermilfoil (*Myriophyllum spicatum*), purple loosestrife (*Lythrum salicaria*), Johnson grass (*Sorghum halepense*), sericea lespedeza (*Lespedeza cuneata*), salt cedar (*Tamarix spp.*), and reed canary grass (*Phalaris arundinacea*). Executive order 13112 Section 2 (3) directs Federal agencies to not authorize, fund, or carry out actions that it believes are likely to cause or promote the introduction or spread of invasive species in the United States or elsewhere and to ensure that all feasible and prudent measures to minimize risk of harm will be taken in conjunction with the actions. Proactive measures to prevent the inadvertent spread of exotic and invasive species would appear to satisfy this directive. Therefore we recommend the implementation of the following BMP.

> All equipment brought on site will be thoroughly washed to remove dirt, seeds, and plant parts. Any equipment that has been in any body of water within the past 30 days will be thoroughly cleaned with hot water greater 140° F (typically the temperature found at commercial car washes) and dried for a minimum of five days before being used at this project site. In addition, before transporting equipment from the project site all visible mud, plants and fish/animals will be removed, all water will be eliminated, and the equipment will be thoroughly cleaned. Anything that came in contact with water will be cleaned and dried following the above procedure.

Section 2 of the Fish and Wildlife Coordination Act requires the Service to identify project related opportunities to enhance fish and wildlife. The enhancement recommendations discussed below refer to project related creation of wildlife habitat, over and above that required to mitigate losses attributable to project construction.

Native trees, grasses and forbs, noted for their high wildlife value, could be established along the landward and stream-side base of the existing levee system. Native vegetation often takes longer to become fully established; however when established, stands of native vegetation provide excellent soil binding characteristics, valuable wildlife habitat and require fewer maintenance costs. The Service, the Kansas Department of Wildlife and Parks, and the Natural Resource Conservation Service offer assistance programs and could work with the City of Topeka to develop vegetation management plans.

If agreeable to the project sponsors and borrow site owners, borrow sites could be designed and managed to enhance wetland and aquatic habitat, and recreational access.

RECOMMENDATIONS

1. Riparian and wetland habitats should be avoided to the maximum extent practicable when selecting borrow sites for the proposed levee improvements. Compensatory mitigation should be undertaken for unavoidable impacts. Since channelization, levee construction and floodplain development have already resulted in dramatic loss of riparian and wetland habitats in the Kansas River basin within the project area, the Corps should focus on bare or cropland areas for borrow.

2. Levees and levee easements should be seeded with native, warm-season grasses such as buffalo grass (*Buchloe dactyloides*). Buffalo grass is a drought tolerant, perennial, native, turf grass that reaches a height of 8 – 10 inches.

3. The Corps should create wetland mitigation habitat to compensate for the loss of wetland acreage from construction of the projects in accordance with the FWS Region 6 Wetland Mitigation Guidelines, generally at a minimum of 1.5:1 ratio for emergent wetland and at a 2:1 ratio for forested wetland. If farmed wetland is directly impacted by borrow activities it should be mitigated at a 1.0 to1.0 ratio.

4. Removal of woodlands and other native vegetation should be avoided where possible. If avoidance if not possible a mitigation plan should be developed in coordination with the U.S. Fish and Wildlife Service (Service), Environmental Protection Agency (EPA), and the Kansas Department of Wildlife and Parks (KDWP). Woody vegetation and native grasses should be replaced by establishing two acres of native vegetation for every acre impacted.

5. Best Management Practices to prevent the transport of invasive species to or from the construction sites should be included as an integral component of the project.

6. Establish native vegetation riverward of levee segments where riparian woodlands are sparse or nonexistent or where invasive species, i.e. reed canary grass, has become established.

7. All disturbed areas should be immediately planted with native vegetation following construction to prevent erosion and the establishment of invasive species.

8. The potential use of borrow sites for wetland and aquatic habitat enhancement and public recreation should be investigated with the project sponsors and borrow site owners. The City of Topeka is interested in developing a greenway and public access to the Kansas River within the project limits.

9. If possible, establish mitigation areas prior to the onset of impacts from the project to lessen the impacts to wildlife from habitat loss.

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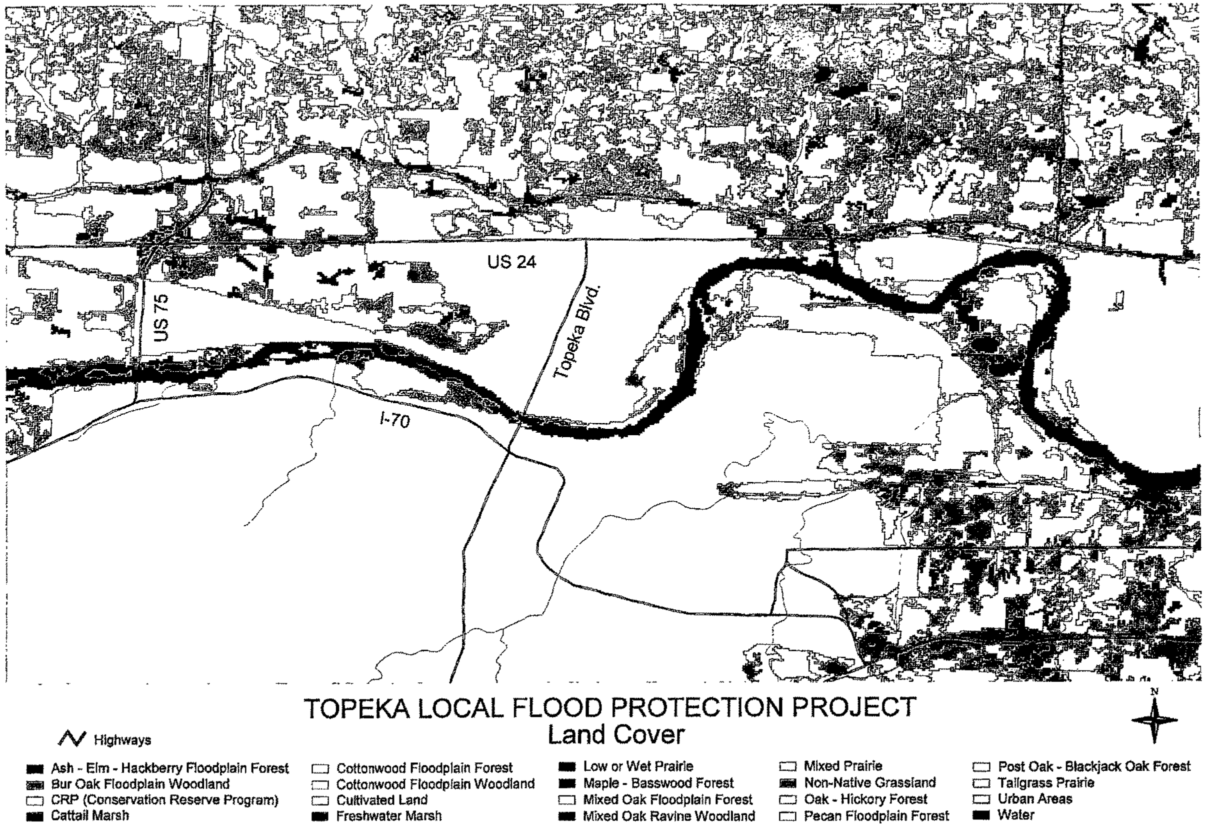
Figure 2


US 24
US 75
Topeka Blvd.
I-70
N
TOPEKA LOCAL FLOOD PROTECTION PROJECT
Land Cover
Highways
Ash - Elm - Hackberry Floodplain Forest
Bur Oak Floodplain Woodland
CRP (Conservation Reserve Program)
Cattail Marsh
Cottonwood Floodplain Forest
Cottonwood Floodplain Woodland
Cultivated Land
Freshwater Marsh
Low or Wet Prairie
Maple - Basswood Forest
Mixed Oak Floodplain Forest
Mixed Oak Ravine Woodland
Mixed Prairie
Non-Native Grassland
Oak - Hickory Forest
Pecan Floodplain Forest
Post Oak - Blackjack Oak Forest
Tallgrass Prairie
Urban Areas
Water

Appendix D.

State Listed Federal Endangered Species List and Kansas Bird List

City of Topeka, Kansas
Flood Risk Management Study
Environmental Assessment

KANSAS BIRDS: Species List for Shawnee County, KS

GEESE, SWANS
____ Greater White-fronted Goose
____ Snow Goose
____ Ross's Goose
____ Cackling Goose
____ Canada Goose*
____ Trumpeter Swan
____ Tundra Swan

DUCKS
____ Wood Duck*
____ Gadwall
____ [Eurasian Wigeon]†
____ American Wigeon
____ American Black Duck
____ Mallard*
____ Blue-winged Teal
____ Cinnamon Teal
____ Northern Shoveler
____ Northern Pintail
____ Green-winged Teal
____ Canvasback
____ Redhead
____ Ring-necked Duck
____ Greater Scaup
____ Lesser Scaup
____ Black Scoter
____ Long-tailed Duck
____ Bufflehead
____ Common Goldeneye
____ Barrow's Goldeneye
____ Hooded Merganser
____ Common Merganser
____ Red-breasted Merganser
____ Ruddy Duck

PHEASANTS
____ Ring-necked Pheasant*

GROUSE
____ Greater Prairie-Chicken*

TURKEYS
____ Wild Turkey*

QUAIL
____ Northern Bobwhite*

LOONS
____ Red-throated Loon
____ Common Loon

GREBES
____ Pied-billed Grebe*
____ Horned Grebe
____ Eared Grebe
____ Western Grebe

PELICANS
____ American White Pelican

CORMORANTS
____ Double-crested Cormorant

HERONS
____ American Bittern
____ Least Bittern
____ Great Blue Heron*
____ Great Egret
____ Snowy Egret
____ Little Blue Heron
____ Tricolored Heron
____ Cattle Egret
____ Green Heron*
____ Black-crowned Night-Heron
____ Yellow-crowned Night-Heron*

VULTURES
____ Turkey Vulture

HAWKS, KITES, EAGLES
____ Osprey
____ Swallow-tailed Kite
____ Mississippi Kite
____ Bald Eagle
____ Northern Harrier*
____ Sharp-shinned Hawk
____ Cooper's Hawk*
____ Northern Goshawk
____ Red-shouldered Hawk
____ Broad-winged Hawk*
____ Swainson's Hawk*
____ Red-tailed Hawk*
____ Ferruginous Hawk
____ Rough-legged Hawk
____ Golden Eagle

FALCONS
____ American Kestrel*
____ Merlin
____ Peregrine Falcon*
____ Prairie Falcon

RAILS, GALLINULES
____ King Rail
____ Virginia Rail
____ Sora
____ Common Moorhen
____ American Coot*

CRANES
____ Sandhill Crane
____ Whooping Crane

PLOVERS
____ Black-bellied Plover
____ American Golden-Plover
____ Snowy Plover
____ Semipalmated Plover
____ Piping Plover*
____ Killdeer*

STILTS, AVOCETS
____ American Avocet

SANDPIPERS
____ Spotted Sandpiper
____ Solitary Sandpiper
____ Greater Yellowlegs
____ Willet
____ Lesser Yellowlegs
____ Upland Sandpiper*
____ Hudsonian Godwit
____ Marbled Godwit
____ Ruddy Turnstone
____ Sanderling
____ Semipalmated Sandpiper
____ Western Sandpiper
____ Least Sandpiper
____ White-rumped Sandpiper
____ Baird's Sandpiper
____ Pectoral Sandpiper
____ Dunlin
____ Stilt Sandpiper
____ Buff-breasted Sandpiper
____ Long-billed Dowitcher
____ Wilson's Snipe
____ American Woodcock
____ Wilson's Phalarope
____ Red-necked Phalarope

GULLS
____ Laughing Gull
____ Franklin's Gull
____ Bonaparte's Gull
____ Ring-billed Gull
____ Herring Gull
____ Glaucous Gull
____ Sabine's Gull
____ Black-legged Kittiwake

TERNS
____ Least Tern*
____ Caspian Tern
____ Black Tern
____ Common Tern
____ Forster's Tern

PIGEONS, DOVES
____ Rock Pigeon*
____ Eurasian Collared-Dove
____ White-winged Dove†
____ Mourning Dove*
____ Inca Dove

CUCKOOS
____ Yellow-billed Cuckoo*
____ Black-billed Cuckoo*
____ Groove-billed Ani

BARN OWLS
____ Barn Owl

OWLS
____ Eastern Screech-Owl
____ Great Horned Owl*
____ Snowy Owl
____ Barred Owl*
____ Long-eared Owl
____ Short-eared Owl
____ Northern Saw-whet Owl

GOATSUCKERS
____ Common Nighthawk*
____ Common Poor-will
____ Chuck-will's-widow*
____ Whip-poor-will

SWIFTS
____ Chimney Swift*

HUMMINGBIRDS
____ Magnificent Hummingbird†
____ Ruby-throated Hummingbird*
____ Rufous Hummingbird

KINGFISHERS
____ Belted Kingfisher*

WOODPECKERS
____ Red-headed Woodpecker*
____ Red-bellied Woodpecker*
____ Yellow-bellied Sapsucker
____ Downy Woodpecker*
____ Hairy Woodpecker*
____ Northern Flicker*
____ Pileated Woodpecker

FLYCATCHERS
____ Olive-sided Flycatcher
____ Eastern Wood-Pewee*
____ Yellow-bellied Flycatcher
____ Alder Flycatcher
____ Willow Flycatcher
____ Least Flycatcher
____ Eastern Phoebe*
____ Vermilion Flycatcher
____ Great Crested Flycatcher*
____ Western Kingbird*
____ Eastern Kingbird*
____ Scissor-tailed Flycatcher*

SHRIKES
____ Loggerhead Shrike*
____ Northern Shrike

VIREOS
____ White-eyed Vireo
____ Bell's Vireo*
____ Yellow-throated Vireo*
____ Blue-headed Vireo
____ Warbling Vireo*
____ Philadelphia Vireo
____ Red-eyed Vireo*

JAYS, MAGPIES, CROWS
____ Blue Jay*
____ Clark's Nutcracker
____ Black-billed Magpie
____ American Crow*

LARKS
____ Horned Lark*

SWALLOWS
____ Purple Martin*
____ Tree Swallow*
____ N. Rough-winged Swallow*
____ Bank Swallow*
____ Cliff Swallow*
____ Barn Swallow*

CHICKADEES, TITMICE
____ Black-capped Chickadee*
____ Tufted Titmouse*

NUTHATCHES
____ Red-breasted Nuthatch
____ White-breasted Nuthatch*

CREEPERS
____ Brown Creeper

WRENS
____ Carolina Wren*
____ Bewick's Wren*
____ House Wren*
____ Winter Wren
____ Sedge Wren
____ Marsh Wren

KINGLETS
____ Golden-crowned Kinglet
____ Ruby-crowned Kinglet

GNATCATCHERS
____ Blue-gray Gnatcatcher*

THRUSHES
____ Eastern Bluebird*
____ Townsend's Solitaire
____ Veery
____ Gray-cheeked Thrush
____ Swainson's Thrush
____ Hermit Thrush
____ Wood Thrush*
____ American Robin*
____ Varied Thrush

THRASHERS
____ Gray Catbird*
____ Northern Mockingbird*
____ Brown Thrasher*

STARLINGS
____ European Starling*

PIPITS
____ American Pipit
____ Sprague's Pipit

WAXWINGS
____ Bohemian Waxwing
____ Cedar Waxwing*

WARBLERS
____ Blue-winged Warbler
____ Golden-winged Warbler
____ Tennessee Warbler
____ Orange-crowned Warbler
____ Nashville Warbler
____ Northern Parula
____ Yellow Warbler*
____ Chestnut-sided Warbler
____ Magnolia Warbler
____ Cape May Warbler
____ Black-throated Blue Warbler
____ Yellow-rumped Warbler
____ Black-throated Gray Warbler
____ Black-throated Green Warbler
____ Blackburnian Warbler
____ Yellow-throated Warbler
____ Pine Warbler
____ Prairie Warbler
____ Palm Warbler
____ Bay-breasted Warbler
____ Blackpoll Warbler
____ Cerulean Warbler
____ Black-and-White Warbler
____ American Redstart
____ Prothonotary Warbler*
____ Worm-eating Warbler
____ Ovenbird
____ Northern Waterthrush
____ Louisiana Waterthrush*
____ Kentucky Warbler*
____ Connecticut Warbler
____ Mourning Warbler
____ Common Yellowthroat*
____ Hooded Warbler
____ Wilson's Warbler
____ Canada Warbler
____ Yellow-breasted Chat

TANAGERS
____ Summer Tanager*
____ Scarlet Tanager
____ Western Tanager

SPARROWS
____ Green-tailed Towhee
____ Spotted Towhee
____ Eastern Towhee
____ American Tree Sparrow
____ Chipping Sparrow*
____ Clay-colored Sparrow
____ Brewer's Sparrow
____ Field Sparrow*
____ Vesper Sparrow
____ Lark Sparrow*

____ Lark Bunting*
____ Savannah Sparrow
____ Grasshopper Sparrow*
____ Baird's Sparrow
____ Henslow's Sparrow*
____ Le Conte's Sparrow
____ Nelson's Sharp-tailed Sparrow
____ Fox Sparrow
____ Song Sparrow
____ Lincoln's Sparrow
____ Swamp Sparrow
____ White-throated Sparrow
____ Harris's Sparrow
____ White-crowned Sparrow
____ Golden-crowned Sparrow
____ Dark-eyed Junco
____ Lapland Longspur
____ Smith's Longspur

GROSBEAKS, BUNTINGS

____ Northern Cardinal*
____ Rose-breasted Grosbeak*
____ Black-headed Grosbeak
____ Blue Grosbeak*
____ Lazuli Bunting
____ Indigo Bunting*
____ Painted Bunting*
____ Dickcissel*

BLACKBIRDS, ORIOLES

____ Bobolink
____ Red-winged Blackbird*
____ Eastern Meadowlark*
____ Western Meadowlark
____ Yellow-headed Blackbird
____ Rusty Blackbird
____ Brewer's Blackbird
____ Common Grackle*
____ Great-tailed Grackle*
____ Brown-headed Cowbird*
____ Orchard Oriole*
____ Baltimore Oriole*

NORTHERN FINCHES

____ Pine Grosbeak
____ Purple Finch
____ House Finch*
____ Red Crossbill*
____ White-winged Crossbill
____ Common Redpoll
____ Pine Siskin
____ Lesser Goldfinch
____ American Goldfinch*
____ Evening Grosbeak

OLD WORLD SPARROWS

____ House Sparrow*

† Fewer than ten Kansas records
[ ] Hypothetical species
* Documented breeding species, meeting the requirements for a Probable or Confirmed Breeder as defined by the Kansas Breeding Bird Atlas Project.

This list was compiled from records of the Kansas Ornithological Society, Kansas Breeding Bird Atlas Project, and the Kansas Biological Survey.

August 20, 2006

Please report any birds not on this list to Max Thompson, Southwestern College, Dept of Biology, 100 College St., Winfield, KS 67156, maxt@cox.net

Rare birds noted with † should be reported to the Kansas Bird Records Committee (KBRC) care of Chuck Otte, 613 Tamerisk, Junction City, KS 66441 otte@nqks.com

More information on reporting rare birds can be found at the KBRC home page on the Kansas Ornithological Society's Web site at: http://ksbirds.org

Please report additions or errors on this list to Chuck Otte, 613 Tamerisk, Junction City, KS 66441 otte@nqks.com

320 species

The taxonomic sequence and nomenclature used in this list follow the *Checklist of North American Birds*, 7th edition, American Ornithologists Union, 1998, updated through the 47th Supplement, 2006, (*Auk* 123:926-936).

Shawnee County

THREATENED AND ENDANGERED SPECIES

American Burying Beetle *Nicrophorus americanus* **State:** END **Federal:** END **Critical Habitat:** NO

Bald Eagle *Haliaeetus leucocephalus* **State:** THR **Federal:** THR **Critical Habitat:** YES

Eastern Spotted Skunk *Spilogale putorius* **State:** THR **Federal:** NA **Critical Habitat:** NO

Eskimo Curlew *Numenius borealis* **State:** END **Federal:** END **Critical Habitat:** NO

Least Tern *Sterna antillarum* **State:** END **Federal:** END **Critical Habitat:** YES

Peregrine Falcon *Falco peregrinus* **State:** END **Federal:** NA **Critical Habitat:** YES

Piping Plover *Charadrius melodus* **State:** THR **Federal:** THR **Critical Habitat:** YES

Silver Chub *Macrhybopsis storeriana* **State:** END **Federal:** NA **Critical Habitat:** NO

Smooth Earth Snake *Virginia valeriae* **State:** THR **Federal:** NA **Critical Habitat:** NO

Snowy Plover *Charadrius alexandrinus* **State:** THR **Federal:** NA **Critical Habitat:** NO

Sturgeon Chub *Macrhybopsis gelida* **State:** THR **Federal:** CAN **Critical Habitat:** YES

Topeka Shiner *Notropis topeka* **State:** THR **Federal:** END **Critical Habitat:** YES

Whooping Crane *Grus americana* **State:** END **Federal:** END **Critical Habitat:** NO

SPECIES IN NEED OF CONSERVATION

Black Tern *Chlidonias niger* **State:** SNC **Federal:** NA **Critical Habitat:** NA

Bobolink *Dolichonyx oryzivorus* **State:** SNC **Federal:** NA **Critical Habitat:** NA

Cerulean Warbler *Dendroica cerulea* **State:** SNC **Federal:** NA **Critical Habitat:** NA

Plains Minnow *Hybognathus placitus* **State:** SNC **Federal:** NA **Critical Habitat:** NA

Short-eared Owl *Asio flammeus* **State:** SNC **Federal:** NA **Critical Habitat:** NA

Southern Bog Lemming *Synaptomys cooperi* **State:** SNC **Federal:** NA **Critical Habitat:** NA

Southern Flying Squirrel *Glaucomys volans* **State:** SNC **Federal:** NA **Critical Habitat:** NA

Tadpole Madtom *Noturus gyrinus* **State:** SNC **Federal:** NA **Critical Habitat:** NA

Timber Rattlesnake *Crotalus horridus* **State:** SNC **Federal:** NA **Critical Habitat:** NA

Whip-poor-will *Camprimulgus vociferus* **State:** SNC **Federal:** NA **Critical Habitat:** NA

Yellow-throated Warbler *Dendroica dominica* **State:** SNC **Federal:** NA **Critical Habitat:** NA

Appendix E.

Figures
(see Figures at end of Main Report)

Appendix F.

Mitigation Plan

Mitigation Plan
City of Topeka
Flood Risk Management Study
Topeka, Kansas

April 2008

U.S. Army Corps of Engineers
Kansas City District
601 E 12th St.
Kansas City, Missouri 64106-2896

Table of Contents

MITIGATION PLAN
TOPEKA, KANSAS, LEVEE FEASIBILITY STUDY

1.0 SITE DESCRIPTION

The Topeka flood risk management project will impact about seven and one-half acres of a 25-acre woodland due to installation of an under seepage berm at the South Topeka unit. This woodland is part of the floodplain forest that extends along the Kansas River in the Topeka, Kansas section of Shawnee County. The riparian floodplain forest that remains along the Kansas River is considered the highest quality habitat in the Topeka area. Specifically, this woodland is located near the South Topeka levee unit, beginning at river miles 86.0 to 85.4. The south border of the woodland is the border for developed urban areas including a railroad and major U.S. Interstate Highway (see Figure 4).

The quality of the woodland is considered moderate based on the habitat quality assessment model, and it is assumed that the woodland is about 30 years old. Woody species found in this area are typical of those found within the Kansas River riparian floodplain which includes species such as the eastern cottonwood (*Populus deltoides*), silver maple (*Acer saccharinum*), black walnut (*Juglans nigra*), sandbar willow, (*Salix exigu*), box elder (*Acer negundo*), Siberian elm (*Ulmus pumila*), sycamore (*Platanus occidentalis*), and white mulberry (*Morus alba*). The herbaceous layer contains species such as Nettle (*Urtica*), pokeweed (*Phytolacca*), white snakeroot (*Polygala sp*), Japanese honeysuckle (*Lonicera japonica),* and common blue violet (*viola septentrionalis*).

2.0 COMPENSATION AND AVOIDANCE

To offset the loss of this habitat, a tree planting program covering 15 acres is recommended based on the results of the habitat model. The assumption that the proposed impacted area would take up to 30 years to reestablish native vegetation equal to the current value was considered in the model. Further, it was assumed that many of the planted trees will not survive to maturity due to weather, predation, disease, etc. The restored site would provide wildlife habitat suitable to support those species found within the existing site.

In accordance with the Migratory Bird Treaty Act, additional mitigation measures would include the avoidance of construction activities in woodland areas during the migratory bird nesting season from April 1 to July 15. These recommendations coincide with the U.S. Fish and Wildlife Coordination Act Report.

3.0 JUSTIFICATION

Quantitative- Habitat Quality Assessment Model

A community habitat suitability model for bottomland hardwoods (LDNR, 1994) was used to quantify net gains and losses of ecological value associated with future with project and future without project conditions. This model is a modification of the U.S. Fish and Wildlife Service's habitat evaluation procedure (HEP). Target years used for the project ranged from baseline, 0 to 50 years. A total of seven variables were used as indicators to assess habitat value (species association, maturity, understory and midstory percentages, hydrology, forest size, surrounding land use, and disturbance). To assess the suitability of the habitat for providing resting, foraging, and breeding for wildlife species, habitat suitability indices (HSI) were calculated for each target year of the project. The HSI is presented as a value between 0 and 1.0, and is a measure of habitat quality. The HSI value is multiplied by the habitat quantity to produce a habitat value measure termed Habitat Units (HU). The habitat units were calculated across the life of the project and the average annual habitat units (AAHUs) were compared under future with project and future with project conditions (see Appendix G).

Future without Project (FWOP)

Without the project, the woodland is expected to continue to grow and reach full maturity by age 50. The total AAHU for Future without the project is 13.92. At the end of 50 years, FWOP would yield HSI value of 0.60, which is considered slightly above a moderate value. A HSI value of 0.60 is generally less than expected for mature woodland, but the model used to generate this value is influenced by the proximity of the site to a major disturbance such as an interstate highway, as well as the land use of the surrounding area which is primarily agriculture, industrial and residential development.

Future with Project Conditions (FWPC)

Future project conditions with and without mitigation were analyzed separately. Based on the HSI indices of the model, removal of about 8 acres would reduce the quality of the woodland from moderate (0.41) to low (0.29) at project year one. In addition, this would reduce the amount of resources available for supporting wildlife and promote opportunities for invasive species establishment within the impacted area. For the model analysis, it was assumed that the remaining 17 acres of disturbed woodland site would continue to develop towards maturity. The output of the model projects by project age 50, the disturbed site without mitigation would yield a HSI value of 0.46. This value is relatively low when compared to the "future project conditions with-mitigation measures" where a HSI value of 0.80 is projected. The average annual habitat units for the "with-mitigation measures" are 7.49, and without-mitigation measures yield an average of 6.62 habitat units. When the AAHUs of mitigation-measures are added to those of the without-mitigation measures, a total of 14.11 AAHUs are gained for future with project conditions (see Appendix G).

Conclusion

The results of the habitat model indicate that future with project AAHUs minus future without project AAHUs would result in a net change of zero. Therefore, a total of 15 acres of mitigation would compensate for the loss of 7.5 acres of habitat.

QualitativeAssessment

The woodland site at the South Topeka unit provides important habitat for various wildlife species and is part of the floodplain forest that extends along the Kansas River. The Kansas River riparian corridor provides crucial habitat for many species which are of biological, cultural, and/or commercial importance. Thousands of waterfowl use the Kansas River channel and floodplain during migration and wintering. Several species of commercially valuable furbearers occur in the riparian habitats, including muskrat, mink, beaver, raccoon, and both red and grey fox. The riparian forests and meadows provide migration and nesting habitat for many species of birds, including many declining neotropical migratory songbirds (USFWS BiOp, 2000). The Kansas Ornithological Society has listed 320 bird species found in Shawnee County. At least 80 of those species have been identified as nesting within Shawnee County. Removal of this woodland area may cause further decline in the numbers of species that depend on these areas, as the native vegetation may take years to reestablish (USFWS, 2007). Also, the project area offers potential perching and nesting habitat for endangered species such as the bald eagle and Indiana bat.

Although the Topeka Levee system separates this area from the river, this woodland provides an important corridor to facilitate the movement of flora and fauna between other patches of natural habitat. Specifically, it allows plants to propagate from one patch to another, and wildlife species to move in response to environmental changes or escape from predators.

Moreover, the availability of riparian woodland areas in the project area is scarce and declining. There is little refuge habitat in close proximity to the project area and available habitat is presumably at carrying capacity, which further reduces the likelihood of wildlife surviving the displacement and intensifies the competition for the limited habitat available (USFWS, 2007). S.H. Long wrote that the Kansas River valley in 1905 contained forests of cottonwood, sycamore, etc, interspersed with meadows about one-half mile wide" (Thwaites 1905b). Further downstream near present-day Lawrence (KS), Douglas County, Fitch and McGregory (1956) reported from early accounts in the 1950's that the floodplain contained "rich mesophytic forest of predominantly oak-hickory type." Continuing bank erosion, coupled with floodplain encroachment, has reduced the perennial riparian vegetation native to the Kansas River channel. Though accurate data are not available for pre- and post-construction periods, it is likely that at present there is very little riparian forest which meets naturalist Thomas Say's (Thwaites 1905b) description. Also, bank stabilization projects, some of which may be detrimental to aquatic habitats and channel hydraulics, could be reduced or eliminated if suitable riparian vegetation were maintained (Sanders et al. 1993).

5.0 MITIGATION SITE SELECTION

The mitigation plantings would be at the impacted site and within at the North Topeka unit of the project area. The North Topeka mitigation site is located between river miles 87.8 to 87.5, and upstream of the impacted site at South Topeka (see Figure 13). It is owned by the city of Topeka and is part of the existing riparian forest corridor along the Kansas River. Selected because it contains similar soil types and plant species to those of the impacted site, it offers the greatest vegetative diversity and degree of interspersion with other habitat types, which are important to many wildlife species.

The area between the levees, which includes the Kansas River, contains much of the remaining available wildlife habitat. The riparian forest that remains along the Kansas River is the highest quality habitat in the Topeka area. The mitigation site provides closer access to the river than the impacted site, which is important for waterfowl and shorebird resting, and feeding and staging areas during migration. Also, this site contains two disturbed areas, one is currently bare land and the other is planted with row crops. If these areas are planted with native species, they would provide beneficial habitat for area wildlife. This is especially important in an area where much of the riparian forest has been developed. Within the impacted site, plantings would consist of native species as well as mast-producing tree species to provide additional year-round sources of food for wildlife.

The proposed North Topeka mitigation site is dominated by cottonwood and box elder (*Acer ndegundo*) trees and Siberian elm shrubs. The agricultural field located within this site contains soy beans, occasional dock (*Rumex* sp.), giant foxtail grass (*Setaria faberii*), and annual ragweed (*Ambrosia artemisiifolia*). The western border of the field is dominated by Johnson grass (*Sorghum halepense*), goosefoot (*Chenopodium* sp.), annual sunflower (*Helianthus annuus*) and goldenrod (*Solidago* sp.), with some occasional Siberian elm (*Ulmus pumila*) and cottonwood (*Populus deltoides*) shrubs.

6.0 PLANT LIST

The mitigation plan will include plantings of various species of native trees, shrubs, forbs and grasses such as those listed below. A planting plan will be developed and made available during the Design Phase of the project.

Acer saccharinum/Sliver Maple
Carya illinuensis/Pecan
Carya laciniosa/Shellbark Hickory
Crataegus phaenopyrum/Hawthorn
Diospyros virginiana/Persimmon
Juglans nigra/Black Walnut
Quercus alba/ White Oak
Quercus macrocarpa/Bur Oak
Prunus Americana/American Plum
Populus deltoids/ Eastern cottonwood

Shrubs
Ribes missouriense/Gooseberry
Cornus drummondii/Roughleaf Dogwood
Cornus foemina/Gray dogwood
Amelanchier arborea/Common serviceberry
Prunus virginiana/Common Chokeberry
Sambucus Canadensis/Elderberry

Forbs
Asclepias tuberosa /Butterfly weed
Aster novae-angliae/ New England Aster
Cassia fasciculate/ Patridge Pea
Coreopsis lanceloata/ Sand Coreopsis
Echinacea purpurea / Broad-Leaved Purple Coneflower
Heliopsis helianthoides / False Sunflower
Liatris aspera/ Rouge Blazing Star
Lupinus perennis/ Wild Lupine
Ratibida pinnata/ Yellow Coneflower
Rudbeckia hirta / Black-Eyed Susan

Temporary Cover and Grasses
Avena sativa/ Seed Oats

Lolium multiflorum/ Annual Rye
Andropogon gerardii/ Big blue stem
Andropogon scoparius/ Little blue stem
Bouteloua curtipendula/ Side Oats Grama
Elymus Canadensis/Canada wild rye
Panicum virgatum/Switch grass
Sorghastrum nutans/ Indian grass

7.0 WORK PLAN

Within the impacted site, about five acres of trees and shrubs would be planted landward of the levee, behind the constructed under seepage berm. All trees and shrubs would be container grown and of the root-production method (RPM). The 3-gallon container grown trees would be at least 2-3 feet tall when planted. Trees would be spaced 20 x 20 feet apart within and between rows to allow trees to canopy in approximately 20 years (NRCS 1999). Larger shrubs such as dogwood and chokecherry would be spaced at least 10 x 10 feet apart. Smaller shrubs such as beautyberry would be spaced at least 4-6 feet apart (NRCS, 1999 and Tylka, 2002). The entire planting area would equal 2,200 linear feet x 100-foot wide.

At the North Topeka site, within the bare area, about five and on-half acres of trees would be planted near the river, followed by one-half acre of shrubs. Trees would be spaced 20 x 20 feet apart and the shrubs would be spaced 10 x 10 feet apart. Within the adjacent crop area, approximately four acres of native grasses and forbs would be planted. The total amount of mitigation plantings at both sites would be 15.0 acres. In addition, the plantings would include native woody species, forbs and grasses that are suitable for the area and that have multiple values suited for timber, cover, nuts, fruit, browse, nesting and aesthetics. A non-competitive, perennial ground cover such as Virginia wild rye (*Elymus virginicus*) or red top panic grass (*Panicum rigidulum*) would be planted within the tree and shrub rows. The method of planting would include hand or machine planting techniques suited to achieving proper depths and placement of planting root stock. Invasive species within the project area would be controlled during site preparation and annual maintenance.

8.0 MONITORING PLAN

Site visits would be made by Corps personnel soon after levee construction, once mitigation plantings are completed, and every year thereafter for five years or until the plants are fully established. Site assessments would include an evaluation of vegetation growth, types of species, hydrology, and photos. This would be done at each visit to help make performance determinations and future recommendations.

9.0 PERFORMANCE STANDARDS

Success of the habitat would be based on the establishment of continuous healthy, flourishing growth of native vegetation. Also, the percentage native species survival would be considered in determining site success. The minimum factor used to determine success would be 85% of the plantings having healthy, flourishing growth at the end of three years. Invasive species would be controlled as they are observed. Best Management Practices (BMPs) would be used to prevent the inadvertent spread of exotic and invasive species to or from the mitigation areas. This includes insuring that all equipment brought on or from the site would be thoroughly washed to remove dirt, seeds, and plant parts. Any equipment that has been in any body of water within the past 30 days will be thoroughly cleaned with hot water greater than 140 degrees Fahrenheit and dried before being used at this project site.

10.0 SITE PROTECTION

Current access to the proposed mitigation site is limited and hard to reach by the general public, making disturbance of the mitigation sites unlikely. The area is owned by the city of Topeka, which is also the local sponsor of the project. The city will retain ownership of the mitigation site after project construction is completed. There is no public access to the levees at this time; and the Corps will obtain a permanent easement to ensure the protection of these areas. In addition, interpretative signs would be posted around the site highlighting the COE's restoration efforts.

11.0 MAINTENANCE

Trees

To minimize the amount of care needed after planting, extra steps would be taken during the installation. This includes using biodegradable weed barrier mat or organic mulch to limit the growth of weeds; a 24/30 photodegradable plastic tree guard or similar protection device to protect young trees against rodent and deer damage; and a slow-release fertilizer applied around each tree. In addition, a noncompetitive, perennial ground cover would be planted over the entire area. This will help reduce the amount of weeds growing after site preparation. In addition, a watering and care plan will be developed and implemented. Also, it is preferred that the areas be allowed to regenerate naturally from the existing seed bank

Native Grass/Forbs

The newly seeded native grass/forbs would receive the equivalent of one inch of water per week for the first 6 to 8 weeks, either via rainfall or irrigation. Since burning is not practical, native grass/forbs areas would be mowed in late fall annually during the first three years, and every third year thereafter to keep out woody growth. Invasive species would be controlled as soon as they are noticed.

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Appendix G

Community Habitat Model Spreadsheet

Summary Sheet AAHU Calculation

Project: Topeka Flood Risk Management Project, Riparian Woodlands

Future With Project-damaged		mitigated	Total	Cumulative
TY	Acres	x HSI	HUs	HUs
0	15	0.00	0.00	
1	15	0.00	0.00	0.00
5	15	0 00	0.00	0.00
10	15	0.34	5.15	12.87
15	15	0.41	6.19	28.36
20	15	0.52	7.74	34.84
30	15	0.62	9 25	84 96
40	15	0.71	10.71	99 78
50	15	0 80	12.06	113 83
			Total	
			CHUs =	374.64
			AAHUs =	7.49

Future With Project r damaged			Total	Cumulative
TY	Acres	x HSI	HUs	HUs
0	17	0.29	4.93	
1	17	0.29	4.97	4.95
5	17	0.32	5.43	20.79
10	17	0.34	5.85	28.18
15	17	0.35	5.95	29.48
20	17	0 41	7.04	32 46
30	17	0.41	7.04	70.39
40	17	0.41	7.04	70.39
50	17	0.46	7.84	74.41
			Total	
			CHUs =	331.04
			AAHUs =	6.62

Future Without Project			Total	Cumulative
TY	Acres	x HSI	HUs	HUs
0	25	0.41	10.25	
1	25	0.41	10.34	10.29
5	25	0.42	10.57	41.82
10	25	0.49	12.33	57.25
15	25	0.55	13.74	65.17
20	25	0.60	15.00	71.83
30	25	0.60	15.00	149.95
40	25	0.60	15.00	149 95
50	25	0.60	15.00	149.95
			Total	
			CHUs =	696.22
			AAHUs =	13.92

NET CHANGE IN CHUs DUE TO PROJECT

A Future With Project CHUs =	705.68
B. Future Without Project CHUs =	696.22
Net Change (FWP - FWOP) =	9.46

NET CHANGE IN AAHUs DUE TO PROJECT

A. Future With Project AAHUs =	14.11
B Future Without Project AAHUs =	13.92
Net Change (FWP - FWOP) =	0.19

Appendix H

Mitigation Cost Analysis

City of Topeka, Kansas
Flood Risk Management Project
Environmental Assessment

SUMMARY

Compensatory mitigation is required for the Topeka Flood Damage Reduction project due to the lost of approximately seven and one-half acres of woodland from project construction. The purpose of this document is to identify and describe the process used for determination of the least cost plan for mitigation. The level of effort for the cost-analysis performed for this project is commensurate with the project's level of impact and in accordance with the cost analysis procedures detailed in ER 1105-2-100, Appendix C-3.E(8), as follows:

(1) Inventory and Categorize Ecological Resources.
(2) Determine Significant Net Losses.
(3) Define Mitigation Planning Objectives.
(4) Determine Unit of Measurement.
(5) Identify and Assess Potential Mitigation Strategies.
(6) Define and Estimate Costs of Mitigation Plan.
(7) Display Costs.

STEPS 1 THROUGH 5

Section 10.4 of the EA, and the Mitigation Plan in Appendix F, present an inventory and categorization of the ecological resources affected by the proposed project and address the resource significance (Steps 1 and 2).

The Mitigation Planning Objective, as identified in the Mitigation Plan, Section 2, is to offset lost habitat due to project implementation (Step 3). A Community Habitat Model (Appendix G) was conducted to determine the quality of lost habitat in Habitat Units (HU)s (Step 4). Based on the results of the habitat assessment model and the qualitative assessment, documented in the mitigation plan, the amount of compensatory mitigation was determined to be 15 acres. The mitigation plan and habitat model were coordinated with the U.S. Fish and Wildlife Service (USFWS). The USFWS concurred with the USACE on October 28, 2008 that the proposed mitigation for the project's impacts is adequate (Appendix B – Feasibility Report)

To determine the most cost effective plan for mitigation, potential mitigation strategies were identified and three alternative plans were formed for consideration (Step 5). The mitigation site and the 15-acre planting regime was the same for each alternative because the USACE's objective was to fully compensate for the number of average annual habitat units lost due to the project. Therefore, the 15-acre planting regime for all three plans was based on the results of the same habitat assessment model. However, each alternative plan differed in the density of trees planted within the mitigation site. The spacing regimes were based on the National Resource Conservation Service's (NRCS) specifications for developing a riparian forest (NRCS, 1999). The difference in cost per alternative was based on the number of trees proposed. The alternative with the lowest cost was selected as the recommended plan for mitigation (Table 1).

STEP 6 – Define and Estimate Costs of Mitigation Plans

For the three alternatives considered, a combination of trees, shrubs, and native grasses was incorporated in each alternative plan to provide optimum wildlife habitat. The plant species selected for all plans were identical and based on coordination with the U.S. Fish and Wildlife Service. Native tree species were incorporated into the plans because natives are easily adapted to the area and are less expensive than non-native species. The spacing of trees within each plan varied from 10-20 feet for trees and 6 to 10 feet for shrubs. The size of tree seedlings affects the overall purchase cost. For each alternative 3-gal container- grown tree stock was used. The cost of the 3-gal container grown tree is about $9.50 per tree. This cost was the lowest rate available in the state-wide area and was provided by the Forest Keeling Nursery in Missouri. The use of bare-root seedlings was considered but eliminated. Typically, bare root-seedling trees cost less than 3-gal container grown trees, but their survival rate has not been as successful. Bare root seedlings require a longer period to establish their root systems and usually require additional care beyond the initial installation period, such as watering, which would increase tree planting cost. Therefore, 3-gal container grown trees were used. The average cost for installation labor was estimated at $35.00 per tree. This estimate was obtained from Terra Technologies, Inc, a local restoration contracting company, and was compared with costs from other contractors that have provided similar services. Compared to other cost estimates, the cost for labor was considered reasonable.

STEP 7 – Display Costs

The three planting plans were developed and their costs were compared and discussed below and displayed in Table 1.

Alternative 1 (Recommended plan): The costs for alternative 1 are represented in Table 2. This alternative assumes that each large tree is spaced 20 x 20 feet and each shrub is spaced 10 x 10 feet apart. This alternative assumes the maximum recommended spacing allowed, which yields a total of 110 trees per acre and 436 shrubs per acre. For 11 acres of trees, this gives a total of 1,972 trees. The total cost for alternative 1 is **$77,806.00**.

Alternative 2: The costs for alternative 2 are represented in Table 3. This alternative assumes that each large tree is spaced 12 x 12 feet and each shrub is spaced 10 x 10 feet apart. This alternative assumes the least recommended spacing allowed, which yields a total of 304 trees per acre and 436 shrubs per acre. For 11 acres of trees, this gives a total of 3,912 trees. The total cost for alternative 2 is **$166,076.00**.

Alternative 3: The costs for alternative 3 are represented in Table 4. This alternative assumes that each large tree is spaced 15 x 15 feet and each shrub is spaced 10 x 10 feet apart. This alternative assumes the median recommended spacing allowed, which yields a total of 195 trees per acre and 436 shrubs per acre. For 11 acres of trees, this gives a total of 2,822 trees. The total cost for alternative 3 is **$116,481.00.**

Recommended Alternative (Selected Plan)

Alternative 1 provides the best planting plan compared to the other two alternatives examined. This alternative is the least cost alternative to provide the required amount of habitat units to offset losses due to the project.

Spacing of trees at 20 x 20 feet apart is the preferred method because this spacing provides enough room for the trees to fully canopy in about 20 years. In large natural areas, restoration plantings have been more successful in the long term when trees were properly spaced, and provided the proper care at installation than those that were planted very densely (NRCS, 1999).

This plan was coordinated with the U.S. Fish and Wildlife Service and their recommendations are incorporated into the plan.

Table 1. Topeka Mitigation Cost Analysis Summary

No. of trees	Cost	Tree spacing
1,972	$77,806.00	20 x20
3,912	$166,076.00	12 x 12
2,822	$116,481.00	15 x 15
*Cost varies with the number of trees proposed per acre		

Table 2. Alternative 1-Recommended Plan

Trees in 3 gallon containers	Acres	Amount/Acre	Purchase	Installation	Total
Shellbark Hickory	10	10	$ 9.50	$ 35.00	$ 4,450.00
Swamp White Oak	10	10	$ 9.50	$ 35.00	$ 4,450.00
Bur Oak	10	10	$ 9.50	$ 35.00	$ 4,450.00
Pin Oak	10	10	$ 9.50	$ 35.00	$ 4,450.00
Silver Maple	10	20	$ 9.50	$ 35.00	$ 8,900.00
Pecan	10	10	$ 9.50	$ 35.00	$ 4,450.00
Cottonwood	10	10	$ 9 50	$ 35.00	$ 4,450.00
American Plum	10	10	$ 9 50	$ 35.00	$ 4,450.00
Hawthorn	10	10	$ 9.50	$ 35.00	$ 4,450.00
Persimmon	10	10	$ 9.50	$ 35.00	$ 4,450.00
Total Trees per acre		110			
3 gallon container Shrubs					
Gray Dogwood	1	72	$ 9.50	$ 35.00	$ 3,204.00
Common Chokecherry	1	72	$ 9.50	$ 35.00	$ 3,204.00
Flowering Dogwood	1	72	$ 9.50	$ 35.00	$ 3,204.00
Serviceberry	1	72	$ 9.50	$ 35.00	$ 3,204.00
Elderberry	1	72	$ 9.50	$ 35.00	$ 3,204.00
Beautyberry	1	72	$ 9 50	$ 35.00	$ 3,204.00
Total shrubs per acre		436			
Native grass seeding mix	4	1	$395/acre	$ 500/acre	$ 3,580.00
Site Preparation-herbicide				$ 250/acre	$ 3,750.00
Delivery Fees				$ 1/tree	$ 1,972 00
Temporary Grass Cover				$ 30/acre	$ 330 00
Total	15	1972			$ 77,806.00
Purchase prices from Forrest Keeling Nursery 2007 Wholesale Catalog					
Installation prices from Terra technologies, Inc. Feb 7, 2007					
Installation prices include labor, weed mat, tree guard, fertilizer and water, w/1-yr guarantee					
Native grass seeding mix prices from JFNew Inc. 2006 Resource Catalog					

Table 3. Alternative 2

Trees in 3 gallon containers	Acres	Amount/Acre	Purchase	Installation	Total
Shellbark Hickory	10	30	$ 9.50	$ 35.00	$ 13,350.00
Swamp White Oak	10	30	$ 9.50	$ 35.00	$ 13,350.00
Bur Oak	10	30	$ 9.50	$ 35.00	$ 13,350.00
Pin Oak	10	30	$ 9.50	$ 35.00	$ 13,350.00
Silver Maple	10	40	$ 9.50	$ 35.00	$ 17,800.00
Pecan	10	30	$ 9.50	$ 35.00	$ 13,350.00
Cottonwood	10	30	$ 9.50	$ 35.00	$ 13,350.00
American Plum	10	30	$ 9.50	$ 35.00	$ 13,350.00
Hawthorn	10	30	$ 9.50	$ 35.00	$ 13,350.00
Persimmon	10	24	$ 9.50	$ 35.00	$ 10,680.00
Total Trees per acre		304			
3 gallon container Shrubs					
Gray Dogwood	1	72	$ 9.50	$ 35.00	$ 3,204.00
Common Chokecherry	1	72	$ 9.50	$ 35.00	$ 3,204.00
Flowering Dogwood	1	72	$ 9.50	$ 35.00	$ 3,204.00
Serviceberry	1	72	$ 9.50	$ 35.00	$ 3,204.00
Elderberry	1	72	$ 9.50	$ 35.00	$ 3,204.00
Beautyberry	1	72	$ 9.50	$ 35.00	$ 3,204.00
Total shrubs per acre		436			
Native grass seeding mix	4	1	$395.00	$ 500/acre	$ 3,580.00
Site Preparation-herbicide				$ 250/acre	$ 3,750.00
Delivery Fees				$ 1/ tree	$ 3,912.00
Temporary Grass Cover				$ 30/ acre	$ 330.00
Total	15	3912			$ 166,076.00
Purchase prices from Forrest Keeling Nursery 2007 Wholesale Catalog					
Installation prices from Terra technologies, Inc. Feb 7, 2007					
Installation prices include labor, weed mat, tree guard, fertilizer and water, w/1-yr guarantee					
Prairie seeding mix prices from JFNew Inc. 2006 Resource Catalog					

Table 4. Alternative 3

Trees in 3 gallon containers	Acres	Amount/Acre	Purchase	Installation	Total
Shellbark Hickory	10	20	$ 9.50	$ 35.00	$ 8,900.00
Swamp White Oak	10	20	$ 9.50	$ 35.00	$ 8,900.00
Bur Oak	10	20	$ 9.50	$ 35.00	$ 8,900.00
Pin Oak	10	20	$ 9.50	$ 35.00	$ 8,900.00
Silver Maple	10	50	$ 9.50	$ 35.00	$ 22,250.00
Pecan	10	20	$ 9.50	$ 35.00	$ 8,900.00
Cottonwood	10	15	$ 9.50	$ 35.00	$ 6,675.00
American Plum	10	10	$ 9.50	$ 35.00	$ 4,450.00
Hawthorn	10	10	$ 9.50	$ 35.00	$ 4,450.00
Persimmon	10	10	$ 9.50	$ 35.00	$ 4,450.00
Total Trees per acre		195			
3 gallon container Shrubs					
Gray Dogwood	1	72	$ 9.50	$ 35.00	$ 3,204.00
Common Chokecherry	1	72	$ 9.50	$ 35.00	$ 3,204.00
Flowering Dogwood	1	72	$ 9.50	$ 35.00	$ 3,204.00
Serviceberry	1	72	$ 9.50	$ 35.00	$ 3,204.00
Elderberry	1	72	$ 9.50	$ 35.00	$ 3,204.00
Beautyberry	1	72	$ 9.50	$ 35.00	$ 3,204.00
Total shrubs per acre		436			
Native grass seeding mix	4	1	$395.00	$ 500/acre	$ 3,580.00
Site Preparation-herbicide				$ 250/acre	$ 3,750.00
Delivery Fees				$ 1/tree	$ 2,822.00
Temporary Grass Cover				$ 30/acre	$ 330.00
Total	15	2822			$ 116,481.00
Purchase prices from Forrest Keeling Nursery 2007 Wholesale Catalog					
Installation prices from Terra technologies, Inc. Feb 7, 2007					
Installation prices include labor, weed mat, tree guard, fertilizer and water, w/1-yr guarantee					
Native grass seeding mix prices from JFNew Inc. 2006 Resource Catalog					

REFERENCES

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JFNew, Inc. 708 Roosevelt Road, Walkerton, Indiana, 46574

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Terra Technologies, 8680 W. 96th St. Ste 100, Overland Park, Kansas 66212

Appendix I

Hazardous, Toxic and Radioactive Wastes Assessment

HAZARDOUS, TOXIC, AND RADIOACTIVE WASTE ASSESSMENT

Topeka Flood Risk Management Project
February 2007

A Hazardous, Toxic, And Radioactive Waste (HTRW) assessment was completed as part of the Topeka, Kansas Reconnaissance Report (USACE, 1997). It included a database search and site visit to identify areas of concern within 500 feet of either side of the levee. No sites registered in the database were reported on the National Priorities List, Comprehensive Environmental Response, Compensation, and Liability Information System, and Kansas Hazardous Waste Sites Report.

The assessment identified four areas of concern if the design included disturbance of land side soil:

- Union Pacific Railroad – a potential area of concern due to three above ground storage tanks currently in use.
- Magnus Co., Inc. AT&SF Yards West Gate – this site showed up in the database as a result of site discovery and two subsequent preliminary assessments, but its location could not be determined.
- Fenced yard – located on the south bank of the Kansas River west of the railroad bridge along river road. Contents unknown.
- Remaining area on Oakland Unit – there were several sites listed either in the Leaking Underground Storage Tank database or Registered Storage Tanks database whose status had not been visually confirmed with site visit.

Since completion of the assessment, more precise areas of proposed work have been identified for the project. With this information an updated environmental assessment was performed to determine the risk of the proposed activities being impacted by contaminated sites. The following sources of information were used in the assessment:

- USEPA Enviromapper Database search for known HTRW Sites
- Kansas Department of Health and Environment (KDHE) Bureau of Environmental Remediation database search for known contaminated sites
- KDHE Bureau of Waste Management Solid Waste database
- KDHE database of Permitted Storage Tanks
- KDHE database of Leaking Above Ground and Underground Storage Tanks
- Discussions with existing and former KDHE employees
- Site photographs

Following is a discussion of each of the proposed areas of work and the potential risks associated with HTRW contamination impacting the alternatives being considered for each of those areas.

North Topeka Unit, Station 165+00 to 189+00 – Problem: Underseepage

Alternatives to address the underseepage problem in this area include the addition of an underseepage berm or installation of relief wells. Based on the data in the assessment, there are no known contaminated sites in the immediate vicinity. There were seven leaking underground storage tank sites located to the north and northwest of this area and two contaminated sites located to the northwest, but the sites were located 2,000 to 6,700 feet from this area. Therefore, there is little or no risk of encountering soil contamination associated with the identified sites. In terms of groundwater contamination that may impact the relief well alternative, groundwater flow in this area is described as being in the east-northeasterly direction. Therefore, there appears to be very low risk that groundwater contamination from these sites would have migrated towards of the work area. The only potential concern is rubble piles that show up on a site photo and may interfere with placement of the underseepage berm. However, this does not appear to be an HTRW concern. The only HTRW concern is to ensure that any soil brought on-site for use in an underseepage berm has been tested and certified to be clean.

North Topeka Unit, Station 246+00 to 250+00 – Problem: Underseepage

For this area, space for installation of an underseepage berm is limited due to the close proximity of railroad tracks. Therefore, relief wells were considered the only feasible alternative to address the underseepage. There are no known contaminated sites in the vicinity of this area. The only potential concern is the close proximity to the railroad tracks. Petroleum and polyaromatic hydrocarbon contamination in soil is not uncommon near railroad tracks, particularly in areas where loading, off-loading, and staging of rail cars occurs. Therefore, there is a potential risk that soil contamination may be encountered in this area. It is recommended that the design of the relief well system minimize soil disturbance to the greatest extent practical. Any soil that is removed from the site during construction will need to be tested to ensure proper disposal.

North Topeka Unit, Station 364+60, Fairchild Pump Station – Problem: Uplift

The alternative selected for this location is removal and disposal of the pump station. There are no known contaminated sites in the vicinity of this proposed work. The nature of this work (demolition and disposal of a structure) is not likely to be significantly impacted even if a contaminated site were located nearby. The only concern would be to ensure any soil brought in to backfill the void left by removal of the structure has been tested and certified to be clean.

Waterworks Unit, Station 0+78 to 7+00 and 10+00 to 16+60 – Problem: Sliding Stability

The alternative selected to address the sliding stability of floodwall in this area includes the addition of a stability berm adjacent to the wall. The only concern is to ensure the material brought on-site for use has been tested and certified to be clean.

South Topeka Unit, Station 75+84, Kansas Avenue Pump Station – Problem Strength

The work associated with this location is reinforcing the structure of the pump station, so there is little or no risk of HTRW impacting this work.

South Topeka Unit, Station 86+00, Madison St. Pump Station – Problem: Uplift

The alternatives considered for this location that could be impacted by HTRW contamination involve removal and replacement or heel extension. However, based on the HTRW assessment, the risk of contamination impacting either alternative is very low. However, any soil removed from the site should be tested to ensure proper disposal and any soil brought onto the site should be tested to ensure it is clean.

South Topeka Unit, Stations 16+07, 84+10, 84+10a, 85+57, Manholes – Problem: Uplift

The alternatives considered at each of these locations are either removal or replacement of the manhole or the addition of a heel extension. Based on the HTRW assessment, there are no known contaminated sites located near the manhole at station 16+07, but there are several known contaminated sites located to the east, south, and west of the manholes at stations 84+10 and 85+67. Even though there are contaminated sites in the vicinity, it is not believed that contamination exists at the exact location of the manholes. Also, the proposed work appears to cover a fairly small footprint at each of these locations. Therefore, the risk of HTRW having a significant impact on this work is considered low. However, any soil removed from these locations should be tested and properly disposed based upon test results.

South Topeka Unit, Station 74+41 to 93+86 – Problem: Floodwall foundation weakness

The alternative selected for this location is removal and replacement of the floodwall on the existing alignment. Also, it includes the replacement of four gate wells and three sluice gates as part of the wall replacement. There are several known contaminated sites located to the east, south, and west of this location. There is no known soil contamination in the immediate vicinity of the wall. However, the description from the Scotch Cleaners site located to the southeast of the site indicates a groundwater plume of chlorinated solvents is emanating from this site and extends north-northeast to the Kansas River. This plume is likely to be present below the floodwall. Therefore, any work associated with the wall, gate well, or sluice gate replacement that will encounter groundwater is at high risk of being negatively impacted by the contaminated plume.

South Topeka Unit, Station 22+00 to 48+00 – Problem: Underseepage

The alternatives being considered for this location are either an underseepage berm or relief wells. Research associated with the HTRW assessment identified two known contaminated sites about 1,000 feet east of this location. The primary contaminates on these sites was lead and some limited petroleum contamination. Based on their proximity and nature of the contamination, the risk of these sites impacting the proposed work is low. There is another site located 2,700 feet to the southwest of the proposed work where an underground storage tank was removed. There was no contamination found during removal of the tank so it is not believed this site poses any HTRW risk to the work. There are also railroad tracks located south of the site, but they appear to be far enough away not to pose a contaminant risk to the proposed work. However, any soil removed from the site should be tested to ensure proper disposal and any material brought onto the site should be tested to ensure it is clean.

Oakland Unit, Station 220+00, East Oakland Pump Station – Problem: Uplift

The work proposed at this location is to add a heel extension to resist uplift pressures. There are several former solid waste facilities identified within 400 feet to the east and north east of this location. These are identified as construction and demolition disposal facilities so there is not believed to be any risk of HTRW contamination associated with these sites. This combined with the fact that the proposed work will be isolated to a small footprint adjacent to the existing pump station, makes the risk of HTRW contamination impacting the work very low.

Oakland Unit, Station 75+50, Manhole – Problem: Uplift

The alternatives considered at this location are removal and replacement of the manhole or the addition of a heel extension. Based on the HTRW assessment, there were several underground storage tanks closed about 1,300 feet southeast of the site. The description provided indicated very little contamination found during these removals. No other sites were identified near this location. Therefore, it is believed the risk of HTRW contamination impacting the work is very low. However, any soil removed from these locations should be tested and properly disposed based upon test results.

Oakland Unit, Station 485+86 to 491+01 – Problem: Sliding Stability

The alternative selected to address the sliding stability of floodwall in this area includes the addition of a stability berm adjacent to the wall. The only HTRW concern for this work is to ensure the material brought on-site for use has been tested and certified to be clean.

Oakland Unit, Station 64+00 to 80+00 – Problem: Underseepage

The alternatives being considered for this location are either an underseepage berm or relief wells. Based on the HTRW assessment , there were several undergrouind storage tanks (UST) closed about 1,300 feet southeast of the site. The description provided indicated very little contamination was found during the removal of the tanks. No other sites were identified near this location. Since these sites are 1,300 feet from the proposed work, there is little or no HTRW risk of impacting the underseepage berm alternative. Also, there was no contaminated groundwater concern cited in associated with the UST removals, therefore risk of groundwater contamination impacting relief well installation and operation is considered low. However, any soil removed from the site should be tested to ensure proper disposal and any material brought onto the site should be tested to ensure it is clean.

South Topeka Borrow Site

The HTRW assessment found only one site with a potential impact to the use of this area as a borrow site. A site located at the southwest corner of the proposed borrow area was once permitted as a city dump. It is not known what types of waste were accepted at this facility or the lateral limits of the disposal cells. Even if contaminated material were disposed in this area, it is unlikely to impact areas outside the disposal cells. Liquid waste or contaminants mobilized by infiltrating precipitation would migrate vertically until intercepting groundwater rather than horizontally. Therefore, the borrow areas would still be usable provided an adequate buffer zone between the disposal cells and borrow areas is established. However, depending on the lateral limits of the disposal cells, there may not be as much borrow material available for use as anticipated.

It is recommended that more detailed information regarding the lateral limits of the disposal areas be obtained through research and field investigations if necessary. After the limits of the disposal area is determined and the remaining area available for borrow established, it is recommended that samples for chemical analysis be collected from the proposed borrow area. This will ensure that no contamination material is being transferred from one location to another within the project limits.

Oakland Borrow Site

The HTRW assessment found only one site with a potential impact to the use of this area as a borrow site. A site located at the southwest corner of the proposed borrow area was once permitted as a city dump. Information provided on the site indicated that debris from the 1968 tornado was buried in that location. The range of waste types is unknown that may have been disposed in this location or the lateral limits of the disposal cells. Even if contaminated material were disposed in this area, it is unlikely to impact areas outside the disposal cells. Liquid waste or contaminants mobilized by infiltrating precipitation would migrate vertically until intercepting groundwater rather than horizontally. Therefore, the borrow areas would still be usable provided an adequate buffer zone between the disposal cells and borrow areas is established.

However, depending on the lateral limits of the disposal cells, there may not be as much borrow material available for use as anticipated. It is recommended that more detailed information regarding the lateral limits of the disposal areas be obtained through research and field investigations if necessary to more closely estimate the amount of borrow available. After the limits of the disposal area is determined and the remaining area available for borrow established, it is recommended that samples for chemical analysis be collected from the proposed borrow area. This will ensure that no contamination material is being transferred from one location to another within the project limits.

Conclusions and Recommendations

Overall, the environmental assessment found very little risk associated with HTRW contamination on proposed activities. However there were three areas where there was a potential HTRW or solid waste impact to the proposed work. There is a need to insure that the lateral limits of any contamination be established to insure that remediation measures are incorporated into the final construction plans.

South Topeka Unit, Station 74+41 to 93+86

There is a high probability that groundwater below this area is contaminated with chlorinated solvents. Any alternatives that will encounter groundwater during construction activities have a high risk of encountering HTRW. Also, if operation of the new facilities results in the discharge of groundwater to the surface, environmental impacts will need to be evaluated.

South Topeka Borrow Site

A former city dump was identified at the southwest corner of the proposed borrow area. The limits of the disposal cells are unknown so there may not be as much borrow area available as anticipated. Investigations are recommended to determine the nature of materials accepted and the lateral limits of the dump. Also, samples from the proposed borrow should be collected and analyzed to ensure material to be used on other sites is clean.

Oakland Borrow Site

A former city dump was identified at the southwest corner of the proposed borrow area. It was described as having debris from a 1968 tornado. The limits of the disposal cells are unknown so there may not be as much borrow area available as anticipated. Investigations are recommended to determine the nature of materials accepted and the lateral limits of the dump. Also, samples from the proposed borrow should be collected and analyzed to ensure material to be used on other sites is clean.

Also, it is recommended that any soil removed from a site associated with the levee work be analyzed to ensure proper disposal. Any soils used to upgrade the levee system should be analyzed to ensure it is not contaminated. Both of these practices ensure that contamination is not being inadvertently spread from one site to another.

Prepared by Paul Speckin,
HTRW Specialist

FEASIBILITY STUDY REPORT
TOPEKA, KANSAS, FLOOD RISK MANAGEMENT PROJECT

APPENDIX A

ENGINEERING

DEPARTMENT OF THE ARMY
Kansas City District, U.S. Army Corps of Engineers
Kansas City, Missouri

FEASIBILITY STUDY REPORT
Topeka, Kansas, Flood Risk Management Project

APPENDIX A
ENGINEERING

A-1 GENERAL

A-1.1 INTRODUCTION

The purpose of the Engineering Appendix is to document engineering efforts completed during the Topeka, Kansas, Local Protection Project Feasibility Study development.

The focus of the engineering effort during the feasibility study is on understanding existing conditions, associated data collection and inventories, framing the nature of problems, developing potential solutions to those problems, refining solutions in light of evaluation criteria, and offering the final engineering necessary to support a plan (or plans) within the planning process.

The engineering for this study was developed to the level of detail sufficient to prepare a feasibility baseline cost estimate(s), general project schedule, and support the recommended plan. The results of engineering investigations, studies, and feasibility level designs (hereinafter normally termed "design") are presented in this engineering appendix to the feasibility report. The location and vicinity map of the project is shown on Plate A-1.1.

This engineering appendix supports the Feasibility Report which is aimed at examining potential improvements to increase the existing project performance consistent with the original authorization. This engineering appendix (similar to the main report) focuses on four of the six levee units that compose the Topeka system: Waterworks, South Topeka, Oakland, and North Topeka. The Auburndale and Soldier Creek Units were determined to meet the authorized level of protection assuming continued adequate operations and maintenance efforts.

A-1.2 PROJECT LOCATION AND LIMITS

The existing project extends along approximately 10 miles of the Kansas River as it passes through Topeka, and includes levees on two tributaries, Soldier Creek and Shunganunga Creek. The six units of the flood protection system were designed and constructed in conjunction with each other, but are independently operated to some extent. The total protected area covers about 32 square miles and is characterized by industrial, commercial, and residential development.

A-1.3 ENGINEERING EFFORTS

A Corps of Engineers (COE) reconnaissance level report was completed in September, 1997. The Reconnaissance Report identified a Federal interest in further investigations. That recommendation led to the current Feasibility Study. An early effort under feasibility was development of the Review of Existing Local Flood Protection Project Report prepared and submitted to the COE by HDR Engineering, Inc. in January, 2000 (the HDR Report). The general purpose was to review and document available historic and current design information and condition of the structural features of each unit.

The HDR Report was incorporated into work on existing conditions analysis of each unit in the system. Additionally, information was gathered (where available) from the original design documents, Operation and Maintenance (O&M) manuals, and associated studies. The Corps utilized current hydrology/hydraulics models, and geotechnical/structural risk and uncertainty (R&U) study methods to develop the engineering portions of the existing conditions (baseline) analysis of the existing project. Much of this analysis was based on data and observations from recent high water events (since the original project design), especially those in 1993. This new engineering analysis, along with the economic (HEC-FDA) analysis, established a complete R&U approach to estimating existing conditions flood damages. The engineering and economic evaluations taken together with a summary baseline environmental review and an HTRW review of the study area formed the full picture of existing conditions. A review of existing conditions results by the study team provided guidance during the scoping and development of future conditions (with and without project). This Engineering Appendix to the Feasibility Report identifies those areas.

The engineering risk and uncertainty analysis is summarized below. Details and calculations supporting the results appear within the various chapters of the engineering appendix.

Geotechnical and Structural engineers determined the most likely expected modes and sites of failure prior to overtopping in each Unit. A full range of conditional probabilities of failure versus river stage elevation encompassing the Probable Failure Point (PFP) and Probably Non-Failure Point (PNP) were determined by geotechnical and structural engineer PDT members for each site/mode of failure in each Unit. The geotechnical probabilities of failure were developed based on procedures identified in ETL 1110-2-556, "Risk-Based analyses for Geotechnical Engineering for Support of Planning Studies", except that the acceptable factor of safety identified in the ETL was modified to a more realistic factor of safety based on Kansas City District 1993 flood observations and historical experience. To produce the structural probability of failure versus river stage curve, critical sections of each structure were analyzed (stability and strength factors of safety determined) using material strengths and soil properties. Next, the soil and material parameters were varied to plus and minus one standard deviation from the mean, one at a time, and the factor of safety was recomputed. A Taylor series expansion was used to compute a probability of failure.

The areas of interest are as follows:

Waterworks Floodwall. Findings for structural risk have led the PDT to undertake evaluations which are aimed at increasing the unit's overall level of performance. This portion of the study examined methods for reduction of structural stability risk.

South Topeka Levee. Findings for geotechnical risk have led the PDT to undertake evaluation of measures to better control underseepage in a reach of the South Topeka levee. The recommended solution is construction of a landside underseepage berm.

South Topeka Floodwall. Findings for structural risk have led the PDT to undertake evaluation of strengthening and/or replacement measures for this floodwall. The South Topeka floodwall is a pile-founded wall with steel sheet pile to provide protection from underseepage. The wall is approximately 1900 ft. long. The wall was constructed in 1938 and original design and construction parameters are not available. The timber piles may be inadequate to support the floodwall under some conditions. The recommended solution is removal and replacement of the existing wall.

South Topeka – Kansas Avenue Pump Station. Findings for structural risk have led the PDT to undertake evaluation of strengthening the foundation of the station to increase its strength bearing capacity. The recommended solution is interior reinforcement of the foundation wall through the installation of a wall stiffener.

Oakland Levee. Findings for geotechnical risk have led the PDT to undertake evaluation of measures to better control underseepage in a reach of the Oakland levee adjacent to the Oakland Wastewater Treatment Plant. The recommended solution is construction of a landside underseepage berm.

Oakland Unit – Shunganunga Floodwall. Findings for structural risk have led the PDT to undertake evaluations which are aimed at increasing structural reliability of the floodwall reach of the Oakland Unit along Shunganunga Creek.

Oakland Unit – East Oakland Pump Station. Findings for structural risk have led the PDT to undertake evaluation of measures to better control uplift at the Station. The recommended solution is construction of a heel extension.

North Topeka Levee. Findings for geotechnical risk indicate the need for measures to improve underseepage control in two areas lying along the left (north) bank of the Kansas River. The recommended solution for the first area is the construction of a landside underseepage berm. The recommended solution of the second area is construction of a series of pressure relief wells with a header discharging to a manhole and provision for temporary pumping to effectively draw down the pressures in this area.

North Topeka Unit – Fairchild Pump Station. Findings for structural risk led the PDT to evaluation measures to better control uplift at the station. The recommended plan is removal of the station.

A-1.4 SELECTED PLAN

The selected plan is the National Economic Development Plan (NED) that maximizes the net benefits while providing a favorable benefit to cost ratio. The NED plan was developed for each of the four units containing the areas of interest and the combination of these individual NED plans is considered the overall system NED plan.

Chapter A-2

HYDROLOGY and HYDRAULICS ANALYSIS

Topeka, Kansas
Flood Risk Management Feasibility Study
Appendix A – Engineering
Chapter 2 – Hydrology and Hydraulics Analysis

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A-2 HYDROLOGIC AND HYDRAULIC ANALYSES

A-2.1 KANSAS RIVER

A-2.1.1 INTRODUCTION

As part of the feasibility study, a hydraulic investigation was conducted on the Kansas River using the HEC-RAS computer software developed by the Hydrologic Engineering Center, U.S. Army Corps of Engineers. The program was used to calculate water surface profiles on the reach of the Kansas River that runs through Topeka, Kansas. The study covers approximately river miles 73 through 96.5 of the Kansas River. A backwater model of this reach was developed using 1997 field surveys and 1995 aerial contour maps, and was calibrated using high water marks from the 1993 Flood. The levee units that protect Topeka along the Kansas River are: North Topeka Unit, Water Works Unit, Auburndale Unit, South Topeka Unit, and Oakland Unit. A general location map can be found with the plates at the end of the main report.

A-2.1.2 PURPOSE

The purpose of this investigation is to develop Kansas River water surface profiles through the City of Topeka reflecting the base (or existing) conditions. The resulting hydraulic model will be used to evaluate a series of alternatives for improving the integrity of the existing flood control system.

A-2.1.3 HYDROLOGY

In March 2002, the Corps of Engineers completed the Kansas River Hydrology[1] study with special attention to the Kansas River near Topeka. This study used a similar procedure as the Upper Mississippi River System Flow Frequency Study[2] (UMRFFS), which is a complex evaluation of the regulated and unregulated flows on the Mississippi, lower Illinois, and Missouri Rivers. UMRFFS has already been published, and the Kansas River Hydrology study has been subject to a full independent technical review. The Kansas River Hydrology study utilized the regulated and unregulated flow data developed in UMRFFS for the Kansas River basin to determine the discharge-frequency relationships at the Kansas River gages. By combining these results, regionalization equations were developed relating drainage area and discharge for different frequency events. These equations were used to determine the discharges on the Kansas River. The results from the Kansas River Hydrology study near Topeka are shown in Table 1-1.

[1] "Kansas River Hydrology with Special Attention To: Kansas River Hydrology near Topeka, KS." U.S. Army Engineer District, Kansas City, March 2002.
[2] "Upper Mississippi River System Flow Frequency Study, Appendix E, Hydrology." U.S. Army Engineer District, Kansas City, pending publication.

Table 1-1 Flow Frequency Data as developed in Kansas River Hydrology 2002

Percent Chance of Exceedance	At Topeka Gage (cfs)	Downstream of Soldier Creek (cfs)	Downstream of Shunganunga Creek (cfs)
0.2	348,000	348,000	348,000
0.5	268,000	270,000	271,000
1	217,000	220,000	221,000
2	173,000	176,000	177,000
5	123,000	126,000	126,000
10	93,600	96,600	97,200
20	67,200	69,600	70,200
50	36,600	38,100	38,500
Drainage Area (sq mi)	56,720 sq. mi.	57,024 sq. mi.	57,094 sq. mi.

Since flood events above the 0.2% chance exceedance (500 year) event need to be considered in this study, the discharge-frequency curves were extended up to the 0.04% chance exceedance (2500 year) event. To accomplish this, a straight-line extrapolation was used on a log-probability plot of the discharge frequency events at the Topeka gage. As in the 0.2% event, the extreme floods do not vary downstream of the Soldier and Shunganunga confluence. Plate A2-1-1 at the end of this chapter shows the discharge-frequency curve for the Kansas River at the Topeka gage. Table 1-2 summarizes all of the discharges used on the Kansas River for the existing conditions model.

Table 1-2 Summary of Flood Discharges Used in this Study

Percent Chance of Exceedance	Return Interval (yr)	At Topeka Gage (cfs)	Downstream of Soldier Creek (cfs)	Downstream of Shunganunga Creek (cfs)
0.04	2500	500,000	500,000	500,000
0.1	1000	410,000	410,000	410,000
0.133	750	387,000	387,000	387,000
0.2	500	348,000	348,000	348,000
0.5	200	268,000	270,000	271,000
1	100	217,000	220,000	221,000
2	50	173,000	176,000	177,000
10	10	93,600	96,600	97,200

A-2.1.4 Hydrologic Uncertainty

In the past, the Corps of Engineers used freeboard as a factor of safety in designing levees to account for uncertainties in discharge, stage, and other engineering parameters (such as geotechnical and structural). Now, the Corps of Engineers has adopted a new methodology called Risk Based Analysis (RBA) for formulating flood risk management projects. This method considers all of the same engineering parameters, but accounts for the uncertainties directly in the analysis in lieu of using freeboard. Using RBA, the project performance will be expressed as the average return period in years of the largest flood that can be accommodated by the plan under study, with a conditional non-exceedance probability of 90%. The concept of freeboard is no longer used.

To use RBA, the hydrologic uncertainty must be characterized. This information is entered into the computer program HEC-FDA (Flood Damage Analysis), which uses Monte Carlo algorithms to quantify the uncertainties. The uncertainty bands used in this program are based on the effective record lengths used to develop the flow frequency estimates. According to Table 4-5 in EM 1110-2-1619, for a regional study the effective record length is taken as the average length of records used. According to the Kansas River Hydrology Study, the length of record used at Wamego, Lecompton, and Desoto was 77 years; at Topeka the record length was 95 years. This averages to 82 years, which was considered the effective record length.

HEC-FDA calculates the uncertainty either analytically or graphically. For an analytical computation the log Pearson Type III statistics are inputted directly. A graphical approach is used on regulated streams, when the stream gage records are small or incomplete, or when partial duration data is used. For the Kansas River, the discharge-probability curve was defined graphically. HEC-FDA uses the procedures outlined in ETL 1110-2-537 "Uncertainty Estimates for Nonanalytic Frequency Curves" to calculate the error limit curves using order statistics. This is related as standard deviation of the discharge estimate. To produce realistic estimates of the uncertainty curves, high probability flood events needed to be estimated. Using the graphical plot features in HEC-FDA, the values were adjusted to obtain a reasonably shaped curve. The full range of discharges was then entered into HEC-FDA under the graphical curve option. Table 1-3 shows hydrologic uncertainty results on the Kansas River near the Topeka gage. For the HEC-FDA analysis, an arbitrary index point was selected for each levee unit to calculate the damage-probability curve. Since the index point on each levee is located upstream of the Soldier Creek confluence, only the discharge uncertainty in the reach near the gage was calculated.

Table 1-3 Hydrologic Uncertainty on Kansas River near Topeka Gage

Exceedance Probability	Discharge (cfs)	Confidence Limit Curves (standard error) Discharge (cfs)			
		-2 SD	-1 SD	+1 SD	+2 SD
0.999	6000	4130	4980	7230	8710
0.99	8880	6490	7590	10,390	12,160
0.95	12,980	9990	11,380	14,790	16,860
0.9	16,070	12,810	14,350	18,000	20,160
0.8	21,060	17,310	19,090	23,230	25,620
0.7	25,800	21,380	23,490	28,340	31,140
0.5	36,600	30,280	33,290	40,240	44,230
0.3	53,450	43,420	48,170	59,290	65,780
0.2	67,200	53,360	59,880	75,420	84,640
0.1	93,600	70,260	81,100	108,030	124,690
0.04	134,350	92,550	111,510	161,870	195,030
0.02	173,000	113,700	140,250	213,400	263,240
0.01	217,000	136,420	172,060	273,680	345,170
0.004	286,250	170,120	220,670	371,310	481,640
0.002	348,000	198,590	262,880	460,680	609,830
0.001	417,980	229,470	309,700	564,120	761,360

A-2.1.5 HYDRAULICS

The hydraulic analysis for this report centered on the development of the HEC-RAS computer model for the study reach of the Kansas River at Topeka, Kansas. For this analysis, version 3.0.1 of the HEC-RAS (River Analysis System) developed by the Hydrologic Engineering Center was used. The computer model was calibrated to the 1993 flood using known water surface elevations (high-water marks) and discharge. Once the model was calibrated, a series of steady flow water surface profiles were created based on flood discharges in Table 1-2 above.

Original Design Water Surface Elevations

The elevation of the crown of the existing levee was determined by selecting a design water surface elevation and then adding freeboard to account for uncertainties. Freeboard for all levee units in the Topeka system on the Kansas River was three feet except at the Waterworks Levee Unit, which ranged from 2.2 to 2.8 feet. The design water surface elevations were determined by using a backwater computer model with the design discharges. The original design discharges for the Topeka levee system assumed the discharge from Soldier Creek was 50,000 cfs while the discharge above Soldier Creek on the Kansas River was 314,000 cfs. The combined flow downstream of the confluence was 364,000 cfs. The resulting top of protection was approximately equal to the 50% non-exceedance probability for the 0.2%-chance (500-yr) flood.

Geometric Data

The computer model required cross section geometry along the length of the study reach. The information used to create the cross-section geometry was obtained from two sources. The U.S. Army Corps of Engineers provided 1997 cross-section surveys of the channel that covered the entire length of the study (RM 73 – 96.5). The City of Topeka provided a surveyed levee-top profile of the North Topeka Unit, and two and four foot contours, from 1995 aerial mapping, within the Topeka city limits. Top of Levee elevations were also obtained from a 2004 COE survey for the Waterworks, Auburndale, Oakland, and North Topeka Units. Outside of the city limits, the overbanks were modeled using United States Geological Survey (U.S.G.S.) 7.5 minute quadrangle maps. In order for the model to more accurately compute friction losses, additional cross sections were interpolated between surveyed cross sections and then modified based on aerial photographs and on-site inspection.

Based on field investigations and review of aerial photography, appropriate Manning's "n" coefficients were selected for each cross section. Values from 0.020 to 0.035 were selected for the channel throughout the entire study reach. Overbank "n" values ranged from 0.040 for well maintained grassy areas to 0.15 for heavily treed areas with dense undergrowth.

Bridge data was obtained from engineering drawings provided by: Kansas Department of Transportation, City of Topeka, Shawnee County, the U.S. Army Corps of Engineers, and the Burlington Northern Santa Fe Railroad. The operational drawings of the Chicago Rock Island Railroad Bridge, located at RM 84.64, detail emergency procedures to raise the bridge eleven feet when a flood event of a certain magnitude is forecast. Since the procedures are in place and the mechanisms tested regularly, this bridge was modeled in the "up" position.

There is a weir in the channel near the waterworks that was not surveyed. Since it is inconsequential during the larger events, it was not included in the model.

Starting Water Surface Elevation

The starting water surface elevations for all discharges are from a rating curve developed from water surface elevation/discharge relationships at the starting point of the study reach (near the confluence of Whetstone Creek). These relationships were taken from the Shawnee County Kansas Flood Insurance Study (Revised May 17, 1993).

Calibration

The model was calibrated using high-water marks that were set during the 1993 flood. The discharge used for these high-water marks was 170,000 cubic feet per second (cfs) and was obtained from U.S.G.S. Peak Flow Data (Water Year 1993) for the gage on the right bank at the downstream side of Sardou Bridge (RM 83.1, U.S.G.S. Station Number 6889000). The 170,000 cfs was used from the beginning cross section at river mile 72.84 to the upper end of the study at river mile 96.55. Soldier Creek enters the Kansas River at approximately river mile 80.6. The discharge from Soldier Creek on the day of the peak Kansas River discharge in 1993 was only 2200 cfs and was not considered in the calibration.

The calibration of the backwater program to the high-water marks was accomplished by adjusting the Manning's "n" values for the channel until the profile matched the high-water marks. In this case, the 170,000 cfs required "n" values of 0.03 to 0.035 in the channel downstream of Sardou Avenue Bridge. Starting just upstream of Sardou Bridge, the "n" values changed to 0.02 and did not vary until about RM 86. Above this point, the "n" values again ranged from 0.03 or 0.035. The overbank "n" values ranged from 0.04 to 0.15 based on overbank conditions. Higher values of "n" were also used to reduce flow in overbanks that were either very wide or contained obstructions. For the side slopes of the levees, "n" values of either 0.040 or 0.045 were used. Table 1-4 compares the observed high water marks to the computed water surface elevation for the 1993 flood event. Plate A2-1-2 shows a graph of this same information.

Table 1-4 Comparison of 1993 High Water Mark Elevations and Computed Water Surface Elevations (WSEL) - Kansas River

HEC-RAS River Station	Location	Observed 1993 High-Water Mark Elevation (ft)	Computed Water Surface Elevation* (ft)	Difference: Computed WSEL vs. High Water Mark (ft)
76.25	Oakland (285+00)	870.5	871.2	0.7
77	Oakland Drainage Structure	871.4	872.2	0.8
77.4	FB-3 Oakland	874.4	872.5	-1.9
78.5	Belmont Rd Ramp on Oakland Levee	874.9	874.3	-0.6
80.4	FB-4 Oakland	877.2	876.9	-0.3
82.7	FB-8 Oakland	880.9	880.6	-0.3
83.1	Sardou Gage	881.6	881.0	-0.6
83.78	DS face A.T. & S.F. RR Bridge	881.6	882.0	0.4
83.79	US face A.T. & S.F. RR Bridge	881.9	882.2	0.3
84.21	DS face of Kansas Ave. Bridge	882.5	883.2	0.7
84.22	US face of Kansas Ave. Bridge	882.7	883.3	0.6
84.57	US face of Topeka Ave. Bridge	883.1	883.5	0.4
85.64	FB-18 South Topeka	884.3	884.6	0.3
87.1	Waterworks Drainage Structure	886.5	886.7	0.2
87.92	Highway 75	888.1	888.1	0.0

*Note: Computed Water Surface Elevation was interpolated the HEC-RAS River Station

Most of the computed water surface elevations matched the 1993 high-water marks within a few tenths of a foot. However, not all the high-water marks were matched precisely. The reason for this may be due, in part, to errors in the establishment of those marks. Some of the high-water marks were taken immediately after the 1993 flood crest receded, by examining the location of debris along the banks or levees. Another set of high-water marks, obtained from the City of Topeka, were taken from the tops of flood walls, freeboard gages, or the tops of gated structures. One example of a problem in meeting these marks occurred downstream of the Oakland Expressway bridge where there is a large jump in the marks between STA. 77 and STA. 77.4. Assuming these elevations were correct, the model could not be made to match this inconsistency without adjusting the "n" values to unreasonable extremes. In general, there are a number of different scenarios that can cause errors or inconsistencies with high water marks. These may include swellhead from debris blockage, relative proximity to the channel, and misinterpretation of field conditions. Because the validity of these particular high water marks is unknown, no additional effort was made to reproduce them in the model.

The flooding limits of the model were compared to a Flooded Area Map from the U.S. Army Corps of Engineers Post Flood Report, 1993 Kansas River Basin Flood, shown on Plates A2-1-3 and A2-1-4. During this process, it became apparent that the aerial photographs used to make the maps were not taken at the flood peak (170,000 cfs). The maps are dated JUL & AUG 1993. The actual river stage at Sardou bridge was within five feet of the peak flow stage (7-25-93) for only five days (five feet of elevation significantly changes the flooding extents). When the HEC-RAS model is run with a discharge of 110,000 cfs, it closely resembles the shape of the flood extents depicted on the map.

Model Verification

A gaging station is operated by the U.S.G.S. at the Sardou Bridge, Kansas River mile 83.1. The 1996 rating curve (rating no. 46 shown on Plate A2-1-5) developed for this gage was used to check the computed stage vs. discharge at this location. During the process of examining various discharges, a check was made of how well the model predicted the water surface elevation at the gage at Sardou Bridge.

To test the calibration of the model over a wide range of discharges, water surface profiles were computed for a series of discharges: 50, 20, 10, 4, 2, 1, 0.5, and 0.2-percent chance (2, 5, 10, 25, 50, 100, 200, and 500-year flood events) as determined by the Corps of Engineers in the 2002 Kansas River Hydrology Report (see Table 1-1). Table 1-5 shows these eight event discharge elevations versus the expected water surface elevation at the gage at Sardou Bridge. The gage elevations were determined from the 1996 rating curve which shows the stage versus the discharge. The stage was converted to an elevation by simply adding the elevation of the gage datum (846.66 feet, N.G.V.D.) to the stage reading. The largest discharge of the 1996 rating curve was 172,000 cfs, so that stages larger than 172,000 cfs were obtained by extrapolation. Rating curve no. 46 was used from January 1996 to September 2000.

Table 1-5 Computed Water Surface Elevation versus Expected Gage Height

Percent Chance of Exceedance (%)	Annual Event Discharge (cfs)	Computed Water Surface Elevation (ft)	Sardou Rating Curve Elevation (ft)	Difference: Computed vs Expected Gage Elevation (ft)
50	36,600	865.74	864.40	1.34
20	67,200	871.59	870.86	0.73
10	93,600	875.30	875.59	-0.29
5	123,000	877.70	878.42	-0.72
2	173,000*	881.24	881.86	-0.62
1	217,000*	883.66	884.46	-0.80
0.5	268,000*	886.04	886.86	-0.82
0.2	348,000*	889.28	890.16	-0.88
Note: All model elevations are from STA 83.1003				

*Discharge values greater than 172,000 cfs were determined by extrapolation of the Rating Curve #46

Kansas River Existing Condition (Base) Profiles

Once the model was calibrated, the existing conditions water surface profiles were generated using the discharges of Table 1-2 above. Plate A2-1-6 shows the profiles for the 10, 2, 1, 0.5, 0.2, 0.133, 0.1, and 0.04-percent chance (10, 50, 100, 200, 500, 750, 1000, and 2500-year) flood events. The tabular data is presented in Table 1-6, found at the end of this section.

The HEC-RAS model indicates that none of the Kansas River Levee Units in this study physically overtop until the water surface elevation reaches the 50% non-exceedance probability stage for the 0.2% chance exceedance (500-yr) flow. Discretion should be used when applying profiles higher than the top of the levee. The model used a confined cross sectional area from levee to levee. Essentially, overbank flow beyond the levee height was not taken into consideration. This assumption was made to avoid trying to predict where a levee would fail. Within the Topeka levee systems, there are many different combinations of failure scenarios that could physically occur. Potentially, each could produce a different overbank flow path. HEC-RAS is a one-dimensional steady state model. It is beyond the limitations for HEC-RAS to predict the overbank flow scenarios or to model multi-dimensional flow. Profiles for the rare frequency events that exceed the top of levee are highly speculative and would not necessarily match what would physically happen. These events were produced to formulate frequency-stage curves for economic analyses in the HEC-FDA computer program.

Hydraulic Uncertainty

Uncertainties in computed stage result from two main sources: natural variations in the river and modeling errors. Natural variations include uncertainties in physical factors such as bed forms, debris and other obstructions, channel scour or deposition, sediment transport, and waves. Modeling uncertainty includes factors such as inexact geometry and loss coefficients, variation in hydraulic roughness with season, and error in setting high water marks (EM 1110-2-1619).

In Risk Based Analysis, the stage uncertainty is express as standard deviation (in feet). The total standard deviation depends on the standard deviation based on natural variations and the standard deviation based on model errors according to the formula below:

$$\text{Total Standard Deviation} = \sqrt{S_{natural}^{2} + S_{model}^{2}}$$

where $S_{natural}$ = standard deviation based on natural variations
S_{model} = standard deviation based on modeling uncertaities

For a gaged reached, $S_{natural}$ is calculated by comparing observed data with the latest rating curve at the gage in the study reach. To avoid potential problems due to shifts in the rating curve over time, only observed data going back to 1990 was used. Only data values for bank full discharges and greater were analyzed. The following formula is used to calculate $S_{natural}$.

$$S_{natural} = \sqrt{\frac{(X-M)^2}{(N-1)}}$$

where: X=Stage corresponding to measured Q
M=best fit curve estimate of stage corresponding to Q
N=number of stage-discharge observations in the range being analyzed

The standard deviation based on historical data and gage readings, $S_{natural}$, was computed as 0.48 feet.

Table 5-2 in EM 1110-2-1619 quantifies S_{model} based on the quality of topographic data and the reliability of the Manning's n-value. A standard deviation of 0.7 feet was chosen since the cross-sections were based on current aerial mapping and the Manning's n-values were assumed to be "fairly" reliable.

Once $S_{natural}$ and S_{model} are known, a total standard deviation can be computed. For this study a total standard deviation of 0.85 feet was computed for the entire discharge set.

A-2.1.6 SUMMARY

A hydraulic investigation was conducted on the Kansas River using the HEC-RAS computer software developed by the Hydrologic Engineering Center, U.S. Army Corps of Engineers. The program was used to calculate water surface profiles on the reach of the Kansas River that runs through Topeka, Kansas. The model was calibrated using high water marks from the 1993 flood. Water surface profiles were then generated for eight different discharge events. These include the 10, 2, 1, 0.5, 0.2, 0.133, 0.1, and 0.04-percent chance (10, 50, 100, 200, 500, 750, 1000, and 2500-year) flood events. The model shows that the existing levees are overtopped by the 0.2% chance exceedance (500-year) flood event with a 50% non-exceedance probability. Finally, the uncertainty in both stage and discharge were calculated. The standard deviation of stage is 0.85 feet. The discharge uncertainty results are shown above in Table 1-3 for a range of frequencies.

Table 1-6 Kansas River Existing Conditions Water Surface Profiles

HEC-RAS River Station	Profile	Q Total (cfs)	Water Surface Elevation (ft)	Energy Grade Elevation (ft)	Energy Grade Slope (ft/ft)	Average Channel Velocity (ft/s)	Flow Area (sq ft)	Top Width (ft)	Channel Froude #
72.843	0.04% (2500-yr)	500000	879.17	879.38	0.000101	5.79	220745.4	12666.12	0.16
72.843	0.1% (1000-yr)	410000	876.13	876.36	0.000114	5.82	182829.5	12267.71	0.17
72.843	0.133% (750-yr)	387000	875.35	875.59	0.000117	5.82	173333.6	12165.89	0.17
72.843	0.2% (500-yr)	348000	874.03	874.28	0.000122	5.79	157414.3	11993.25	0.17
72.843	0.5% (200-yr)	271000	871.43	871.7	0.000127	5.63	113783.7	11652.27	0.17
72.843	1% (100-yr)	221000	869.74	869.98	0.000117	5.21	100747.4	10508.8	0.17
72.843	2% (50-yr)	177000	867.46	867.71	0.000122	5.04	83149.5	9153.81	0.17
72.843	10% (10-yr)	97200	860.67	861.06	0.000195	5.3	31090.44	7354.23	0.2
73.355	0.04% (2500-yr)	500000	879.48	879.71	0.000125	6.25	223394.7	13601.15	0.18
73.355	0.1% (1000-yr)	410000	876.47	876.73	0.000142	6.33	182671.1	13464.22	0.19
73.355	0.133% (750-yr)	387000	875.7	875.97	0.000147	6.34	172318.5	13429.19	0.19
73.355	0.2% (500-yr)	348000	874.39	874.67	0.000154	6.33	154806.2	13369.73	0.19
73.355	0.5% (200-yr)	271000	871.8	872.09	0.000158	6.07	111270	13235.94	0.19
73.355	1% (100-yr)	221000	870.08	870.35	0.000149	5.68	97258.56	13134.64	0.19
73.355	2% (50-yr)	177000	867.82	868.07	0.000143	5.27	81009.14	7130.71	0.18
73.355	10% (10-yr)	97200	861.23	861.63	0.000237	5.62	34497.89	6980.34	0.22
74.307	0.04% (2500-yr)	500000	880.05	880.33	0.000111	5.8	195333.3	14305.34	0.17
74.307	0.1% (1000-yr)	410000	877.11	877.43	0.000127	5.86	154632.8	13404.42	0.18
74.307	0.133% (750-yr)	387000	876.36	876.71	0.000134	5.93	138366.3	13166.64	0.18
74.307	0.2% (500-yr)	348000	875.08	875.44	0.000139	5.88	124175.6	12711.61	0.18
74.307	0.5% (200-yr)	271000	872.5	872.87	0.000144	5.67	95608.34	11814.83	0.18
74.307	1% (100-yr)	221000	870.74	871.11	0.000142	5.4	76125.95	11762.57	0.18
74.307	2% (50-yr)	177000	868.46	868.76	0.000128	4.85	58643.15	5769.48	0.17
74.307	10% (10-yr)	97200	862.25	862.5	0.00013	4.06	29402.84	3882.23	0.16
75.21	0.04% (2500-yr)	500000	880.48	880.81	0.000152	6.62	189776.1	14836.82	0.19
75.21	0.1% (1000-yr)	410000	877.62	878.05	0.000189	6.99	137550.8	14613.31	0.21
75.21	0.133% (750-yr)	387000	876.91	877.36	0.000196	7.03	128996.5	14545.27	0.22
75.21	0.2% (500-yr)	348000	875.66	876.15	0.00021	7.1	114044.6	14425.83	0.22
75.21	0.5% (200-yr)	271000	873.13	873.71	0.000239	7.16	83947.42	12601.82	0.23
75.21	1% (100-yr)	221000	871.37	872.01	0.000254	7.08	63255.57	12263.26	0.24
75.21	2% (50-yr)	177000	869.04	869.62	0.000246	6.56	41029.38	6269.33	0.23
75.21	10% (10-yr)	97200	862.93	863.36	0.000234	5.32	20681.82	2005.55	0.22
75.309	0.04% (2500-yr)	500000	880.6	880.89	0.000156	6.56	199643.8	15531.12	0.19
75.309	0.1% (1000-yr)	410000	877.77	878.15	0.000199	7.02	144352	15317.31	0.22
75.309	0.133% (750-yr)	387000	877.06	877.46	0.000208	7.08	135595.3	15248.63	0.22
75.309	0.2% (500-yr)	348000	875.82	876.26	0.000228	7.21	120211.1	15127.93	0.23
75.309	0.5% (200-yr)	271000	873.27	873.84	0.000275	7.48	88727.73	13143.05	0.25
75.309	1% (100-yr)	221000	871.48	872.17	0.000315	7.66	66574.78	13064.69	0.26
75.309	2% (50-yr)	177000	869	869.86	0.000387	7.96	39847.99	8419.97	0.29
75.309	10% (10-yr)	97200	862.91	863.59	0.000398	6.65	15060.17	975.51	0.28
75.484	0.04% (2500-yr)	500000	880.72	881.05	0.000192	7.5	187650.4	16183.75	0.22
75.484	0.1% (1000-yr)	410000	877.93	878.35	0.000242	7.98	140278.3	14465.62	0.24

HEC-RAS River Station	Profile	Q Total (cfs)	Water Surface Elevation (ft)	Energy Grade Elevation (ft)	Energy Grade Slope (ft/ft)	Average Channel Velocity (ft/s)	Flow Area (sq ft)	Top Width (ft)	Channel Froude #
75.484	0.133% (750-yr)	387000	877.22	877.67	0.000256	8.1	131509.6	14396.68	0.25
75.484	0.2% (500-yr)	348000	875.98	876.5	0.000286	8.35	116088.9	14275.39	0.26
75.484	0.5% (200-yr)	271000	873.43	874.16	0.000367	8.96	84341.23	12444.85	0.29
75.484	1% (100-yr)	221000	871.6	872.59	0.000451	9.52	61518.19	12434.25	0.32
75.484	2% (50-yr)	177000	869	870.49	0.000624	10.5	33710.06	8945.02	0.37
75.484	10% (10-yr)	97200	863.02	864.18	0.0006	8.66	11329.21	623.85	0.34
76.29	0.04% (2500-yr)	500000	881.28	881.67	0.000194	7.51	169714.7	14888.49	0.22
76.29	0.1% (1000-yr)	410000	878.66	879.1	0.000222	7.64	136154.8	12581.6	0.23
76.29	0.133% (750-yr)	387000	878	878.46	0.000228	7.65	128527	12520.28	0.23
76.29	0.2% (500-yr)	348000	876.89	877.37	0.000239	7.66	115553.9	12414.21	0.24
76.29	0.5% (200-yr)	270000	874.71	875.24	0.00025	7.49	90610.23	12197.03	0.24
76.29	1% (100-yr)	220000	873.3	873.84	0.000246	7.19	74685.91	12059.46	0.23
76.29	2% (50-yr)	176000	871.5	872.13	0.000266	7.17	54719.37	11884.64	0.24
76.29	10% (10-yr)	96600	865.34	865.95	0.000289	6.31	18339.51	2854.59	0.24
77.045	0.04% (2500-yr)	500000	881.84	882.29	0.000187	7.49	170751.1	12572.11	0.22
77.045	0.1% (1000-yr)	410000	879.31	879.81	0.000205	7.47	131600.8	12352.35	0.22
77.045	0.133% (750-yr)	387000	878.68	879.19	0.000207	7.42	125122.6	12284.54	0.22
77.045	0.2% (500-yr)	348000	877.61	878.13	0.000209	7.29	114048.2	12165.88	0.22
77.045	0.5% (200-yr)	270000	875.52	876.02	0.000201	6.83	92369.34	11936.17	0.22
77.045	1% (100-yr)	220000	874.14	874.6	0.000183	6.33	78243.71	10077.32	0.21
77.045	2% (50-yr)	176000	872.49	872.93	0.000172	5.9	62056.17	9595.31	0.2
77.045	10% (10-yr)	96600	866.46	866.8	0.000159	4.81	28111.46	2852.69	0.18
77.73	0.04% (2500-yr)	500000	882	883.43	0.000645	11.44	133787.5	12048.43	0.34
77.73	0.1% (1000-yr)	410000	879.62	881.02	0.000641	10.88	106230.7	10041.62	0.34
77.73	0.133% (750-yr)	387000	879.04	880.4	0.000631	10.66	100344.8	9963.58	0.33
77.73	0.2% (500-yr)	348000	878.03	879.33	0.000608	10.24	90396.52	9830.28	0.32
77.73	0.5% (200-yr)	270000	876.04	877.14	0.000525	9.11	71078.86	9566.11	0.3
77.73	1% (100-yr)	220000	874.68	875.61	0.000449	8.16	58242.48	9385.96	0.27
77.73	2% (50-yr)	176000	873.08	873.86	0.000388	7.29	43500.34	8997.63	0.25
77.73	10% (10-yr)	96600	867.13	867.6	0.000306	5.5	17966.27	1125.15	0.21
78.577	0.04% (2500-yr)	500000	884.26	885.58	0.000609	11.78	137476.1	9622.91	0.34
78.577	0.1% (1000-yr)	410000	881.97	883.2	0.000575	10.99	115477.7	9595.44	0.32
78.577	0.133% (750-yr)	387000	881.37	882.56	0.000563	10.75	109705.9	9588.22	0.32
78.577	0.2% (500-yr)	348000	880.32	881.44	0.000536	10.28	99276.34	9332.05	0.31
78.577	0.5% (200-yr)	270000	878.09	879.03	0.00046	9.11	82742.23	7039.63	0.28
78.577	1% (100-yr)	220000	876.49	877.29	0.0004	8.21	71905.92	6481.55	0.26
78.577	2% (50-yr)	176000	874.69	875.38	0.000353	7.41	60253.82	6457.09	0.24
78.577	10% (10-yr)	96600	868.49	869.1	0.000355	6.32	20325.08	6431.25	0.23
78.853	0.04% (2500-yr)	500000	885.18	886.25	0.000493	10.54	133877.8	7007.12	0.3
78.853	0.1% (1000-yr)	410000	882.88	883.83	0.000453	9.69	117836.3	6982	0.29
78.853	0.133% (750-yr)	387000	882.27	883.19	0.000441	9.44	113564.9	6974.2	0.28
78.853	0.2% (500-yr)	348000	881.19	882.04	0.000418	9	106027.8	6960.4	0.27
78.853	0.5% (200-yr)	270000	878.85	879.56	0.000362	7.98	90138.63	6625.38	0.25
78.853	1% (100-yr)	220000	877.16	877.76	0.000318	7.22	78929.08	6591.17	0.23

HEC-RAS River Station	Profile	Q Total (cfs)	Water Surface Elevation (ft)	Energy Grade Elevation (ft)	Energy Grade Slope (ft/ft)	Average Channel Velocity (ft/s)	Flow Area (sq ft)	Top Width (ft)	Channel Froude #
78.853	2% (50-yr)	176000	875.28	875.81	0.000284	6.53	66623.87	6552.88	0.22
78.853	10% (10-yr)	96600	869.11	869.58	0.000294	5.61	26625.19	6401.51	0.21
79.654	0.04% (2500-yr)	500000	886.97	887.69	0.000386	9.79	122596.4	5950.71	0.27
79.654	0.1% (1000-yr)	410000	884.55	885.2	0.000364	9.13	108200.5	5947.69	0.26
79.654	0.133% (750-yr)	387000	883.9	884.53	0.000357	8.94	104322.7	5946.9	0.26
79.654	0.2% (500-yr)	348000	882.74	883.34	0.000345	8.61	97455.21	5945.74	0.25
79.654	0.5% (200-yr)	270000	880.22	880.75	0.000316	7.86	82450.42	5939.83	0.24
79.654	1% (100-yr)	220000	878.38	878.86	0.000293	7.3	71526.41	5917.92	0.23
79.654	2% (50-yr)	176000	876.39	876.85	0.000278	6.81	59811.82	5891.31	0.22
79.654	10% (10-yr)	96600	870.35	871.19	0.000451	7.49	18049.65	4119.18	0.27
79.858	0.04% (2500-yr)	500000	887.48	887.94	0.000223	7.23	123074.5	5263.07	0.2
79.858	0.1% (1000-yr)	410000	885.04	885.44	0.000206	6.65	110242.9	5256.98	0.19
79.858	0.133% (750-yr)	387000	884.38	884.76	0.000201	6.49	106783.3	5255.33	0.19
79.858	0.2% (500-yr)	348000	883.22	883.57	0.000192	6.2	100657.6	5252.98	0.19
79.858	0.5% (200-yr)	270000	880.67	880.96	0.000171	5.56	87271.55	5240.02	0.17
79.858	1% (100-yr)	220000	878.8	879.06	0.000155	5.09	77530.07	5216.72	0.16
79.858	2% (50-yr)	176000	876.81	877.04	0.000143	4.67	67164.35	5189.33	0.16
79.858	10% (10-yr)	96600	871.2	871.54	0.000201	4.77	25291.26	4864.94	0.18
79.862		Bridge							
79.867	0.04% (2500-yr)	500000	887.57	887.98	0.000202	6.88	123482.5	5263.27	0.19
79.867	0.1% (1000-yr)	410000	885.1	885.46	0.000188	6.36	110487.5	5257.09	0.19
79.867	0.133% (750-yr)	387000	884.44	884.78	0.000184	6.21	107012.4	5255.44	0.18
79.867	0.2% (500-yr)	348000	883.27	883.59	0.000176	5.95	100872.7	5253.06	0.18
79.867	0.5% (200-yr)	270000	880.71	880.98	0.000159	5.36	87446.2	5240.23	0.17
79.867	1% (100-yr)	220000	878.84	879.08	0.000146	4.93	77688.97	5217.14	0.16
79.867	2% (50-yr)	176000	876.84	877.06	0.000136	4.55	67288.21	5189.66	0.15
79.867	10% (10-yr)	96600	871.26	871.57	0.000191	4.66	25385.12	4865.82	0.17
80.037	0.04% (2500-yr)	500000	887.6	888.21	0.000275	8.09	114528.3	4919.53	0.23
80.037	0.1% (1000-yr)	410000	885.13	885.67	0.000254	7.44	102416.3	4915.84	0.22
80.037	0.133% (750-yr)	387000	884.47	884.99	0.000247	7.25	99175.27	4914.85	0.21
80.037	0.2% (500-yr)	348000	883.31	883.78	0.000235	6.93	93447.89	4913.1	0.21
80.037	0.5% (200-yr)	270000	880.76	881.15	0.000208	6.19	80925.71	4892.7	0.19
80.037	1% (100-yr)	220000	878.89	879.24	0.000187	5.64	71838.7	4862.47	0.18
80.037	2% (50-yr)	176000	876.9	877.2	0.00017	5.14	62194.46	4647.27	0.17
80.037	10% (10-yr)	96600	871.41	871.75	0.000192	4.73	25499.77	4568.1	0.17
80.593	0.04% (2500-yr)	500000	888.35	889.34	0.000495	10.69	95307.88	4581.22	0.3
80.593	0.1% (1000-yr)	410000	885.83	886.74	0.000477	10.03	83766.68	4572.4	0.29
80.593	0.133% (750-yr)	387000	885.15	886.04	0.000471	9.85	80668.34	4570.03	0.29
80.593	0.2% (500-yr)	348000	883.95	884.81	0.00046	9.51	75188.16	4565.83	0.29
80.593	0.5% (200-yr)	270000	881.32	882.1	0.000433	8.75	63204.71	4531.03	0.27
80.593	1% (100-yr)	220000	879.41	880.09	0.000393	8	54781.08	4167.8	0.26
80.593	2% (50-yr)	176000	877.37	877.99	0.000373	7.44	46322.62	4123.24	0.25
80.593	10% (10-yr)	96600	871.96	872.65	0.000418	6.81	19551.62	3851.21	0.25

HEC-RAS River Station	Profile	Q Total (cfs)	Water Surface Elevation (ft)	Energy Grade Elevation (ft)	Energy Grade Slope (ft/ft)	Average Channel Velocity (ft/s)	Flow Area (sq ft)	Top Width (ft)	Channel Froude #
80.945	0.04% (2500-yr)	500000	888.95	890.34	0.000463	10.86	69519.51	2857	0.31
80.945	0.1% (1000-yr)	410000	886.47	887.64	0.000417	9.85	62430.02	2857	0.29
80.945	0.133% (750-yr)	387000	885.8	886.91	0.000404	9.57	60515.35	2857	0.29
80.945	0.2% (500-yr)	348000	884.61	885.62	0.00038	9.07	57121.83	2853.93	0.28
80.945	0.5% (200-yr)	268000	881.99	882.79	0.000321	7.9	49664.05	2840.2	0.25
80.945	1% (100-yr)	217000	880.04	880.7	0.00028	7.06	44153.85	2825.97	0.23
80 945	2% (50-yr)	173000	878.02	878.56	0.000245	6.29	38448.99	2812.15	0.21
80.945	10% (10-yr)	93600	872.85	873.18	0.00018	4.68	24016.14	2766.89	0.18
81.633	0.04% (2500-yr)	500000	890.28	892.64	0.000767	14.43	62794.39	2744	0.4
81.633	0.1% (1000-yr)	410000	887.7	889.72	0.000693	13.13	55710 8	2744	0.38
81.633	0.133% (750-yr)	387000	887	888.92	0.000672	12.76	53787.62	2744	0.37
81.633	0.2% (500-yr)	348000	885.75	887.52	0.000634	12.12	50371.33	2741.24	0.36
81.633	0.5% (200-yr)	268000	882.99	884.4	0.00054	10.6	42833.62	2716.41	0.33
81.633	1% (100-yr)	217000	880.94	882.11	0.000474	9.51	37270.23	2706.82	0.3
81.633	2% (50-yr)	173000	878.82	879.8	0.000415	8.49	31617.52	2623.2	0.28
81.633	10% (10-yr)	93600	873.49	874.08	0.000295	6.25	19106	2097.84	0.23
82.333	0.04% (2500-yr)	500000	893.12	894.67	0.000451	11.13	62690.79	2210	0.31
82.333	0.1% (1000-yr)	410000	890.27	891.57	0.000408	10.08	56388.97	2210	0.29
82.333	0.133% (750-yr)	387000	889.49	890.72	0.000396	9.79	54669.69	2210	0.29
82.333	0.2% (500-yr)	348000	888.11	889.23	0.000375	9.28	51613.27	2210	0.28
82.333	0.5% (200-yr)	268000	885	885.88	0.000324	8.11	44777.52	2189.5	0.25
82.333	1% (100-yr)	217000	882.71	883.43	0.000288	7.27	39773.99	2177.9	0.24
82 333	2% (50-yr)	173000	880.38	880.97	0.000256	6.49	34714.91	2165.08	0.22
82.333	10% (10-yr)	93600	874.61	874.96	0.000194	4.83	22354.68	2110.59	0.18
83.032	0.04% (2500-yr)	500000	894.37	896.63	0.000529	13.86	58958.72	2169.13	0.37
83 032	0.1% (1000-yr)	410000	891.42	893.35	0.000482	12.62	52555.92	2169.13	0.35
83.032	0.133% (750-yr)	387000	890.61	892.45	0.000469	12.28	50805.81	2169.13	0.35
83.032	0.2% (500-yr)	348000	889.18	890.87	0.000446	11.68	47694.04	2169.13	0 34
83.032	0.5% (200-yr)	268000	885.95	887.3	0 000389	10.27	40760.62	2129.52	0.31
83.032	1% (100-yr)	217000	883.56	884.7	0.000348	9.27	35703.82	2115.69	0.29
83.032	2% (50-yr)	173000	881.15	882.1	0.000311	8.31	30615.44	2101.82	0.27
83.032	10% (10-yr)	93600	875.23	875.79	0.000227	6.12	18552.4	1610.55	0.22
83.1	0.04% (2500-yr)	500000	894.45	896.88	0.000565	14.35	56502.53	2052.6	0.38
83.1	0.1% (1000-yr)	410000	891.5	893.57	0.000513	13.05	50455.98	2052.6	0.36
83.1	0.133% (750-yr)	387000	890.7	892.66	0.000499	12.69	48802.15	2052.6	0.36
83.1	0.2% (500-yr)	348000	889.26	891.07	0.000473	12.06	45860.31	2052.6	0.34
83.1	0.5% (200-yr)	268000	886.03	887.47	0.00041	10.58	39304.98	2012.78	0.32
83.1	1% (100-yr)	217000	883.65	884.85	0.000366	9.53	34522.04	1999.02	0.3
83.1	2% (50-yr)	173000	881.23	882.23	0.000325	8.53	29709.37	1984.95	0.27
83.1	10% (10-yr)	93600	875.3	875.88	0.000235	6.26	18289.41	1550.8	0.23
83.105		Bridge							
83.109	0.04% (2500-yr)	500000	894.64	897.04	0.000555	14.27	56866.77	2052.6	0.38

HEC-RAS River Station	Profile	Q Total (cfs)	Water Surface Elevation (ft)	Energy Grade Elevation (ft)	Energy Grade Slope (ft/ft)	Average Channel Velocity (ft/s)	Flow Area (sq ft)	Top Width (ft)	Channel Froude #
83.109	0.1% (1000-yr)	410000	891.58	893.63	0.00051	13.02	50591.57	2052.6	0.36
83.109	0.133% (750-yr)	387000	890.77	892.72	0.000496	12.66	48922.08	2052.6	0.36
83.109	0.2% (500-yr)	348000	889.33	891.12	0.00047	12.03	45974.36	2052.6	0.34
83.109	0.5% (200-yr)	268000	886.09	887.52	0.000408	10.56	39397.76	2013.05	0.32
83.109	1% (100-yr)	217000	883.7	884.9	0.000364	9.51	34599.95	1999.17	0.29
83.109	2% (50-yr)	173000	881.27	882.27	0.000324	8.52	29773.18	1985.22	0.27
83.109	10% (10-yr)	93600	875.34	875.92	0.000234	6.25	18329.31	1558.91	0.22
83.429	0.04% (2500-yr)	500000	894.31	898.21	0.000375	16.9	38472.84	1282	0.47
83.429	0.1% (1000-yr)	410000	891.45	894.62	0.000332	15.16	34798.59	1282	0.43
83.429	0.133% (750-yr)	387000	890.68	893.67	0.00032	14.68	33812.84	1282	0.42
83.429	0.2% (500-yr)	348000	889.31	891.98	0.000298	13.81	32071.35	1269.2	0.41
83.429	0.5% (200-yr)	268000	886.2	888.2	0.000249	11.89	28167.43	1239.12	0.37
83.429	1% (100-yr)	217000	883.87	885.47	0.000216	10.53	25303.21	1220.45	0.34
83.429	2% (50-yr)	173000	881.49	882.75	0.000187	9.27	22422.63	1201.38	0.31
83.429	10% (10-yr)	93600	875.58	876.22	0.000127	6.52	16136.55	983.83	0.24
83.699	0.04% (2500-yr)	500000	894.51	898.88	0.000411	17.66	35229.29	1144.85	0.49
83.699	0.1% (1000-yr)	410000	891.67	895.2	0.000362	15.78	31983.06	1137.22	0.45
83.699	0.133% (750-yr)	387000	890.91	894.22	0.000347	15.26	31117.97	1131.08	0.44
83.699	0.2% (500-yr)	348000	889.55	892.49	0.000322	14.34	29588.8	1120.15	0.42
83.699	0.5% (200-yr)	268000	886.42	888.62	0.000268	12.3	26119.78	1099.58	0.38
83.699	1% (100-yr)	217000	884.08	885.82	0.000231	10.87	23563.79	1084.49	0.35
83.699	2% (50-yr)	173000	881.69	883.04	0.000199	9.54	20987.64	1069.07	0.32
83.699	10% (10-yr)	93600	875.73	876.41	0.000135	6.7	15295.66	897.62	0.25
83.783	0.04% (2500-yr)	500000	894.26	899.27	0.000484	19	33305.11	1104.22	0.53
83.783	0.1% (1000-yr)	410000	891.43	895.56	0.000431	17.09	29250.57	1099.89	0.49
83.783	0.133% (750-yr)	387000	890.69	894.55	0.000413	16.51	28508.26	1097.09	0.48
83.783	0.2% (500-yr)	348000	889.37	892.79	0.000382	15.5	27184.48	1090.36	0.46
83.783	0.5% (200-yr)	268000	886.31	888.85	0.000316	13.26	24145.74	1069.56	0.41
83.783	1% (100-yr)	217000	884.01	886.01	0.000271	11.71	21880.56	1053.37	0.38
83.783	2% (50-yr)	173000	881.64	883.2	0.000233	10.27	19573.45	1039.1	0.34
83.783	10% (10-yr)	93600	875.71	876.51	0.000161	7.27	14137.98	877.36	0.27
83.786		Bridge							
83.789	0.04% (2500-yr)	500000	897.84	901.88	0.000353	17.17	37242.78	1104.22	0.46
83.789	0.1% (1000-yr)	410000	894.23	897.62	0.000326	15.6	33264.85	1104.22	0.43
83.789	0.133% (750-yr)	387000	893.26	896.47	0.000319	15.17	32185.83	1104.22	0.43
83.789	0.2% (500-yr)	348000	891.41	894.4	0.000311	14.52	29221.01	1099.78	0.42
83.789	0.5% (200-yr)	268000	886.54	889.04	0.000308	13.16	24366.42	1071.17	0.41
83.789	1% (100-yr)	217000	884.3	886.25	0.000262	11.58	22152.98	1055.37	0.37
83.789	2% (50-yr)	173000	881.85	883.38	0.000227	10.19	19768.8	1040.35	0.34
83.789	10% (10-yr)	93600	875.81	876.6	0.000159	7.24	14212.22	878.38	0.27
84.047	0.04% (2500-yr)	500000	899.64	902.37	0.00021	13.59	40856.88	1004	0.36
84.047	0.1% (1000-yr)	410000	895.84	898.06	0.000192	12.23	37044.76	1004	0.34
84.047	0.133% (750-yr)	387000	894.81	896.9	0.000186	11.86	36009.63	1004	0.33

HEC-RAS River Station	Profile	Q Total (cfs)	Water Surface Elevation (ft)	Energy Grade Elevation (ft)	Energy Grade Slope (ft/ft)	Average Channel Velocity (ft/s)	Flow Area (sq ft)	Top Width (ft)	Channel Froude #
84.047	0.2% (500-yr)	348000	892.93	894.81	0.000178	11.22	34128.72	1004	0.32
84.047	0.5% (200-yr)	268000	887.94	889.44	0.00017	10.01	29133.73	990.6	0.31
84.047	1% (100-yr)	217000	885.42	886.59	0.000146	8.81	26653	981.04	0.28
84.047	2% (50-yr)	173000	882.77	883.67	0.000127	7.72	24068.26	970.99	0.26
84.047	10% (10-yr)	93600	876.33	876.79	0.00009	5.48	17896.44	946.54	0.21
84.209	0.04% (2500-yr)	500000	900.02	902.56	0.000198	13.2	42942.83	1085.01	0.35
84.209	0.1% (1000-yr)	410000	896.14	898.23	0.000183	11.93	38739.81	1085.01	0.33
84.209	0.133% (750-yr)	387000	895.09	897.07	0.000178	11.58	37601.03	1085.01	0.32
84.209	0.2% (500-yr)	348000	893.19	894.97	0.000171	10.98	35537.16	1085.01	0.31
84.209	0.5% (200-yr)	268000	888.14	889.59	0.000166	9.85	30108.18	1067.18	0.3
84.209	1% (100-yr)	217000	885.58	886.72	0.000144	8.69	27385	1058.08	0.28
84.209	2% (50-yr)	173000	882.9	883.78	0.000126	7.65	24558.93	1047.98	0.25
84.209	10% (10-yr)	93600	876.41	876.87	0.000092	5.48	17956.86	987.54	0.21
84.214		Bridge							
84.218	0.04% (2500-yr)	500000	900.36	902.9	0.000195	13.16	42989.02	1085.01	0.34
84.218	0.1% (1000-yr)	410000	896.35	898.45	0.000181	11.92	38640.84	1085.01	0.33
84.218	0.133% (750-yr)	387000	895.29	897.27	0.000177	11.57	37493.84	1085.01	0.32
84.218	0.2% (500-yr)	348000	893.37	895.15	0.00017	10.97	35407.8	1084.11	0.31
84.218	0.5% (200-yr)	268000	888.28	889.73	0.000165	9.84	29970.51	1052.5	0.3
84.218	1% (100-yr)	217000	885.69	886.82	0.000143	8.68	27263.98	1036.08	0.28
84.218	2% (50-yr)	173000	882.98	883.86	0.000125	7.64	24482.56	1018.93	0.25
84.218	10% (10-yr)	93600	876.46	876.92	0.000091	5.47	17970	977.59	0.21
84.309	0.04% (2500-yr)	500000	900.62	903	0.000182	12.73	44291.75	1109.68	0.33
84.309	0.1% (1000-yr)	410000	896.57	898.54	0.000169	11.54	39802.56	1109.68	0.32
84.309	0.133% (750-yr)	387000	895.51	897.36	0.000165	11.2	38617.84	1109.68	0.31
84.309	0.2% (500-yr)	348000	893.57	895.24	0.000158	10.62	36465.5	1108.92	0.3
84.309	0.5% (200-yr)	268000	888.45	889.81	0.000154	9.52	30873.44	1077.3	0.29
84 309	1% (100-yr)	217000	885.83	886.9	0.000134	8.41	28069.37	1060.68	0.27
84.309	2% (50-yr)	173000	883.1	883.93	0.000117	7.4	25193.48	1043.35	0.25
84.309	10% (10-yr)	93600	876 53	876.96	0.000086	5.31	18477.37	1001.72	0.2
84.556	0.04% (2500-yr)	500000	900.31	903 52	0.000236	14.78	38755.65	986.6	0.38
84.556	0.1% (1000-yr)	410000	896.36	898.99	0.000217	13.35	34850.93	986.6	0.36
84.556	0.133% (750-yr)	387000	895.31	897.79	0.000211	12.95	33819.29	986.6	0.35
84.556	0.2% (500-yr)	348000	893.43	895.63	0.000199	12.2	31976.77	944.59	0.34
84.556	0.5% (200-yr)	268000	888.4	890.15	0.000188	10.84	27292.46	916.89	0 32
84.556	1% (100-yr)	217000	885.81	887.18	0.000161	9.53	24942.32	902.59	0.29
84.556	2% (50-yr)	173000	883.11	884.16	0.000138	8.34	22522.94	887.16	0.27
84.556	10% (10-yr)	93600	876.58	877.11	0.000095	5.86	16856.88	848.34	0.21
84.563		Bridge							
84.569	0.04% (2500-yr)	500000	900.61	903.77	0.000231	14.67	39048.13	986 6	0.38
84.569	0.1% (1000-yr)	410000	896.59	899.19	0.000213	13.27	35077.22	986.6	0 36
84.569	0.133% (750-yr)	387000	895.52	897.98	0.000207	12.88	34028.54	986.6	0.35

HEC-RAS River Station	Profile	Q Total (cfs)	Water Surface Elevation (ft)	Energy Grade Elevation (ft)	Energy Grade Slope (ft/ft)	Average Channel Velocity (ft/s)	Flow Area (sq ft)	Top Width (ft)	Channel Froude #
84.569	0.2% (500-yr)	348000	893.61	895.79	0.000196	12.14	32144.4	945.56	0.34
84.569	0.5% (200-yr)	268000	888.54	890.28	0.000185	10.8	27424.02	917.68	0.32
84.569	1% (100-yr)	217000	885.92	887.27	0.000159	9.5	25038.55	903.2	0.29
84.569	2% (50-yr)	173000	883.19	884.24	0.000137	8.31	22599.25	887.65	0.27
84.569	10% (10-yr)	93600	876.62	877.15	0.000095	5.85	16892.72	848.6	0.21
84.621	0.04% (2500-yr)	500000	900.95	903.85	0.000211	14.09	40356.91	979.31	0.36
84.621	0.1% (1000-yr)	410000	896.88	899.27	0.000194	12.73	36373.62	979.31	0.34
84.621	0.133% (750-yr)	387000	895.8	898.05	0.000189	12.34	35320.49	979.31	0.33
84.621	0.2% (500-yr)	348000	893.83	895.86	0.000181	11.69	33390.07	978.79	0.32
84.621	0.5% (200-yr)	268000	888.73	890.34	0.000172	10.41	28463.78	949.94	0.31
84.621	1% (100-yr)	217000	886.06	887.32	0.000148	9.16	25956.43	934.74	0.28
84.621	2% (50-yr)	173000	883.31	884.28	0.000127	8.03	23402.17	918.46	0.26
84.621	10% (10-yr)	93600	876.69	877.18	0.000089	5.66	17452.75	877.74	0.21
84.641	0.04% (2500-yr)	500000	900.83	903.94	0.000227	14.56	39037.95	951	0.37
84.641	0.1% (1000-yr)	410000	896.79	899.34	0.000209	13.15	35192.67	951	0.35
84.641	0.133% (750-yr)	387000	895.72	898.12	0.000203	12.75	34175.86	951	0.35
84.641	0.2% (500-yr)	348000	893.76	895.92	0.000194	12.08	32310.9	950.02	0.34
84.641	0.5% (200-yr)	268000	888.67	890.39	0.000184	10.75	27547.61	921.91	0.32
84.641	1% (100-yr)	217000	886.02	887.37	0.000158	9.46	25127.59	907.22	0.29
84.641	2% (50-yr)	173000	883.28	884.31	0.000136	8.29	22658.81	891.49	0.27
84.641	10% (10-yr)	93600	876.67	877.2	0.000095	5.85	16899.8	852.03	0.21
84.644		Bridge							
84.647	0.04% (2500-yr)	500000	903.23	906.01	0.000191	13.81	41308.02	951	0.35
84.647	0.1% (1000-yr)	410000	898.48	900.82	0.000182	12.62	36797.09	951	0.33
84.647	0.133% (750-yr)	387000	897.13	899.36	0.000181	12.31	35506.64	951	0.33
84.647	0.2% (500-yr)	348000	897.04	898.85	0.000147	11.09	35421.37	951	0.3
84.647	0.5% (200-yr)	268000	888.76	890.48	0.000182	10.72	27625.74	922.38	0.32
84.647	1% (100-yr)	217000	886.15	887.49	0.000156	9.42	25238.61	907.93	0.29
84.647	2% (50-yr)	173000	883.39	884.41	0.000135	8.26	22747.27	892.06	0.27
84.647	10% (10-yr)	93600	876.74	877.26	0.000094	5.83	16945.37	852.35	0.21
84.812	0.04% (2500-yr)	500000	903.84	906.28	0.000416	13.58	45822	1160	0.34
84.812	0.1% (1000-yr)	410000	898.92	901.07	0.00041	12.66	40106.95	1160	0.33
84.812	0.133% (750-yr)	387000	897.51	899.6	0.000411	12.44	38479.39	1160	0.33
84.812	0.2% (500-yr)	348000	897.34	899.05	0.000337	11.24	38279.73	1160	0.3
84.812	0.5% (200-yr)	268000	888.95	890.74	0.000442	11.3	28668.06	1117.62	0.34
84.812	1% (100-yr)	217000	886.28	887.73	0.000387	10.09	25708.39	1099.79	0.31
84.812	2% (50-yr)	173000	883.46	884.64	0.000343	9	22640.56	1080.7	0.29
84.812	10% (10-yr)	93600	876.77	877.42	0.000246	6.58	15617.84	961.85	0.24
84.974	0.04% (2500-yr)	500000	904.57	906.53	0.000143	11.8	56970.96	1408	0.3
84.974	0.1% (1000-yr)	410000	899.62	901.31	0.000141	10.89	50010.2	1408	0.29
84.974	0.133% (750-yr)	387000	898.22	899.84	0.000141	10.66	48034.15	1408	0.29
84.974	0.2% (500-yr)	348000	897.91	899.24	0.000117	9.67	47599.05	1408	0.26
84.974	0.5% (200-yr)	268000	889.68	890.99	0.00015	9.47	36159.36	1363.57	0.29

HEC-RAS River Station	Profile	Q Total (cfs)	Water Surface Elevation (ft)	Energy Grade Elevation (ft)	Energy Grade Slope (ft/ft)	Average Channel Velocity (ft/s)	Flow Area (sq ft)	Top Width (ft)	Channel Froude #
84.974	1% (100-yr)	217000	886.9	887.95	0.000134	8.43	32390.3	1346.53	0.27
84.974	2% (50-yr)	173000	884	884.83	0.00012	7.49	28503.63	1329.52	0.25
84.974	10% (10-yr)	93600	877.1	877.56	0.000095	5.52	19487.6	1259.1	0.21
85.337	0.04% (2500-yr)	500000	905.39	906.82	0.000112	10.31	74115.1	1939	0.26
85.337	0.1% (1000-yr)	410000	900.33	901.59	0.000112	9.6	64312.88	1939	0.26
85.337	0.133% (750-yr)	387000	898.9	900.12	0.000113	9.42	61540.6	1939	0.26
85.337	0.2% (500-yr)	348000	898.47	899.48	0.000095	8.58	60692.99	1939	0.24
85.337	0.5% (200-yr)	268000	890.25	891.28	0.000127	8.54	44922.93	1891.16	0.26
85.337	1% (100-yr)	217000	887.36	888.2	0.000117	7.69	39476.09	1874.01	0.25
85.337	2% (50-yr)	173000	884.37	885.06	0.000109	6.93	33893.61	1856.51	0.24
85.337	10% (10-yr)	93600	877.29	877.75	0.000101	5.44	17320.85	1672.17	0.22
85.642	0.04% (2500-yr)	500000	905.8	907.01	0.000105	10.29	84216.66	2520	0.26
85.642	0.1% (1000-yr)	410000	900.63	901.78	0.000111	9.83	71188.91	2520	0.26
85.642	0.133% (750-yr)	387000	899.17	900.31	0.000114	9.73	67508.28	2520	0.26
85.642	0.2% (500-yr)	348000	898.68	899.63	0.000097	8.89	66268.88	2520	0.24
85.642	0.5% (200-yr)	268000	890.38	891.53	0.000142	9.35	45481.76	2489.37	0.28
85.642	1% (100-yr)	217000	887.45	888.45	0.000135	8.6	38308.87	2401.3	0.27
85.642	2% (50-yr)	173000	884.42	885.31	0.000131	7.92	31100.96	2365.65	0.26
85.642	10% (10-yr)	93600	877.37	877.97	0.000117	6.21	15286.77	1260.52	0.23
85.931	0.04% (2500-yr)	500000	906.57	907.24	0.000136	7.68	97839.95	3095	0.19
85.931	0.1% (1000-yr)	410000	901.35	902.02	0.000151	7.49	81687.36	3095	0.2
85.931	0.133% (750-yr)	387000	899.88	900.55	0.000157	7.46	77137.04	3095	0.2
85.931	0.2% (500-yr)	348000	899.27	899.84	0.000136	6.87	75241.77	3095	0.19
85.931	0 5% (200-yr)	268000	891	891.83	0.000234	7.78	45609.87	2989.75	0.24
85.931	1% (100-yr)	217000	887.99	888.74	0.00023	7.23	38178.81	2965.11	0.23
85.931	2% (50-yr)	173000	884.92	885.59	0.000229	6.72	30614.58	2939.93	0.23
85.931	10% (10-yr)	93600	877.81	878.22	0.000199	5.11	18373.13	942.77	0.2
86.127	0.04% (2500-yr)	500000	906.73	907.39	0.000174	7.44	98245.02	2962	0 19
86.127	0.1% (1000-yr)	410000	901.54	902.19	0.000188	7.19	82886.7	2962	0.19
86.127	0.133% (750-yr)	387000	900.09	900.73	0.000194	7.13	78569.52	2962	0.19
86.127	0.2% (500-yr)	348000	899.45	899.99	0.000168	6.56	76674.9	2962	0.18
86.127	0.5% (200-yr)	268000	891.38	892.1	0.000263	7.13	49529.69	2847.06	0.22
86.127	1% (100-yr)	217000	888.38	889	0.000251	6.53	42426.75	2823.32	0.21
86.127	2% (50-yr)	173000	885.31	885.85	0.000241	5.97	35194.48	2799.11	0.2
86.127	10% (10-yr)	93600	878.12	878.43	0.000209	4.53	21708.27	1549.19	0.18
86.339	0.04% (2500-yr)	500000	906.5	907.85	0.000312	10.05	70111.62	2344	0 25
86.339	0.1% (1000-yr)	410000	901.38	902.65	0.000327	9.57	58096.62	2344	0.25
86.339	0.133% (750-yr)	387000	899.94	901.19	0.000333	9.45	54722.97	2344	0.25
86.339	0.2% (500-yr)	348000	899.33	900.39	0.000285	8.67	53294.17	2344	0.23
86 339	0.5% (200-yr)	268000	891.44	892.57	0.00038	8.71	35429.77	1925.92	0.26
86.339	1% (100-yr)	217000	888.49	889.42	0.000346	7.83	30485.48	1426.54	0.25
86 339	2% (50-yr)	173000	885.47	886.22	0.000316	7	26220.88	1300.66	0.23
86.339	10% (10-yr)	93600	878.31	878.72	0.000249	5.13	18379.5	965.38	0.2

HEC-RAS River Station	Profile	Q Total (cfs)	Water Surface Elevation (ft)	Energy Grade Elevation (ft)	Energy Grade Slope (ft/ft)	Average Channel Velocity (ft/s)	Flow Area (sq ft)	Top Width (ft)	Channel Froude #
86.608	0.04% (2500-yr)	500000	906.87	908.33	0.000316	10.14	66069.94	2026	0.25
86.608	0.1% (1000-yr)	410000	901.81	903.11	0.000318	9.48	55941.48	1980.15	0.25
86.608	0.133% (750-yr)	387000	900.39	901.65	0.00032	9.31	53137.25	1973.77	0.25
86.608	0.2% (500-yr)	348000	899.72	900.78	0.000275	8.53	51811.75	1970.95	0.23
86.608	0.5% (200-yr)	268000	892.05	893.09	0.000337	8.28	37549.83	1749.37	0.25
86.608	1% (100-yr)	217000	889.05	889.89	0.000305	7.42	32320.97	1730.55	0.23
86.608	2% (50-yr)	173000	885.98	886.64	0.000275	6.59	28059.54	1180.82	0.22
86.608	10% (10-yr)	93600	878.69	879.05	0.000217	4.82	19652.95	1089.9	0.18
86.809	0.04% (2500-yr)	500000	907.37	908.67	0.000301	9.82	71519.61	2149	0.25
86.809	0.1% (1000-yr)	410000	902.26	903.46	0.000311	9.28	60550.16	2133.38	0.25
86.809	0.133% (750-yr)	387000	900.83	902	0.000315	9.14	57513.57	2116.71	0.25
86.809	0.2% (500-yr)	348000	899.96	901.12	0.000307	8.89	47311.64	2106.72	0.24
86.809	0.5% (200-yr)	268000	892.38	893.49	0.000372	8.58	35944.58	2042.91	0.26
86.809	1% (100-yr)	217000	889.35	890.25	0.000339	7.69	31449.16	2023.74	0.24
86.809	2% (50-yr)	173000	886.25	886.97	0.00031	6.86	27118.43	1756.4	0.23
86.809	10% (10-yr)	93600	878.91	879.31	0.00025	5.06	18514.37	890.76	0.2
86.992	0.04% (2500-yr)	500000	907.68	908.96	0.000304	9.76	71776.44	2505.4	0.25
86.992	0.1% (1000-yr)	410000	902.55	903.77	0.000321	9.32	59052.97	2455.37	0.25
86.992	0.133% (750-yr)	387000	901.12	902.32	0.000328	9.19	55559.79	2435.02	0.25
86.992	0.2% (500-yr)	348000	900.41	901.42	0.000284	8.46	53819.08	2424.81	0.23
86.992	0.5% (200-yr)	268000	892.82	893.85	0.000362	8.34	37971.92	1624.89	0.25
86.992	1% (100-yr)	217000	889.73	890.58	0.000337	7.54	32991.37	1595.76	0.24
86.992	2% (50-yr)	173000	886.58	887.28	0.000316	6.79	28266.28	1344.89	0.23
86.992	10% (10-yr)	93600	879.15	879.57	0.000277	5.18	18791.44	1242.26	0.2
87.681	0.04% (2500-yr)	500000	908.95	910.02	0.000266	8.71	75171.95	2565.67	0.23
87.681	0.1% (1000-yr)	410000	903.92	904.87	0.000274	8.16	64956.38	2540.01	0.23
87.681	0.133% (750-yr)	387000	902.52	903.44	0.000277	8.01	62109.86	2532.86	0.23
87.681	0.2% (500-yr)	348000	901.62	902.4	0.000244	7.4	60271.37	2528.25	0.21
87.681	0.5% (200-yr)	268000	894.33	895.1	0.000312	7.25	45534.09	2422.1	0.23
87.681	1% (100-yr)	217000	891.11	891.76	0.000305	6.65	39095.53	2370.16	0.22
87.681	2% (50-yr)	173000	887.86	888.42	0.000303	6.1	32873.54	1715.14	0.22
87.681	10% (10-yr)	93600	880.29	880.67	0.00033	4.94	20384.42	1557.93	0.22
87.907	0.04% (2500-yr)	500000	908.88	910.55	0.000318	10.95	60985.01	1717.82	0.29
87.907	0.1% (1000-yr)	410000	903.9	905.39	0.000329	10.27	52511.45	1689.56	0.29
87.907	0.133% (750-yr)	387000	902.52	903.96	0 000334	10.09	50174.28	1683.32	0.29
87.907	0.2% (500-yr)	348000	901.62	902.86	0.000294	9.33	48668.72	1679.48	0.27
87.907	0.5% (200-yr)	268000	894.42	895.64	0.000382	9.18	36682.91	1648.49	0.3
87.907	1% (100-yr)	217000	891.24	892.28	0.000377	8.45	31542.16	1524.37	0.29
87.907	2% (50-yr)	173000	888.02	888.93	0.000382	7.79	26665.87	1511.09	0.29
87.907	10% (10-yr)	93600	880.56	881.2	0.000446	6.46	15806.45	1337.95	0.29
87.911		Bridge							
87.916	0.04% (2500-yr)	500000	909.07	910.72	0.000314	10.9	61302.86	1718.87	0.29
87.916	0.1% (1000-yr)	410000	904.05	905.52	0.000325	10.23	52750.25	1690.25	0.29

HEC-RAS River Station	Profile	Q Total (cfs)	Water Surface Elevation (ft)	Energy Grade Elevation (ft)	Energy Grade Slope (ft/ft)	Average Channel Velocity (ft/s)	Flow Area (sq ft)	Top Width (ft)	Channel Froude #
87.916	0.133% (750-yr)	387000	902.65	904.08	0.00033	10.05	50393.98	1683.93	0.29
87.916	0.2% (500-yr)	348000	901.71	902.94	0.000292	9.3	48817.25	1679.86	0.27
87.916	0.5% (200-yr)	268000	894.49	895.7	0.00038	9.16	36782.65	1648.8	0.3
87.916	1% (100-yr)	217000	891.3	892.35	0.000374	8.42	31634.88	1524.69	0.29
87.916	2% (50-yr)	173000	888.09	888.98	0.000379	7.77	26754.39	1511.33	0.29
87.916	10% (10-yr)	93600	880.63	881.26	0.00044	6.44	15884.48	1341.61	0.29
87.933	0.04% (2500-yr)	500000	909.22	910.76	0.000296	10.6	61555.89	1719.73	0.28
87.933	0.1% (1000-yr)	410000	904.18	905.56	0.000308	9.99	52952.36	1690.93	0.28
87.933	0.133% (750-yr)	387000	902.77	904.12	0.000314	9.83	50583.02	1684.48	0.28
87.933	0.2% (500-yr)	348000	901.82	902.97	0.000279	9.1	48970.82	1680.26	0.27
87.933	0.5% (200-yr)	268000	894.57	895.74	0.000368	9.03	36904.29	1649.2	0.29
87.933	1% (100-yr)	217000	891.37	892.38	0.000366	8.33	31718.19	1525	0.29
87.933	2% (50-yr)	173000	888.14	889.02	0.000372	7.7	26820.03	1511.53	0.28
87.933	10% (10-yr)	93600	880.67	881.3	0.000437	6.42	15927.16	1344.12	0.29
87.938		Bridge							
87.943	0.04% (2500-yr)	500000	909.29	910.89	0.000304	10.76	61662.72	1720.1	0.29
87.943	0.1% (1000-yr)	410000	904.24	905.68	0.000316	10.12	53048.38	1691.26	0.29
87.943	0.133% (750-yr)	387000	902.83	904.23	0.000322	9.96	50676.89	1684.75	0.29
87.943	0.2% (500-yr)	348000	901.86	903.07	0.000286	9.22	49045.46	1680.46	0.27
87.943	0.5% (200-yr)	268000	894.63	895.83	0.000374	9.11	36993.11	1649.48	0.3
87.943	1% (100-yr)	217000	891.43	892.46	0.000369	8.39	31798.38	1525.28	0.29
87.943	2% (50-yr)	173000	888.2	889.09	0.000374	7.73	26901.56	1511.75	0.28
87.943	10% (10-yr)	93600	880.75	881.37	0.000431	6.39	16020.64	1348.41	0.29
88.254	0.04% (2500-yr)	500000	910.95	911.26	0.000084	5.78	184385.9	10759.21	0.15
88.254	0.1% (1000-yr)	410000	905.27	906.14	0.000196	8.07	71053.93	10754.95	0.22
88.254	0.133% (750-yr)	387000	903.82	904.7	0.000206	8.06	66291.4	10753.91	0.23
88.254	0.2% (500-yr)	348000	902.69	903.49	0.000189	7.58	62600.62	10753.35	0.22
88.254	0.5% (200-yr)	268000	895.43	896.38	0.000279	7.98	38731.09	6182.27	0.26
88.254	1% (100-yr)	217000	892.18	893	0.000275	7.35	31400.32	1447.46	0.25
88.254	2% (50-yr)	173000	888.94	889.63	0.000273	6.71	26743.19	1426.85	0.24
88.254	10% (10-yr)	93600	881.52	881.96	0.000281	5.31	17649.8	1098.59	0.23
89.065	0.04% (2500-yr)	500000	911.38	911.61	0.000076	5.4	211507	11529.74	0.14
89.065	0.1% (1000-yr)	410000	906.45	906.83	0.00012	6.28	137837.5	11506.59	0.18
89.065	0.133% (750-yr)	387000	905.03	905.45	0.000133	6.46	126199	11501.6	0.18
89.065	0.2% (500-yr)	348000	903.78	904.19	0.000132	6.28	116027.9	11497.19	0.18
89.065	0.5% (200-yr)	268000	896.72	897.6	0.000288	8.07	58392.13	8411.05	0.26
89.065	1% (100-yr)	217000	893.37	894.37	0.000343	8.15	32351.39	2081.11	0.28
89.065	2% (50-yr)	173000	890.13	891	0.000348	7.54	25691.1	2011.23	0.27
89.065	10% (10-yr)	93600	882.8	883.35	0.00036	5.98	15757.27	1018.43	0.26
89.85	0.04% (2500-yr)	500000	911.73	911.94	0.000075	5.4	229743.4	12763.6	0.14
89.85	0.1% (1000-yr)	410000	907.03	907.33	0.000111	6.1	169718.9	12739.13	0.17
89.85	0.133% (750-yr)	387000	905.65	906.01	0.000128	6.39	152199.6	12732.25	0.18
89.85	0.2% (500-yr)	348000	904.38	904.76	0.000132	6.37	136061.4	12725.91	0.18

HEC-RAS River Station	Profile	Q Total (cfs)	Water Surface Elevation (ft)	Energy Grade Elevation (ft)	Energy Grade Slope (ft/ft)	Average Channel Velocity (ft/s)	Flow Area (sq ft)	Top Width (ft)	Channel Froude #
89.85	0.5% (200-yr)	268000	897.97	898.79	0.000275	8.12	59974.77	10023.69	0.26
89.85	1% (100-yr)	217000	894.92	895.67	0.000277	7.61	45093.14	2472.44	0.25
89.85	2% (50-yr)	173000	891.65	892.33	0.000286	7.12	37059.01	2437.47	0.25
89.85	10% (10-yr)	93600	884.25	884.76	0.000319	5.94	20636.03	1982.72	0.25
90.204	0.04% (2500-yr)	500000	911.86	912.07	0.000066	5.11	227673.5	13917.41	0.13
90.204	0.1% (1000-yr)	410000	907.21	907.53	0.000097	5.74	165988.1	13881.54	0.16
90.204	0.133% (750-yr)	387000	905.87	906.23	0.000111	6.01	148135.8	13867.06	0.17
90.204	0.2% (500-yr)	348000	904.61	904.99	0.000114	5.98	131440.7	13848.94	0.17
90.204	0.5% (200-yr)	268000	898.45	899.25	0.000224	7.46	54894.03	10747.9	0.23
90.204	1% (100-yr)	217000	895.41	896.14	0.000224	6.96	36993.15	2574.47	0.23
90.204	2% (50-yr)	173000	892.18	892.8	0.000218	6.36	30531.17	2511.53	0.22
90.204	10% (10-yr)	93600	884.87	885.24	0.000198	4.86	19301.62	1119.65	0.2
90.551	0.04% (2500-yr)	500000	912	912.19	0.000075	4.56	234145.1	15877.01	0.13
90.551	0.1% (1000-yr)	410000	907.41	907.71	0.000118	5.3	161352.9	15804.41	0.16
90.551	0.133% (750-yr)	387000	906.08	906.44	0.000137	5.6	140450.5	15794.15	0.17
90.551	0.2% (500-yr)	348000	904.83	905.21	0.000145	5.61	120603	15784.41	0.17
90.551	0.5% (200-yr)	268000	899.05	899.7	0.000253	6.56	50770.23	9196.71	0.22
90.551	1% (100-yr)	217000	896.01	896.59	0.000252	6.09	36698.95	2246.29	0.22
90.551	2% (50-yr)	173000	892.76	893.24	0.000255	5.61	31393	1577.93	0.22
90.551	10% (10-yr)	93600	885.34	885.68	0.000297	4.68	19999.72	1408.31	0.22
91.207	0.04% (2500-yr)	500000	912.22	912.53	0.000118	6.4	205061.6	15571.7	0.18
91.207	0.1% (1000-yr)	410000	907.72	908.3	0.000206	7.81	135060.4	15518.3	0.23
91.207	0.133% (750-yr)	387000	906.43	907.16	0.000248	8.38	115092.1	15487.71	0.25
91.207	0.2% (500-yr)	348000	905.17	906	0.000273	8.58	95562.35	15457.73	0.26
91.207	0.5% (200-yr)	268000	899.55	901.23	0.00053	10.6	34259.94	5921.11	0.35
91.207	1% (100-yr)	217000	896.59	898.09	0.000531	9.86	23422.39	1206.14	0.34
91.207	2% (50-yr)	173000	893.45	894.7	0.000526	9	19769.12	1131.83	0.33
91.207	10% (10-yr)	93600	886.39	887.18	0.000543	7.11	13218.2	870.57	0.32
91.503	0.04% (2500-yr)	500000	912.4	912.73	0.000125	6.49	200125.4	15554.19	0.18
91.503	0.1% (1000-yr)	410000	908.02	908.65	0.000217	7.93	132247.8	15478.43	0.23
91.503	0.133% (750-yr)	387000	906.8	907.57	0.000261	8.49	113281.5	15470.79	0.25
91.503	0.2% (500-yr)	348000	905.57	906.46	0.000288	8.71	94224.27	15463.4	0.26
91.503	0.5% (200-yr)	268000	900.52	902.03	0.000481	10.1	37292.94	8209.73	0.33
91.503	1% (100-yr)	217000	897.52	898.9	0.00049	9.46	24252.93	1162.65	0.33
91.503	2% (50-yr)	173000	894.35	895.5	0.000488	8.64	20675.69	1101.79	0.32
91.503	10% (10-yr)	93600	887.27	888	0.000512	6.86	13686.93	912.94	0.31
91.984	0.04% (2500-yr)	500000	912.72	913.06	0.000141	6.83	197526.1	16159.24	0.19
91.984	0.1% (1000-yr)	410000	908.57	909.24	0.000249	8.46	130730.8	16029.02	0.25
91.984	0.133% (750-yr)	387000	907.45	908.28	0.000299	9.07	112823.2	15983.14	0.27
91.984	0.2% (500-yr)	348000	906.27	907.26	0.000335	9.38	94080.72	15925.88	0.28
91.984	0.5% (200-yr)	268000	901.64	903.44	0.000568	11.08	37061.8	8835.82	0.36
91.984	1% (100-yr)	217000	898.65	900.37	0.000595	10.54	21265.72	978.86	0.36
91.984	2% (50-yr)	173000	895.51	896.93	0.000582	9.57	18307.48	876.74	0.35
91.984	10% (10-yr)	93600	888.55	889.41	0.000566	7.44	12588.13	791.16	0.33

HEC-RAS River Station	Profile	Q Total (cfs)	Water Surface Elevation (ft)	Energy Grade Elevation (ft)	Energy Grade Slope (ft/ft)	Average Channel Velocity (ft/s)	Flow Area (sq ft)	Top Width (ft)	Channel Froude #
92.648	0.04% (2500-yr)	500000	913.21	913.55	0.000146	6.89	198381.6	16750.94	0.19
92.648	0.1% (1000-yr)	410000	909.46	910.09	0.000241	8.27	135827.3	16635.89	0.24
92.648	0.133% (750-yr)	387000	908.55	909.28	0.000274	8.68	120610.3	16604.08	0.26
92.648	0.2% (500-yr)	348000	907.53	908.36	0.000295	8.82	103765.1	16553.72	0.27
92.648	0.5% (200-yr)	268000	903.86	905.19	0.000429	9.87	50773.52	9917.19	0.32
92.648	1% (100-yr)	217000	900.71	902.31	0.000528	10.16	22164.52	996.5	0.34
92 648	2% (50-yr)	173000	897.51	898.83	0.000514	9.22	19089.03	892.79	0.33
92.648	10% (10-yr)	93600	890.44	891.22	0.000486	7.11	13188.23	798.04	0.31
93.523	0.04% (2500-yr)	500000	913.82	914.47	0.000248	8.53	157886.7	16447.8	0.25
93.523	0.1% (1000-yr)	410000	910.46	911.56	0.000377	9.87	103679.2	16164.02	0.3
93.523	0.133% (750-yr)	387000	909.7	910.92	0.000409	10.13	91476.16	16085.93	0.31
93.523	0.2% (500-yr)	348000	908.79	910.08	0.000418	10.05	76976.01	15992.65	0.31
93.523	0.5% (200-yr)	268000	905.92	907.11	0.000405	9.28	49116.2	7434.02	0.3
93.523	1% (100-yr)	217000	903.33	904.54	0.000429	8.97	30549.05	7170.86	0.31
93.523	2% (50-yr)	173000	900	901.06	0 000441	8.31	23757.86	1585.31	0.31
93.523	10% (10-yr)	93600	892.75	893.44	0.000468	6.68	14139.64	1093.61	0.3
94.323*	0.04% (2500-yr)	500000	914.75	915.56	0.000302	9.19	144924.1	16632.14	0.27
94.323*	0.1% (1000-yr)	410000	911.97	913.09	0.000391	9.9	99752.65	16318.71	0.31
94.323*	0.133% (750-yr)	387000	911.39	912.55	0.000402	9.91	90333.29	16249.77	0.31
94.323*	0.2% (500-yr)	348000	910.58	911.74	0.000396	9.66	77330.42	16169.7	0.31
94.323*	0.5% (200-yr)	268000	907.61	908.83	0.000419	9.3	45352.68	7724.41	0.31
94.323*	1% (100-yr)	217000	905.23	906.3	0.0004	8.56	32189.68	1865.08	0.3
94.323*	2% (50-yr)	173000	901.93	902.87	0.000416	7.96	26706.13	1821.55	0.3
94.323*	10% (10-yr)	93600	894.77	895.44	0.000479	6.61	15196.7	1472.81	0.3
95.122	0.04% (2500-yr)	500000	916.17	916.8	0.000335	8.29	150789.3	16829.69	0 25
95.122	0.1% (1000-yr)	410000	913.9	914.69	0.000397	8.63	112711.8	16680.62	0.27
95.122	0.133% (750-yr)	387000	913.38	914.2	0.000403	8.61	104145.7	16648.23	0.27
95.122	0.2% (500-yr)	348000	912.56	913.39	0.000401	8.44	90471.64	16596.41	0.26
95.122	0.5% (200-yr)	268000	909.73	910.64	0.000432	8.23	54779.72	7297.95	0.27
95.122	1% (100-yr)	217000	907.24	908.05	0.000418	7.62	40700.43	2093.94	0.26
95.122	2% (50-yr)	173000	903.97	904.68	0.000432	7.09	33918.22	2055.73	0.26
95.122	10% (10-yr)	93600	896.96	897.47	0 000476	5.83	19831.92	1950.24	0.26
95.837*	0.04% (2500-yr)	500000	917.13	917.66	0.000284	7.47	165489.9	15794.15	0.23
95.837*	0.1% (1000-yr)	410000	915.17	915.7	0.000285	7.19	134730.4	15596.63	0.22
95.837*	0.133% (750-yr)	387000	914.71	915.23	0.00028	7.05	127530.4	15452.45	0.22
95.837*	0.2% (500-yr)	348000	913.92	914.43	0.000267	6.78	115543.5	15169.51	0.22
95.837*	0.5% (200-yr)	268000	911.3	911.82	0.000277	6.49	80020.52	11775.16	0.22
95.837*	1% (100-yr)	217000	908.76	909.28	0.000291	6.25	53808.43	3272.71	0.22
95.837*	2% (50-yr)	173000	905.51	906	0.000316	5.94	43241.64	3244.08	0.22
95.837*	10% (10-yr)	93600	898.67	899 06	0.000384	5.12	21845.7	3026.51	0.23
96.553	0.04% (2500-yr)	500000	917.98	918.33	0.000206	6.17	170407.9	14580.41	0.19
96.553	0.1% (1000-yr)	410000	916.07	916.4	0.000199	5.82	143418.8	13615.95	0.19
96.553	0.133% (750-yr)	387000	915.6	915.92	0.000195	5.7	137090.8	13379.76	0.18

HEC-RAS River Station	Profile	Q Total (cfs)	Water Surface Elevation (ft)	Energy Grade Elevation (ft)	Energy Grade Slope (ft/ft)	Average Channel Velocity (ft/s)	Flow Area (sq ft)	Top Width (ft)	Channel Froude #
96.553	0.2% (500-yr)	348000	914.79	915.1	0.000185	5.46	126480.3	12974.08	0.18
96.553	0.5% (200-yr)	268000	912.25	912.55	0.000188	5.18	95120.86	11693.12	0.18
96.553	1% (100-yr)	217000	909.79	910.12	0.000211	5.14	67865.09	10557.95	0.18
96.553	2% (50-yr)	173000	906.64	906.99	0.000252	5.11	49109.74	4409.57	0.2
96.553	10% (10-yr)	93600	900.1	900.45	0.000353	4.72	20711.3	4158.98	0.22

A-2.2 SOLDIER CREEK

A-2.2.1 INTRODUCTION

As part of the feasibility study, hydrologic and hydraulic analyses were conducted on Soldier Creek, located in Topeka, Kansas, and Shawnee and Jefferson Counties. The hydrologic analysis was completed to determine the expected discharges at the flood reduction works based upon statistical analyses of four stream flow gages in the watershed. The hydraulic investigation was completed to calculate water surface profiles on the first ten miles of Soldier Creek. To accomplish this, the HEC-RAS (River Analysis System) computer software developed by the Hydrologic Engineering Center, U.S. Army Corps of Engineers was used. The hydraulic model was developed using 1997 field surveys and 1995 aerial contour maps used in the reconnaissance report, supplemented by additional four-foot contours, supplied by the City of Topeka. Plates A2-2-1 and A2-2-2 show maps of the study area.

A-2.2.2 PURPOSE

The purpose of this investigation is to develop Soldier Creek water surface profiles from the Kansas River to the upstream limit of the flood reduction works reflecting the base (or existing) conditions. The resulting hydraulic model will be used to evaluate a series of alternatives for improving the integrity of the existing flood control system.

A-2.2.3 BACKGROUND

The Soldier Creek Diversion Unit, which was included in the Topeka, Kansas Flood Reduction Project, was authorized by the Flood Control Act approved in September 1954, House Document 642, 81st Congress, 2nd Session. Construction was initiated in March 1957 and was completed in November 1961.

The Soldier Creek study area is located near the north side of the Kansas River valley. The flood reduction project, developed by the Kansas City District, consists of approximately 10 miles of new and modified Soldier Creek channel and about 18 miles of levees along one or both sides of the modified channel. Tieback levees were also provided for several left bank tributaries.

The combination of the Soldier Creek Diversion Unit and the North Topeka Unit, which is located on the north bank of the Kansas River, provides flood reduction for 5,130 acres of agricultural, commercial and residential land.

A-2.2.4 HYDROLOGY

The following steps were used to complete the hydrologic investigation. First, a statistical frequency analysis was conducted on four USGS gages within Soldier Creek watershed. Next, relationships were developed between drainage area and discharge based for each frequency event. These relationships were then applied to the drainage areas within the flood reduction works to determine discharges for the first ten miles of Soldier Creek. Lastly, the hydrologic uncertainty was quantified.

Frequency Analysis

The frequency analysis was completed using the HEC-FFA (Flow Frequency Analysis) computer program developed by the Hydrologic Engineering Center, U.S. Army Corps of Engineers. There are four different USGS gages (Soldier, Circleville, Delia, and Topeka) within the Soldier Creek watershed. Plate A2-2-3 shows the location of the gages. The Topeka gage had the longest record (78 years) and is located within the study reach.

A frequency analysis of Soldier Creek was originally completed for the feasibility study in 2003, but in October of 2005, Soldier Creek experienced the largest flood of record at the Topeka and Delia gages. The magnitude of this flood relative to the rest of the gage record warranted a restudy of Soldier Creek's frequency discharges. Therefore, a new frequency analysis was conducted for the Topeka and Delia gages with a period of record through water year 2006. The full details of that analysis are recorded in a Memorandum for NWK-PM-PF prepared by Gordon Lance that was dated January 25, 2006.

The frequency curve results from the HEC-FFA analyses are illustrated in Figures 1 and 2 and summarized in Table 2-1. The confidence limits for these plots are set at +/- one standard deviation. It is noted that there were very large discharges for 1999 in both records, and an extremely high value for 2006. For the analysis at Delia, the frequency curve has an extremely high positive skew, even with the 2006 discharge (59,600 cfs) being treated as a high outlier. It is noted, however, that almost all of the data points on Figure 1 fall within one standard deviation of the computed value. The obvious exception is the very great value for the 2006 event, which is clearly an isolated high outlier. An estimated frequency for the 2006 event would be in the 0.5 % to 0.2% chance flood range.

Figure 2-1 Plot of Soldier Creek near Delia Gage Record

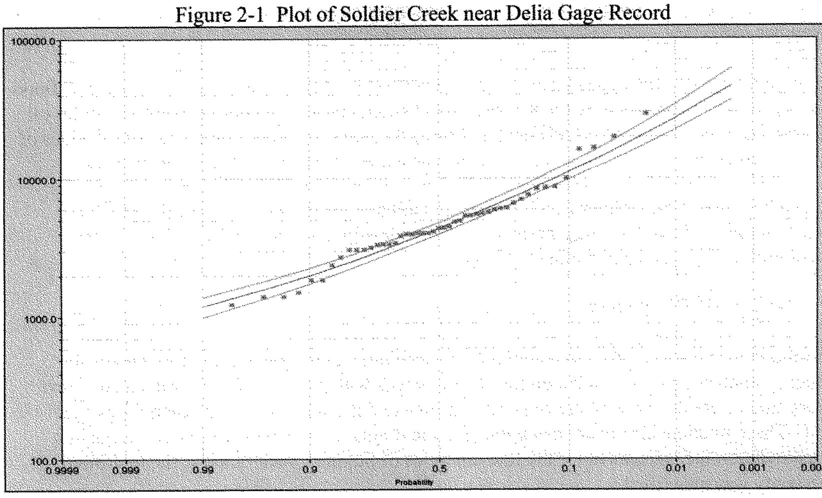


Figure 2-2 Plot of Soldier Creek near Topeka Gage

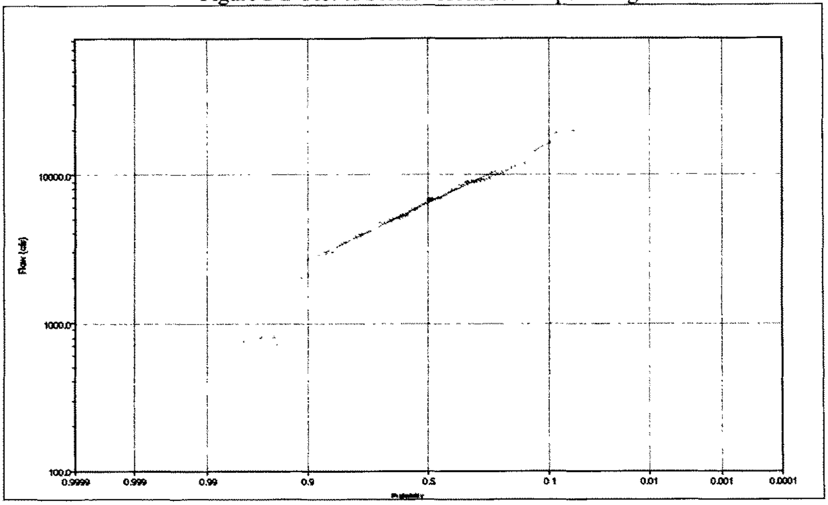


Table 2-1 Frequency Analysis Results

% Chance Exceedance	Discharge (cfs)	
	Delia	Topeka
0.2	103,000	56,400
0.5	66,100	44,300
1	46,800	36,400
2	32,800	29,400
5	20,000	21,500
10	13,400	16,300
20	8,650	11,800
50	4,290	6,480
Mean	3.6831	3.7759
Std Deviation	0.3316	0.3536
Regional Skew	0.9314	0.1531
Drainage Area	157 sq. mi.	290 sq. mi.
Period of Record	1958 to 2006	1929 to 2006
Yrs of Record	48	78

The Topeka record contains six very low peak annual discharge records. These records reflect the drought conditions experienced in the 1930's and 1950's, periods before the Delia gage was established. Since this is a flood study, it is important to secure a better definition of the right side of the curve. Therefore, the low outlier screen was set at 1000 cfs to screen out the effects of the four lowest discharges. Once this was done, the skew turned mildly positive to a value of +0.15, and the fit to the data points at the high end of the curve was improved. The use of a positive skew in lieu of the negative skew used in the previous study did not have the dramatic effect one might expect. This is due to the reduction in the standard deviation resulting from abandoning the four low outliers. One may note from the results in Table 2-1 that the peak discharges for large flood events actually decrease downstream from Delia to Topeka. The floodplain widens out considerably downstream of Delia, and the available storage causes attenuation of the peak flows, as occurred during October 2005 and other historic flood events.

Feasibility Discharges

The discharges were calculated for the first ten miles of Soldier Creek for the 0.2, 0.5, 1, 2, 5, 10, 20, 50- percent frequency events based on an analysis of the flows through the October 2005 flood event. The following recommended discharges, which are based on the Topeka gage record as described above, are proposed for the entire studied reach of Soldier Creek upstream of Halfday Creek. Proposed discharges downstream from the mouth of that creek have been increased using the coefficients proposed by HNTB in the previous hydrology report. Table 2-2 summarizes the feasibility discharges used on the Kansas River for the existing conditions model. Since flood events above the 0.2% chance exceedance (500 year) event need to be considered in this study, the discharge-frequency curves were extended up to the 0.04% chance exceedance (2500 year) event. This was accomplished through a straight-line extrapolation on a log-probability plot of the discharge frequency events at the Topeka gage.

Table 2-2 Feasibility Flood Discharges

Percent Chance of Exceedance	Approximate Return Interval	Study Limits to Halfday Creek	From Halfday Creek to Indian Creek	From Indian Creek to the Mouth
	(yrs)	(cfs)	(cfs)	(cfs)
River Miles		9.870 – 4.396	4.396 – 1.681	1.681 - 0
0.2	500	56400	61500	64300
0.5	200	44300	48300	50500
1	100	36400	39700	41500
2	50	29400	32000	33500
5	20	21500	23400	24500
10	10	16300	17800	18600
20	5	11800	12900	13500
50	2	6480	7060	7390

Hydrologic Uncertainty

In the past, the Corps of Engineers used freeboard as a factor of safety in designing levees to account for uncertainties in discharge, stage, and other engineering parameters (such as geotechnical and structural). Now, the Corps of Engineers has adopted a new methodology called Risk Based Analysis (RBA) for formulating flood risk management projects. This method considers all of the same engineering parameters, but accounts for the uncertainties directly in the analysis in lieu of using freeboard. Using RBA, the project's performance will be expressed as the average return period in years of the largest flood that can be accommodated by the plan under study, with a conditional non-exceedance probability of 90%. The concept of freeboard is no longer used.

To use RBA, the hydrologic uncertainty must be characterized. This information is entered into the computer program HEC-FDA (Flood Damage Analysis), which uses Monte Carlo algorithms to quantify the uncertainties. The uncertainty bands used in this program are based on the effective record lengths used to develop the flow frequency estimates. On Soldier Creek, the hydrology was computed using gage statistics from 1929 through 2006. This gives an equivalent record length of 78 years.

HEC-FDA calculates the uncertainty either analytically or graphically. For an analytical computation the log Pearson Type III statistics are inputted directly. A graphical approach is used on regulated streams, when the stream gage records are small or incomplete, or when partial duration data is used. On Soldier Creek, it was possible to use the analytical approach due to the type of stream and the available gage records. For the HEC-FDA analysis, an arbitrary index point was selected at River Mile 4.2, just downstream of the Halfday Creek confluence. To calculate the hydrologic uncertainty at this point, the "compute synthetic statistics" option was used in HEC-FDA. With this option, the program fits a log Pearson Type III curve to the 50, 10, and 1 percent chance exceedance frequency events. The discharge uncertainty was calculated for the reach containing the index point at river mile 4.2.

A-2.2.5 HYDRAULICS

The hydraulic analysis for this report centered on the development of the HEC-RAS computer model for the study reach of Soldier Creek near Topeka, Kansas. For this analysis, version 3.1.3 of the HEC-RAS (River Analysis System) developed by the Hydrologic Engineering Center was used. The computer model was used to generate a series of steady flow water surface profiles based on flood discharges in Table 2-2 above.

Original Design Water Surface Elevations

The elevation of the crown of the existing levee was determined by selecting a design water surface elevation and then adding freeboard of 3 feet to account for uncertainties. The design water surface elevations were determined by using a backwater computer model with the design discharges. The original design discharge for Soldier Creek was 50,000 cfs.

Geometric Data

The computer model required cross section geometry along the length of the study reach. The cross section locations are shown in Plates A2-2-1 and A2-2-2. Field surveys were primarily made at bridges and selected channel locations. Where available, City of Topeka aerial contour maps (2' interval), dated 1995, were used to supplement the field survey data. Beyond the limits of the City mapping, in areas north of Soldier Creek and without a constructed levee, U.S.G.S. mapping and field investigation were used to extend cross sections to completely describe the overbank flow area.

When available, existing bridge plans were obtained and utilized in the model. Bridge plans were collected for U.S. Hwy. 24, U.S. Hwy 75, Topeka Avenue, Union Pacific Railroad, and the Santa Fe Railroad bridges. The levee heights were determined in three ways. First, where available, the top of levee elevation was taken from the cross section surveys (January 1997).

Second, where survey data was not available, the top of levee elevation was interpolated from spot elevation on the City of Topeka aerial contour maps. Third, when necessary, levee elevations were taken from the "Operation and Maintenance Manual" for the Topeka Flood Protection Project[3].

Manning's n-values were estimated through field investigations and limited calibration of the 1993 and 2005 floods. Downstream of the gage, the Manning's n-value for the channel was 0.031. Some portions of the upstream channel were assigned an n-value of 0.040, because of thicker vegetation on the channel banks. Overbank n-values ranged from 0.040 in the well-maintained areas between the channel and the levee, to 0.080 and 0.100 in wooded areas north of the channel in reaches with no north levee.

During a field investigation trip, accumulations of significant quantities of debris were observed at the Santa Fe and Atchison Railroad, Rochester Road, abandoned railroad, Brickyard Road, Menoken Road, and Landon Road bridges. The effects of this debris were not incorporated into the hydraulic model. Other observations made during the field investigation included exposed footings at the U.S. Hwy. 24 and Atchison and Santa Fe Railroad bridges and a scour hole at the bridge at Button Road.

Starting Water Surface Elevations

The starting water surface elevation was determined using the Topeka USGS gage records on Soldier Creek and Kansas River. Plate A2-2-5 shows a plot of the annual instantaneous peak Soldier Creek discharge (between 1960 and 1997) versus the daily discharge on the Kansas River. A curve was drawn through the upper portion of the data points which represents a conservative estimate of the highest discharge on the Kansas River that could reasonably be expected based on the Soldier Creek discharge. Using a rating curve developed from the calculated water surface profiles of the HEC –RAS computer model, the corresponding Kansas River elevations were determined. Table 2-3 lists the corresponding discharges and Soldier Creek starting water surface elevations.

Table 2-3 Soldier Creek Starting Water Surface Elevations

Percent Chance of Exceedance	Soldier Creek Discharge at Topeka Gage (cfs)	Kansas River Discharge at Topeka Gage (cfs)	Soldier Creek Starting Water Surface Elevation (ft)
0.2	56400	209,600	879.13
0.5	44300	179,700	877.73
1	36400	157,400	876.48
2	29400	136,300	875.10
5	21500	108,600	873.10
10	16300	88,100	871.29
20	11800	67,800	868.33
50	6480	39,900	863.18

[3] "Operation and Maintenance Manual for Flood Protection Project, Topeka, Kansas, Volume Eight, Master Flood Emergency Operation and Maintenance Manual." U.S. Army Engineer District, Kansas City, August 1978.

Model Calibration

The model was calibrated to the July 10, 1993 flood event, and the calibration was later checked against data from the October 2, 2005 flood event. The Soldier Creek near Topeka gaging station (06889500) is operated by the U.S.G.S. on the downstream side of Brickyard Road. The gage reading at this site was the only available information to calibrate the model from the 1993 event. The Corps of Engineers provided high water mark data on Soldier Creek from the 1993 flood. However, the high water marks were influenced by backwater from the July 25, 1993 flood event on the Kansas River and could not be used. Previously recorded high water marks under the U.S. 75 Bridge were eliminated when the bridge was replaced in 1995. According to City personnel, during the 1993 flood event, no readings were made using freeboard gages.

The Topeka gage reading on July 10, 1993 was 23.42 feet, M.S.L. and the discharge was 18,900 cfs. With the gage datum of 862.95 feet, M.S.L., the target elevation at the gage was 886.37 feet. Table 2-4 shows the discharges used in the calibration run. These discharges were determined by multiplying the ratio of drainage areas to the discharge at the gage.

Table 2-4 Calibration Discharges on Soldier Creek

Upstream of Messhoss Creek (cfs)	Messhoss Creek to Silver Lake Ditch (cfs)	Silver Lake Ditch to Halfday Creek (cfs)	Halfday Creek to Indian Creek (cfs)	Indian Creek to the Mouth (cfs)
17,100	18,100	18,900	20,500	21,600

The model was started at 865.0 feet, which is the estimated Kansas River elevation based on the daily discharge of 47,300 cfs recorded on July 10, 1993. Only the channel "n" was varied in the calibration runs, because there was no overbank flow at most cross sections. A change in starting river stage of 2 feet at the Kansas River resulted in less than 0.10 feet difference at the gage. Plate A2-2-6 shows the resulting water surface profile. The computed water surface elevation at the gage was 886.38 ft, only 0.01 foot higher than the observed reading. The model is calibrated as well as possible with the limited data available.

During the 2005 flood event, a discharge measurement was made at the gage by the USGS as the event was nearing its peak. The recorded peak discharge at the Topeka gage on Soldier Creek was 47,800 cfs with a stage of 34.78 ft (at elevation 897.73 ft NGVD 1929). Several locations upstream of US Hwy 75 also experienced levee overtopping during the 2005 event, and the simulated overtopping locations from the HEC-RAS model were checked against the actual observed overtopping locations. The profile and overtopping locations of the model were found to be consistent with the observed data.

To test the calibration of the model over a wider range of discharges, water surface profiles were computed for a series of discharges: 50, 20, 10, 4, 2, 1, 0.5 and 0.2-percent chance (2, 5, 10, 25, 50, 100, 200, and 500-year flood events). The starting water surface elevations were taken from Table 2-3 above. The computed water surface elevation at the gage was compared to the expected gage elevation. Table 2-5 lists the discharges and expected water surface elevations. The expected gage elevations were determined from rating curve number 43, in use between 1993 and 1997, which shows the stage versus discharge. The stage was converted to an elevation by simply adding the elevation of the gage datum (862.95 feet, N.G.V.D.) to the stage reading. The largest discharge of the rating curve was 19,000 cfs. Stages larger than that were obtained by extrapolation.

The results show that the computed water surface profiles match the expected gage heights fairly well, except for the largest discharge. At this discharge, water downstream is higher than the levee. Therefore, the computed water surface profile would not necessarily match what would physically happen. This phenomenon is discussed in more detail in the following section.

Table 2-5 Computed Water Surface Elevation versus Expected Gage Height

Percent Chance of Exceedance (%)	Annual Event Discharge (cfs)	Computed Water Surface Elevation (ft)	Soldier Creek near Topeka Rating Curve Elevation (ft)	Difference: Computed vs Expected Gage Elevation (ft)
50	6080	875.57	875.94	-0.37
20	11,800	881.14	881.8	-0.66
10	16,400	884.78	884.96	-0.18
5	21,300	887.83	887.65*	0.18
2	28,300	891.08	890.85*	0.23
1	33,900	893.20	892.95*	0.25
0.5	40,000	895.31	894.95*	0.36
0.2	48,500	899.96	897.95*	2.01
Note: All model elevations are from STA 6.0				

<u>Soldier Creek Existing Condition (Base) Profiles</u>

Once the model was calibrated, the existing conditions water surface profiles were generated using the discharges of Table 2-5 above. Plate A2-2-7 shows the profiles for the 50% non-exceedance probability profiles for the 50, 20, 10, 5, 2, 1, 0.5, 0.2-percent chance (2, 5, 10, 20, 50, 100, 200, and 500-year) flood events. The tabular data is presented in Table 2-6, located at the end of this section.

The HEC-RAS model indicates that none of the Soldier Creek Levee Units in this study begin to physically overtop until the water surface elevation reaches approximately the 50% non-exceedance probability stage for the 0.5% chance exceedance (200-year) event. Discretion should be used when applying profiles higher than the top of the levee. The model used a confined cross sectional area from levee to levee. Essentially, overbank flow beyond the levee height was not taken into consideration. This assumption was made to avoid trying to predict where a levee would fail. Within the Topeka levee systems, there are many different combinations of failure scenarios that could physically occur. Potentially, each could produce a different overbank flow path. HEC-RAS is a one-dimensional steady state model. It is beyond the limitations for HEC-RAS to predict the overbank flow scenarios or to model multi-dimensional flow. Profiles for the rare frequency events that exceed the top of levee are highly speculative and would not necessarily match what would physically happen. These events were produced to formulate frequency-stage curves for economic analyses in the HEC-FDA computer program.

Hydraulic Uncertainty

Uncertainties in computed stage result from two main sources: natural variations in the river and modeling errors. Natural variations include uncertainties in physical factors such as bed forms, debris and other obstructions, channel scour or deposition, sediment transport, and waves. Modeling uncertainty includes factors such as inexact geometry and loss coefficients, variation in hydraulic roughness with season, and error in setting high water marks (EM 1110-2-1619).

In Risk Based Analysis, the stage uncertainty is express as standard deviation (in feet). The total standard deviation depends on the standard deviation based on natural variations and the standard deviation based on model errors according to the formula below:

$$\text{Total Standard Deviation} = \sqrt{S_{natural}^2 + S_{model}^2}$$

where $S_{natural}$ = standard deviation based on natural variations
S_{model} = standard deviation based on modeling uncertainties

For a gaged reached, $S_{natural}$ is calculated by comparing observed data with the latest rating curve at the gage in the study reach. To avoid potential problems due to shifts in the rating curve over time, only observed data going back to 1990 was used. Only data values for bank full discharges and greater were analyzed. The following formula is used to calculate $S_{natural}$.

$$S_{natural} = \sqrt{\frac{\Sigma(X - M)^2}{(N-1)}}$$

where: X=Stage corresponding to measured Q
M=best fit curve estimate of stage corresponding to Q
N=number of stage-discharge observations in the range being analyzed

The best fit curve through data from the rating curve is defined by the equation, Stage = $-4.638E\text{-}8 * Q^2 + 0.001957 * Q + 865.55$ where Q is the measured discharge. The standard deviation based on historical data and gage readings, $S_{natural}$, was computed as 0.75 feet.

Table 5-2 in EM 1110-2-1619 quantifies S_{model} based on the quality of topographic data and the reliability of the Manning's n-value. A standard deviation of 1.5 feet was chosen since some of the cross-sections were based on mapping and the Manning's n-values were assumed to have "poor" reliability (due to the limited amount of calibration data available).

Once $S_{natural}$ and S_{model} are known, a total standard deviation can be computed. For this study a total standard deviation of 1.68 was computed for the entire discharge set.

A-2.2.6 SUMMARY

First, a hydrologic analysis was completed to determine the expected discharges at the flood reduction works based upon statistical analyses of two stream flow gages in the watershed. Next, a hydraulic investigation was conducted on Soldier Creek using the HEC-RAS computer software developed by the Hydrologic Engineering Center, U.S. Army Corps of Engineers. The program was used to calculate water surface profiles on the first ten miles of Soldier Creek in Topeka, Kansas. The model was calibrated using the Topeka gage height during the 1993 flood and then checked against observed stages from the 2005 flood event. Water surface profiles were then generated for eight different discharge events. These include the 50, 20, 10, 5, 2, 1, 0.5, and 0.2-percent chance flood events. The model shows that the existing levees are not overtopped until the 0.5% chance exceedance (200-year) flood event. Last, the uncertainty in both stage and discharge were calculated. The standard deviation of stage is 1.68 feet.

Table 2-6 Soldier Creek Existing Conditions Water Surface Profiles

HEC-RAS River Station	Profile	Q Total (cfs)	Water Surface Elevation (ft)	Energy Grade Elevation (ft)	Energy Grade Slope (ft/ft)	Average Channel Velocity (ft/s)	Flow Area (sq ft)	Top Width (ft)	Channel Froude #
0.334	10% (10-yr)	17800	871.29	871.73	0.000371	5.31	3355.23	237.39	0.25
0.334	2% (50-yr)	31800	875.1	875.94	0.000536	7.39	4435.05	311.3	0.31
0.334	1% (100-yr)	38700	876.48	877.53	0.000611	8.3	4871.4	321.09	0.33
0.334	0.5% (200-yr)	46000	877.73	879.02	0.00069	9.2	5278.3	329.95	0.36
0.334	0.2% (500-yr)	56400	879.13	880.79	0.000819	10.47	5747.19	339.88	0.39
0.334	0.133% (750-yr)	61100	879.79	881.6	0.000864	10.97	5973.04	344.56	0.41
0.334	0.1% (1000-yr)	63900	880.03	881.96	0.000909	11.34	6055.96	346.26	0.42
0.334	0.04% (2500-yr)	76500	881.35	883.77	0.001063	12.73	6519.18	355.62	0.46
0.391	10% (10-yr)	17800	871.38	871.84	0.000325	5.4	3298.1	202.27	0.24
0 391	2% (50-yr)	31800	875.2	876.13	0.000564	7.74	4107.01	221.29	0.32
0.391	1% (100-yr)	38700	876.58	877.77	0.000684	8.76	4415.77	228.33	0.35
0.391	0.5% (200-yr)	46000	877.82	879.3	0.000813	9.78	4703.15	237.88	0.38
0.391	0.2% (500-yr)	56400	879.19	881.15	0.000988	11.22	5028.95	247.13	0.43
0.391	0.133% (750-yr)	61100	879.83	881.99	0.001051	11.8	5180.52	251.09	0.44
0.391	0.1% (1000-yr)	63900	880.06	882.38	0.00111	12.21	5235.66	252.53	0.46
0.391	0.04% (2500-yr)	76500	881.32	884.29	0.001324	13.83	5533.37	260.31	0.5
0.3945		Bridge							
0.398	10% (10-yr)	17800	871.4	871.85	0.000324	5.39	3301.86	202.37	0.24
0.398	2% (50-yr)	31800	875.25	876.18	0 00056	7.72	4118.38	221.54	0.32
0.398	1% (100-yr)	38700	876.65	877.83	0.000677	8.73	4432.75	228.91	0.35
0.398	0.5% (200-yr)	46000	877.92	879.39	0.000802	9.73	4727.63	238.68	0.38
0.398	0.2% (500-yr)	56400	879.35	881.28	0.000964	11.14	5066.35	248.11	0.42
0.398	0.133% (750-yr)	61100	880.02	882.15	0.001021	11.7	5225.36	252.27	0.44
0.398	0.1% (1000-yr)	63900	880.27	882.54	0 001076	12.1	5284.46	253.81	0.45
0.398	0.04% (2500-yr)	76500	881.6	884.5	0.001272	13.67	5599.63	262.05	0.49
0.424	10% (10-yr)	17800	871.45	871.9	0.000313	5.38	3325.6	223.99	0.23
0.424	2% (50-yr)	31800	875.36	876.26	0.000483	7.66	4376.59	298.46	0.3
0.424	1% (100-yr)	38700	876.8	877.93	0.000559	8.62	4813.19	307.44	0.32
0.424	0.5% (200-yr)	46000	878.13	879.5	0.000636	9.56	5226.45	315.71	0.35
0.424	0 2% (500-yr)	56400	879.65	881.41	0 000755	10.87	5716.13	325.23	0.39
0.424	0.133% (750-yr)	61100	880.38	882.29	0.000796	11.38	5952.62	329.73	0 4
0.424	0.1% (1000-yr)	63900	880.66	882.7	0.000835	11.74	6047.12	331.51	0 41
0.424	0.04% (2500-yr)	76500	882.18	884.7	0.000966	13.12	6556.61	340.95	0.44
0.461	10% (10-yr)	17800	871.42	872.01	0.000422	6.18	2878.21	172.51	0.27
0.461	2% (50-yr)	31800	875.24	876.47	0.000746	8.91	3569.35	189.21	0 36
0.461	1% (100-yr)	38700	876.62	878.2	0.000909	10.09	3834.18	195.19	0.4
0.461	0.5% (200-yr)	46000	877.87	879.84	0.001083	11.27	4081.35	200.62	0.44
0.461	0.2% (500-yr)	56400	879.26	881.85	0.001355	12.92	4366.03	206.7	0 5
0 461	0.133% (750-yr)	61100	879.92	882.78	0.001462	13.57	4503.12	209.56	0.52
0.461	0.1% (1000-yr)	63900	880.16	883.22	0.00155	14.03	4554.04	210.61	0.53
0.461	0.04% (2500-yr)	76500	881.47	885 36	0.00189	15.83	4833.58	216.3	0.59
0.47		Bridge							

HEC-RAS River Station	Profile	Q Total (cfs)	Water Surface Elevation (ft)	Energy Grade Elevation (ft)	Energy Grade Slope (ft/ft)	Average Channel Velocity (ft/s)	Flow Area (sq ft)	Top Width (ft)	Channel Froude #
0.479	10% (10-yr)	17800	871.49	872.07	0.000417	6.16	2889.8	172.81	0.27
0.479	2% (50-yr)	31800	875.42	876.63	0.000727	8.82	3604.05	190	0.36
0.479	1% (100-yr)	38700	876.88	878.42	0.000876	9.96	3885.62	196.34	0.39
0.479	0.5% (200-yr)	46000	878.23	880.13	0.001031	11.07	4154.81	202.21	0.43
0.479	0.2% (500-yr)	56400	879.82	882.28	0.001262	12.59	4481.4	209.11	0.48
0.479	0.133% (750-yr)	61100	880.57	883.26	0.001348	13.17	4639.34	212.37	0.5
0.479	0.1% (1000-yr)	63900	880.88	883.75	0.001417	13.58	4706.7	213.74	0.51
0.479	0.04% (2500-yr)	76500	882.53	886.08	0.001665	15.1	5064.96	220.9	0.56
0.507	10% (10-yr)	17800	871.55	872.14	0.00039	6.13	2964.42	255.32	0.26
0.507	2% (50-yr)	31800	875.66	876.74	0.000569	8.52	4159.16	307.18	0.32
0.507	1% (100-yr)	38700	877.24	878.55	0.00064	9.48	4653.62	318.5	0.35
0.507	0.5% (200-yr)	46000	878.74	880.3	0.000706	10.38	5140.42	329.27	0.37
0.507	0.2% (500-yr)	56400	880.58	882.48	0.000796	11.57	5759.94	342.48	0.4
0.507	0.133% (750-yr)	61100	881.46	883.48	0.000821	12.01	6061.43	348.73	0.4
0.507	0.1% (1000-yr)	63900	881.86	883.98	0.000847	12.32	6201.83	351.6	0.41
0.507	0.04% (2500-yr)	76500	883.89	886.37	0.000914	13.41	6932.13	366.18	0.43
0.602	10% (10-yr)	17800	871.74	872.35	0.00042	6.28	2870.08	249.27	0.27
0.602	2% (50-yr)	31800	875.91	877.05	0.000605	8.71	4034.16	294.02	0.33
0.602	1% (100-yr)	38700	877.52	878.9	0.000678	9.67	4516.17	305.08	0.35
0.602	0.5% (200-yr)	46000	879.05	880.68	0.000746	10.59	4990.6	315.59	0.38
0.602	0.2% (500-yr)	56400	880.93	882.92	0.00084	11.8	5596.08	328.52	0.4
0.602	0.133% (750-yr)	61100	881.81	883.93	0.000866	12.25	5887.8	334.56	0.41
0.602	0.1% (1000-yr)	63900	882.22	884.45	0.000893	12.56	6026.09	337.39	0.42
0.602	0.04% (2500-yr)	76500	884.28	886.87	0.000962	13.68	6734.14	351.53	0.44
0.719	10% (10-yr)	17800	872.08	872.59	0.000341	5.74	3125.33	211.02	0.24
0.719	2% (50-yr)	31800	876.43	877.4	0.000493	8.01	4331.21	365.62	0.3
0.719	1% (100-yr)	38700	878.14	879.3	0.000542	8.84	4960.59	370.61	0.32
0.719	0.5% (200-yr)	46000	879.77	881.12	0.000584	9.59	5571.81	375.39	0.34
0.719	0.2% (500-yr)	56400	881.82	883.41	0.000637	10.57	6345.5	381.35	0.36
0.719	0.133% (750-yr)	61100	882.76	884.44	0.000651	10.92	6705.36	384.1	0.36
0.719	0.1% (1000-yr)	63900	883.22	884.97	0.000666	11.17	6882.29	385.44	0.37
0.719	0.04% (2500-yr)	76500	885.43	887.44	0.000704	12.07	7743.73	393.89	0.38
0.837	10% (10-yr)	17800	872.28	872.82	0.000363	5.85	3058.25	200.15	0.25
0.837	2% (50-yr)	31800	876.72	877.72	0.000515	8.13	4244.2	365.06	0.31
0.837	1% (100-yr)	38700	878.46	879.65	0.000562	8.95	4883.49	370.22	0.33
0.837	0.5% (200-yr)	46000	880.12	881.49	0.000601	9.69	5503.8	375.16	0.34
0.837	0.2% (500-yr)	56400	882.2	883.82	0.000652	10.64	6290.38	381.32	0.36
0.837	0.133% (750-yr)	61100	883.15	884.86	0.000664	11	6653.58	384.14	0.37
0.837	0.1% (1000-yr)	63900	883.62	885.39	0.000678	11.24	6834.42	385.53	0.37
0.837	0.04% (2500-yr)	76500	885.86	887.88	0.000712	12.11	7706.28	392	0.39
0.883	10% (10-yr)	17800	872.36	872.92	0.000421	6	2968.71	183.69	0.26
0.883	2% (50-yr)	31800	876.8	877.89	0.000621	8.37	3817.1	198.57	0.33
0.883	1% (100-yr)	38700	878.49	879.86	0.000702	9.38	4167.39	215.41	0.35

HEC-RAS River Station	Profile	Q Total (cfs)	Water Surface Elevation (ft)	Energy Grade Elevation (ft)	Energy Grade Slope (ft/ft)	Average Channel Velocity (ft/s)	Flow Area (sq ft)	Top Width (ft)	Channel Froude #
0.883	0.5% (200-yr)	46000	880.09	881.75	0.00078	10.36	4517.31	223.34	0.38
0.883	0.2% (500-yr)	56400	882.05	884.15	0.000889	11.68	4964.95	233.1	0.41
0.883	0.133% (750-yr)	61100	882.94	885.22	0.000926	12.2	5173.77	237.52	0.42
0.883	0.1% (1000-yr)	63900	883.37	885.78	0.000957	12.53	5277.34	239.68	0.43
0.883	0.04% (2500-yr)	76500	885.44	888.36	0.001055	13.83	5781.2	247.63	0.46
0.884		Bridge							
0.885	10% (10-yr)	17800	872.46	873.01	0.000414	5.96	2986.22	184.01	0.26
0.885	2% (50-yr)	31800	877.02	878.09	0.0006	8.28	3861.87	199.33	0.32
0.885	1% (100-yr)	38700	878.81	880.13	0.000669	9.24	4235.19	216.97	0.35
0.885	0.5% (200-yr)	46000	880.5	882.1	0.000735	10.18	4609.87	225.4	0.37
0.885	0.2% (500-yr)	56400	882.62	884.62	0.000823	11.4	5099.52	235.96	0.4
0.885	0.133% (750-yr)	61100	883.58	885.75	0.000851	11.88	5327.93	240.73	0.4
0.885	0.1% (1000-yr)	63900	884.07	886.34	0.000874	12.19	5445.46	242.84	0.41
0.885	0.04% (2500-yr)	76500	885.91	888.73	0.000995	13.59	5897.95	248.94	0.44
0.914	10% (10-yr)	17800	872.42	873.13	0.000543	6.77	2653.28	191.66	0.3
0.914	2% (50-yr)	31800	876.97	878.25	0.000745	9.16	3651	244.18	0.37
0.914	1% (100-yr)	38700	878.76	880.3	0.000804	10.09	4103.72	261.11	0.39
0.914	0.5% (200-yr)	46000	880.48	882.28	0.000857	10.97	4564.84	275.39	0.4
0.914	0.2% (500-yr)	56400	882.64	884.8	0.000924	12.09	5173.61	287.17	0.42
0.914	0.133% (750-yr)	61100	883.62	885.92	0.00094	12.51	5458	292.51	0.43
0.914	0.1% (1000-yr)	63900	884.12	886.52	0.000958	12.79	5604.44	295.22	0.44
0.914	0.04% (2500-yr)	76500	886.03	888.9	0.001057	14.07	6176.49	301.03	0.46
1.057	10% (10-yr)	17800	872.82	873.56	0.00058	6.92	2590.69	187.67	0.31
1.057	2% (50-yr)	31800	877.52	878.83	0.00077	9.25	3607.39	242.49	0.37
1.057	1% (100-yr)	38700	879.36	880.92	0.000823	10.17	4068.89	259.85	0.39
1.057	0.5% (200-yr)	46000	881.12	882.93	0.00087	11.02	4539.33	274.88	0.41
1.057	0.2% (500-yr)	56400	883.33	885.5	0.000929	12.11	5162.57	286.96	0.43
1.057	0.133% (750-yr)	61100	884.33	886.63	0.000943	12.53	5450.99	292.38	0.43
1.057	0.1% (1000-yr)	63900	884.84	887.24	0.000959	12.8	5601.86	295.18	0.44
1 057	0.04% (2500-yr)	76500	886.86	889.69	0.001042	14	6205.03	301.13	0.46
1.199	10% (10-yr)	17800	873.29	873.99	0.000559	6.71	2653.82	175.11	0.3
1.199	2% (50-yr)	31800	878.22	879.41	0.000736	8.81	3743.22	257.78	0.36
1.199	1% (100-yr)	38700	880.13	881.54	0.000769	9.62	4251.29	273.68	0.37
1.199	0.5% (200-yr)	46000	881.96	883.58	0.000798	10.38	4766.18	288.91	0.39
1.199	0.2% (500-yr)	56400	884.28	886.19	0.000836	11.34	5458.42	308.21	0.4
1.199	0.133% (750-yr)	61100	885.31	887.33	0.000842	11.7	5780.61	314.53	0.41
1.199	0.1% (1000-yr)	63900	885.86	887.95	0 000851	11.92	5952.96	316.77	0.41
1.199	0.04% (2500-yr)	76500	888.01	890 46	0.000906	12.98	6645.35	323.76	0.43
1.342	10% (10-yr)	17800	873.71	874.43	0.000591	6.85	2598.47	173.32	0.31
1.342	2% (50-yr)	31800	878.76	879.98	0.000762	8.91	3695.73	256.24	0.37
1.342	1% (100-yr)	38700	880.7	882.13	0.000791	9.71	4207.56	272.35	0.38
1.342	0.5% (200-yr)	46000	882.55	884.2	0.000817	10.45	4726.24	287.76	0.39
1.342	0.2% (500-yr)	56400	884.9	886.83	0.00085	11.4	5424.72	307.3	0.41

HEC-RAS River Station	Profile	Q Total (cfs)	Water Surface Elevation (ft)	Energy Grade Elevation (ft)	Energy Grade Slope (ft/ft)	Average Channel Velocity (ft/s)	Flow Area (sq ft)	Top Width (ft)	Channel Froude #
1.342	0.133% (750-yr)	61100	885.93	887.98	0.000855	11.76	5747.43	314.1	0.41
1.342	0.1% (1000-yr)	63900	886.49	888.6	0.000863	11.98	5921.79	316.37	0.41
1.342	0.04% (2500-yr)	76500	888.69	891.15	0.000912	13	6628.75	323.7	0.43
1.372	10% (10-yr)	17800	873.81	874.53	0.000581	6.8	2616.37	173.9	0.31
1.372	2% (50-yr)	31800	878.87	880.11	0.000758	8.92	3600.25	213.06	0.37
1.372	1% (100-yr)	38700	880.79	882.27	0.000804	9.81	4020.42	226.03	0.38
1.372	0.5% (200-yr)	46000	882.61	884.36	0.000848	10.67	4442.86	238.35	0.4
1.372	0.2% (500-yr)	56400	884.9	887.03	0.00091	11.8	5006.36	253.86	0.42
1.372	0.133% (750-yr)	61100	885.9	888.19	0.00093	12.25	5264.43	260.65	0.43
1.372	0.1% (1000-yr)	63900	886.43	888.83	0.000946	12.53	5404.07	264.26	0.43
1.372	0.04% (2500-yr)	76500	888.54	891.43	0.001034	13.8	5980.02	283.32	0.46
1.375		Bridge							
1.378	10% (10-yr)	17800	873.86	874.58	0.000575	6.78	2626.05	174.22	0.31
1.378	2% (50-yr)	31800	878.99	880.21	0.000742	8.87	3625.07	213.85	0.36
1.378	1% (100-yr)	38700	880.93	882.4	0.000784	9.74	4053.82	227.02	0.38
1.378	0.5% (200-yr)	46000	882.79	884.51	0.000825	10.58	4485.97	239.57	0.39
1.378	0.2% (500-yr)	56400	885.12	887.21	0.000881	11.68	5064.47	255.41	0.41
1.378	0.133% (750-yr)	61100	886.15	888.39	0.000899	12.12	5329.13	262.33	0.42
1.378	0.1% (1000-yr)	63900	886.69	889.04	0.000914	12.4	5473.22	266.03	0.43
1.378	0.04% (2500-yr)	76500	888.71	891.56	0.001013	13.7	6027.04	284.67	0.45
1.389	10% (10-yr)	17800	873.9	874.61	0.000571	6.76	2632.79	174.44	0.31
1.389	2% (50-yr)	31800	879.08	880.25	0.000717	8.74	3778	258.9	0.36
1.389	1% (100-yr)	38700	881.08	882.45	0.000741	9.51	4312.09	275.53	0.37
1.389	0.5% (200-yr)	46000	883	884.57	0.000761	10.23	4856.31	291.5	0.38
1.389	0.2% (500-yr)	56400	885.44	887.29	0.000788	11.14	5594.3	311.85	0.39
1.389	0.133% (750-yr)	61100	886.53	888.47	0.00079	11.48	5934.23	316.53	0.4
1.389	0.1% (1000-yr)	63900	887.11	889.12	0.000797	11.69	6118.96	318.92	0.4
1.389	0.04% (2500-yr)	76500	889.29	891.66	0.000855	12.76	6822.94	324.41	0.42
1.535	10% (10-yr)	17800	874.37	875.04	0.000521	6.53	2724.41	177.37	0.29
1.535	2% (50-yr)	31800	879.7	880.78	0.000634	8.41	3952.87	264.46	0.34
1.535	1% (100-yr)	38700	881.73	883	0.000657	9.16	4507.3	281.36	0.35
1.535	0.5% (200-yr)	46000	883.68	885.14	0.000678	9.86	5071.41	297.58	0.36
1.535	0.2% (500-yr)	56400	886.17	887.88	0.000704	10.75	5836.65	315.26	0.37
1.535	0.133% (750-yr)	61100	887.26	889.06	0.000709	11.08	6182.09	319.73	0.38
1.535	0.1% (1000-yr)	63900	887.85	889.72	0.000715	11.3	6371.4	322.16	0.38
1 535	0.04% (2500-yr)	76500	890.09	892.3	0.000768	12.34	7100.35	325.42	0.4
1.681	10% (10-yr)	17800	874.76	875.47	0.000569	6.78	2624.91	169.64	0.3
1.681	2% (50-yr)	31800	880.18	881.31	0.000702	8.6	4002.61	341.45	0.35
1.681	1% (100-yr)	38700	882.26	883.53	0.000701	9.22	4724.76	354.03	0.36
1.681	0.5% (200-yr)	46000	884.28	885.67	0.000695	9.76	5452.9	366.28	0.36
1.681	0.2% (500-yr)	56400	886.87	888.43	0.000689	10.44	6423.12	382	0.36
1.681	0.133% (750-yr)	61100	888	889.62	0.000683	10.7	6857.53	388.83	0.37
1.681	0.1% (1000-yr)	63900	888.61	890.28	0.000685	10.87	7097.66	394.71	0.37

HEC-RAS River Station	Profile	Q Total (cfs)	Water Surface Elevation (ft)	Energy Grade Elevation (ft)	Energy Grade Slope (ft/ft)	Average Channel Velocity (ft/s)	Flow Area (sq ft)	Top Width (ft)	Channel Froude #
1.681	0.04% (2500-yr)	76500	891.04	892.9	0.0007	11.63	8067.45	401.2	0.38
1.867	10% (10-yr)	17200	875.44	875.99	0.000451	5.92	2904.86	196.21	0.27
1.867	2% (50-yr)	30400	881.08	881.91	0.000494	7.35	4343.15	328.52	0.3
1.867	1% (100-yr)	36800	883.19	884.14	0.000495	7.89	5061.74	347.38	0.3
1.867	0.5% (200-yr)	43500	885.24	886.28	0.000492	8.36	5779.96	355.07	0.31
1.867	0.2% (500-yr)	53200	887.85	889.04	0.000493	8.99	6721.21	364.9	0.31
1.867	0.133% (750-yr)	58100	888.96	890.23	0.000503	9.33	7127.63	369.07	0.32
1.867	0.1% (1000-yr)	60800	889.58	890.89	0.000505	9.5	7357.38	371.4	0.32
1.867	0.04% (2500-yr)	72800	892.03	893.53	0.000524	10.24	8274.39	374	0.33
2.053	10% (10-yr)	17200	875.87	876.42	0.000432	5.92	2904.4	189.64	0.27
2.053	2% (50-yr)	30400	881.56	882.42	0.000512	7.44	4143.16	289.43	0.3
2.053	1% (100-yr)	36800	883.65	884.65	0.00052	8.04	4808.73	336.71	0.31
2.053	0.5% (200-yr)	43500	885.69	886.8	0.00052	8.55	5511.4	351.07	0.31
2.053	0.2% (500-yr)	53200	888.3	889.56	0.000522	9.21	6444.16	364.12	0.32
2.053	0.133% (750-yr)	58100	889.41	890.76	0.000531	9.55	6852.76	369.7	0.33
2.053	0.1% (1000-yr)	60800	890.03	891.42	0.000534	9.72	7083.57	372.81	0.33
2.053	0.04% (2500-yr)	72800	892.5	894.09	0.000552	10.47	8006.83	374	0.34
2.239	10% (10-yr)	17200	876.28	876.86	0.000442	6.08	2830.68	180.26	0.27
2.239	2% (50-yr)	30400	882.04	882.96	0.000551	7.71	3942.05	206.16	0.31
2.239	1% (100-yr)	36800	884.13	885.23	0.0006	8.39	4384.83	222	0.33
2.239	0.5% (200-yr)	43500	886.14	887.39	0.00061	9.01	4934.41	321.09	0.34
2.239	0.2% (500-yr)	53200	888.72	890.17	0.000617	9.75	5790.88	341.76	0.34
2.239	0.133% (750-yr)	58100	889.83	891.39	0.000627	10.11	6176.08	350.67	0.35
2.239	0.1% (1000-yr)	60800	890.45	892.06	0.000629	10.29	6394.86	355.62	0.35
2.239	0.04% (2500-yr)	72800	892.92	894.74	0.000647	11.07	7309.51	374	0.36
2.277	10% (10-yr)	17200	876.38	876.94	0.000435	6.04	2848.13	180.85	0.27
2.277	2% (50-yr)	30400	882.16	883.07	0.000541	7.66	3969.27	207.1	0.31
2.277	1% (100-yr)	36800	884.27	885.35	0.000591	8.33	4416.53	216.69	0.33
2.277	0.5% (200-yr)	43500	886.27	887.52	0.000637	8.95	4860.64	226.44	0.34
2.277	0.2% (500-yr)	53200	888.84	890.31	0.000699	9.75	5457.52	239.77	0.36
2.277	0.133% (750-yr)	58100	889.94	891.54	0.000734	10.15	5724.82	245.5	0.37
2.277	0.1% (1000-yr)	60800	890.55	892.21	0.00075	10.35	5875.99	248.69	0.38
2.277	0.04% (2500-yr)	72800	892.98	894.93	0.000817	11.21	6495.55	267.64	0.4
2.2805		Bridge							
2.284	10% (10-yr)	17200	876.44	877	0.000431	6.02	2859.2	181.13	0.27
2.284	2% (50-yr)	30400	882.26	883.16	0.000534	7.62	3990.68	207.57	0.31
2.284	1% (100-yr)	36800	884.39	885.46	0.000581	8.28	4443.68	217.26	0.32
2.284	0.5% (200-yr)	43500	886.42	887.65	0.000626	8.89	4894.02	227.2	0.34
2.284	0.2% (500-yr)	53200	889.01	890.47	0.000685	9.67	5500.53	240.7	0.36
2.284	0.133% (750-yr)	58100	890.13	891.71	0.000718	10.06	5773.32	246.53	0.37
2.284	0.1% (1000-yr)	60800	890.75	892.39	0.000733	10.26	5927.38	249.76	0.37
2.284	0.04% (2500-yr)	72800	894.85	896.52	0.000642	10.43	6989	343.37	0.35

HEC-RAS River Station	Profile	Q Total (cfs)	Water Surface Elevation (ft)	Energy Grade Elevation (ft)	Energy Grade Slope (ft/ft)	Average Channel Velocity (ft/s)	Flow Area (sq ft)	Top Width (ft)	Channel Froude #
2.299	10% (10-yr)	17200	876.48	877.04	0.000427	6	2865.69	181.13	0.27
2.299	2% (50-yr)	30400	882.31	883.21	0.00053	7.6	3998.54	207.39	0.31
2.299	1% (100-yr)	36800	884.44	885.51	0.00057	8.27	4456.53	238.36	0.32
2.299	0.5% (200-yr)	43500	886.48	887.7	0.000578	8.86	5046.74	323.88	0.33
2.299	0.2% (500-yr)	53200	889.13	890.52	0.000581	9.56	5930.78	345.02	0.33
2.299	0.133% (750-yr)	58100	890.28	891.77	0.000589	9.91	6333.14	354.23	0.34
2.299	0.1% (1000-yr)	60800	890.92	892.45	0.00059	10.08	6561.09	359.34	0.34
2.299	0.04% (2500-yr)	72800	895.1	896.6	0.00049	10.11	8124.26	374	0.32
2.479	10% (10-yr)	17200	876.88	877.44	0.000428	6.03	2851.79	179.38	0.27
2.479	2% (50-yr)	30400	882.81	883.71	0.000525	7.61	3993.58	205.79	0.3
2.479	1% (100-yr)	36800	884.99	886.05	0.000571	8.26	4452.53	215.49	0.32
2.479	0.5% (200-yr)	43500	887.04	888.26	0.000596	8.87	4919.71	256.26	0.33
2.479	0.2% (500-yr)	53200	889.66	891.1	0.000607	9.65	5713.5	348.18	0.34
2.479	0.133% (750-yr)	58100	890.82	892.35	0.000615	10.01	6126.83	360	0.35
2.479	0.1% (1000-yr)	60800	891.46	893.04	0.000616	10.18	6356.86	360	0.35
2.479	0.04% (2500-yr)	72800	895.53	897.1	0.000519	10.27	7822.84	360	0.33
2.527	10% (10-yr)	17200	876.99	877.55	0.000419	5.99	2871.47	179.44	0.26
2.527	2% (50-yr)	30400	882.95	883.84	0.000514	7.57	4016.82	205.19	0.3
2.527	1% (100-yr)	36800	885.14	886.19	0.000558	8.22	4476.93	214.67	0.32
2.527	0.5% (200-yr)	43500	887.2	888.41	0.000599	8.83	4927.76	223.56	0.33
2.527	0.2% (500-yr)	53200	889.82	891.26	0.000654	9.62	5528.59	234.9	0.35
2.527	0.133% (750-yr)	58100	890.96	892.52	0.00067	10.02	5797.99	239.83	0.36
2.527	0.1% (1000-yr)	60800	891.59	893.21	0.000674	10.23	5946.08	243.75	0.36
2.527	0.04% (2500-yr)	72800	895.57	897.28	0.000597	10.51	7118.09	382.7	0.35
2.53		Bridge							
2.533	10% (10-yr)	17200	877.06	877.61	0.000414	5.96	2883.76	179.74	0.26
2.533	2% (50-yr)	30400	883.07	883.95	0.000506	7.52	4041.14	205.7	0.3
2.533	1% (100-yr)	36800	885.29	886.32	0.000548	8.16	4507.99	215.29	0.31
2.533	0.5% (200-yr)	43500	887.37	888.56	0.000587	8.76	4966.21	224.31	0.33
2.533	0.2% (500-yr)	53200	890.03	891.44	0.000638	9.54	5577.31	235.79	0.35
2.533	0.133% (750-yr)	58100	891.12	892.66	0.000655	9.96	5835.98	240.78	0.35
2.533	0.1% (1000-yr)	60800	891.78	893.38	0.000658	10.15	5990.13	244.94	0.36
2.533	0.04% (2500-yr)	72800	897.28	898.76	0.000485	9.85	7770.18	382.7	0.31
2.546	10% (10-yr)	17200	877.09	877.64	0.000412	5.95	2889.86	180.1	0.26
2.546	2% (50-yr)	30400	883.11	883.98	0.000503	7.5	4052.58	206.51	0.3
2.546	1% (100-yr)	36800	885.33	886.36	0.000545	8.14	4522.44	216.27	0.31
2.546	0.5% (200-yr)	43500	887.42	888.6	0.000573	8.73	4999.26	247.19	0.33
2.546	0.2% (500-yr)	53200	890.09	891.48	0.000602	9.49	5730.17	307.16	0.34
2.546	0.133% (750-yr)	58100	891.21	892.71	0.000613	9.87	6135.8	418.9	0.34
2.546	0.1% (1000-yr)	60800	891.89	893.43	0.00061	10.02	6442.07	486.55	0.34
2.546	0.04% (2500-yr)	72800	897.59	898.82	0.000399	9.23	9281.02	498	0.29
2.66	10% (10-yr)	17200	877.35	877.89	0.000394	5.86	2936.92	181.25	0.26
2.66	2% (50-yr)	30400	883.43	884.28	0.000481	7.38	4120.09	207.94	0.29

HEC-RAS River Station	Profile	Q Total (cfs)	Water Surface Elevation (ft)	Energy Grade Elevation (ft)	Energy Grade Slope (ft/ft)	Average Channel Velocity (ft/s)	Flow Area (sq ft)	Top Width (ft)	Channel Froude #
2.66	1% (100-yr)	36800	885.69	886.68	0.00052	8	4599.79	217.84	0.31
2.66	0.5% (200-yr)	43500	887.8	888.94	0.000544	8.58	5094.28	254.65	0.32
2.66	0.2% (500-yr)	53200	890.5	891.84	0.000568	9.32	5863.09	347.76	0.33
2.66	0.133% (750-yr)	58100	891.63	893.07	0.000578	9.69	6321.11	461.02	0.33
2.66	0.1% (1000-yr)	60800	892.31	893.79	0.000575	9.83	6653.45	498	0.34
2.66	0.04% (2500-yr)	72800	897.86	899.06	0.000386	9.13	9415.22	498	0.28
2.691	10% (10-yr)	17200	877.44	877.95	0.00038	5.77	2981.51	183.42	0.25
2.691	2% (50-yr)	30400	883.54	884.36	0.000466	7.26	4188.51	211.88	0.29
2.691	1% (100-yr)	36800	885.81	886.77	0.000503	7.86	4681.03	222.45	0.3
2.691	0.5% (200-yr)	43500	887.95	889.04	0.000505	8.39	5433.22	503.21	0.31
2 691	0.2% (500-yr)	53200	890.79	891.95	0.000477	8.81	6963.37	556.94	0.3
2.691	0.133% (750-yr)	58100	892	893.18	0.00047	9.01	7639.63	562.98	0.3
2.691	0.1% (1000-yr)	60800	892.71	893.9	0.00046	9.07	8042.3	563	0.3
2.691	0.04% (2500-yr)	72800	898.23	899.14	0.000299	8.25	11148.97	563	0.25
2.837	10% (10-yr)	17200	877.73	878.29	0.000458	6.01	2863.98	190.29	0.27
2.837	2% (50-yr)	30400	883.9	884.73	0.000487	7.32	4259.36	325.14	0.29
2.837	1% (100-yr)	36800	886.22	887.15	0.000474	7.79	5037.45	342.92	0.3
2.837	0.5% (200-yr)	43500	888.4	889.41	0.000464	8.21	5800.82	357.58	0.3
2.837	0.2% (500-yr)	53200	891.17	892.31	0.000458	8.78	6818.19	376.98	0.3
2.837	0.133% (750-yr)	58100	892.34	893.55	0.000463	9.09	7266.48	385.8	0.3
2.837	0.1% (1000-yr)	60800	893.04	894.27	0.000461	9.21	7534.14	385.8	0.3
2.837	0.04% (2500-yr)	72800	898.34	899.44	0.00034	8.87	9581.75	385.8	0.27
2.954	10% (10-yr)	17200	878.01	878.55	0.000385	5.89	2919.34	175.17	0.25
2.954	2% (50-yr)	30400	884.18	885.02	0.000437	7.39	4289.43	292.82	0.28
2.954	1% (100-yr)	36800	886.48	887.44	0.000441	7.95	4983.13	309.1	0.29
2.954	0.5% (200-yr)	43500	888.64	889.71	0.000444	8.46	5667.41	324.36	0.29
2.954	0.2% (500-yr)	53200	891.39	892.62	0.000452	9.13	6586.23	342	0.3
2.954	0.133% (750-yr)	58100	892.56	893.86	0.000461	9.48	6984.86	342	0.31
2.954	0.1% (1000-yr)	60800	893.25	894.59	0.000462	9.63	7219.57	342	0.31
2.954	0.04% (2500-yr)	72800	898.46	899.71	0.00036	9.44	9001.85	342	0.28
2.992	10% (10-yr)	17200	878.09	878.62	0.000381	5.86	2936.9	176.37	0.25
2.992	2% (50-yr)	30400	884.27	885.11	0.000487	7.36	4129.89	211.73	0.29
2.992	1% (100-yr)	36800	886.57	887.55	0.000533	7.94	4633.45	227.03	0.31
2.992	0.5% (200-yr)	43500	888.71	889.83	0.000572	8.47	5136.53	241.35	0.32
2.992	0.2% (500-yr)	53200	891.45	892.74	0.000618	9.14	5821.06	259.13	0.34
2.992	0.133% (750-yr)	58100	892.6	894	0.000624	9.49	6122.17	263.34	0.34
2.992	0.1% (1000-yr)	60800	893.28	894.73	0.000622	9.66	6301.43	265.81	0.35
2 992	0.04% (2500-yr)	72800	898.45	899.83	0.000461	9.46	8001.43	379.2	0.31
2.9955		Bridge							
2.999	10% (10-yr)	17200	878.14	878.67	0.000378	5.84	2945.43	176.62	0.25
2.999	2% (50-yr)	30400	884.35	885.19	0.000482	7.33	4147.05	212.27	0.29
2.999	1% (100-yr)	36800	886.66	887.63	0.000527	7.91	4655.28	227.67	0.31
2.999	0.5% (200-yr)	43500	888.82	889.93	0.000565	8.42	5163.22	242.09	0.32

HEC-RAS River Station	Profile	Q Total (cfs)	Water Surface Elevation (ft)	Energy Grade Elevation (ft)	Energy Grade Slope (ft/ft)	Average Channel Velocity (ft/s)	Flow Area (sq ft)	Top Width (ft)	Channel Froude #
2.999	0.2% (500-yr)	53200	891.54	892.83	0.000609	9.1	5845.32	259.48	0.34
2.999	0.133% (750-yr)	58100	894.3	895.52	0.000494	8.85	6574.65	269.55	0.31
2.999	0.1% (1000-yr)	60800	894.58	895.88	0.000523	9.17	6646.79	270.54	0.32
2.999	0.04% (2500-yr)	72800	899.8	901.05	0.000395	9.02	8513.97	379.2	0.29
3.018	10% (10-yr)	17200	878.18	878.71	0.000375	5.83	2949.51	176.05	0.25
3.018	2% (50-yr)	30400	884.41	885.23	0.000421	7.31	4357.6	294.46	0.28
3.018	1% (100-yr)	36800	886.74	887.68	0.000427	7.88	5061.94	310.89	0.28
3.018	0.5% (200-yr)	43500	888.91	889.98	0.000434	8.42	5755.45	326.27	0.29
3.018	0.2% (500-yr)	53200	891.65	892.88	0.000449	9.15	6671.75	342	0.3
3 018	0.133% (750-yr)	58100	894.41	895.57	0.00038	8.95	7615.94	342	0.28
3.018	0.1% (1000-yr)	60800	894.69	895.93	0.000402	9.26	7711.77	342	0.29
3.018	0.04% (2500-yr)	72800	899.87	901.09	0.000328	9.26	9486.19	342	0.27
3.173	10% (10-yr)	17200	878.48	879.03	0.000405	5.96	2886.95	177.14	0.26
3.173	2% (50-yr)	30400	884.8	885.58	0.000414	7.21	5230.98	544.81	0.27
3.173	1% (100-yr)	36800	887.19	888.03	0.000397	7.58	6558.79	563.44	0.27
3.173	0.5% (200-yr)	43500	889.44	890.33	0.000384	7.92	7847.21	580.96	0.27
3.173	0 2% (500-yr)	53200	892.29	893.24	0.000375	8.39	9524.75	595	0.28
3.173	0.133% (750-yr)	58100	895.02	895.88	0.000308	8.08	11149.52	595	0.25
3.173	0.1% (1000-yr)	60800	895.34	896.26	0.000324	8.33	11344.65	595	0.26
3.173	0.04% (2500-yr)	72800	900.53	901.36	0.000252	8.13	14430.88	595	0.24
3.327	10% (10-yr)	17200	878.83	879.37	0.000425	5.91	2908.77	186.31	0.26
3.327	2% (50-yr)	30400	885.26	885.91	0.000369	6.7	7350.8	875.97	0.26
3.327	1% (100-yr)	36800	887.69	888.34	0.00034	6.91	9523.41	915.52	0.25
3.327	0.5% (200-yr)	43500	889.97	890.64	0.000318	7.12	11652.02	952.67	0.25
3.327	0.2% (500-yr)	53200	892.86	893.54	0.000298	7.4	14420.07	959.2	0.24
3.327	0.133% (750-yr)	58100	895.53	896.12	0.000241	7.07	16977.9	959.2	0.22
3.327	0.1% (1000-yr)	60800	895.89	896.52	0.000251	7.27	17323.55	959.2	0.23
3.327	0.04% (2500-yr)	72800	901.02	901.57	0.00019	6.99	22243.72	959.2	0.2
3.482	10% (10-yr)	17200	879.17	879.74	0.000449	6.05	2842.03	183.22	0.27
3.482	2% (50-yr)	30400	885.73	886.2	0.000304	6.04	9330.2	1212.57	0.23
3.482	1% (100-yr)	36800	888.19	888.6	0.000251	5.92	12341.77	1232.2	0.22
3.482	0.5% (200-yr)	43500	890.5	890.88	0.000218	5.87	15203.68	1250.57	0.21
3.482	0.2% (500-yr)	53200	893.41	893.77	0.000191	5.9	18876.29	1267.24	0.2
3.482	0.133% (750-yr)	58100	896.01	896.31	0.000149	5.53	22180.1	1275.9	0.18
3.482	0.1% (1000-yr)	60800	896.4	896.71	0.000154	5.66	22674.39	1277.19	0.18
3.482	0.04% (2500-yr)	72800	901.46	901.71	0.00011	5.29	29180.6	1289.2	0.15
3.623	10% (10-yr)	17200	879.49	880.09	0.000476	6.2	2773.86	180.01	0.28
3.623	2% (50-yr)	30400	885.87	886.52	0.000401	6.8	6815.44	876.84	0.27
3.623	1% (100-yr)	36800	888.27	888.89	0.000349	6.84	8968.25	911.42	0.25
3.623	0.5% (200-yr)	43500	890.55	891.14	0.000312	6.9	11075.75	939.76	0.24
3.623	0.2% (500-yr)	53200	893.43	894.01	0.00028	7.03	13810	952.63	0.24
3.623	0.133% (750-yr)	58100	896.01	896.5	0.000221	6.64	16271.19	955.21	0 21
3.623	0.1% (1000-yr)	60800	896.4	896.91	0.000229	6.81	16639.21	955.6	0.22
3.623	0.04% (2500-yr)	72800	901.44	901.87	0.000166	6.42	21470.46	959.2	0.19

HEC-RAS River Station	Profile	Q Total (cfs)	Water Surface Elevation (ft)	Energy Grade Elevation (ft)	Energy Grade Slope (ft/ft)	Average Channel Velocity (ft/s)	Flow Area (sq ft)	Top Width (ft)	Channel Froude #
3.65	10% (10-yr)	17200	879.73	880.16	0.000319	5.3	3244.49	201.68	0.23
3.65	2% (50-yr)	30400	885.94	886.57	0.000312	6.49	5357.32	515.58	0.24
3.65	1% (100-yr)	36800	888.27	888.96	0.000304	6.86	6643.97	582.55	0.24
3.65	0.5% (200-yr)	43500	890.5	891.22	0.000295	7.16	8009.6	641.56	0.24
3.65	0.2% (500-yr)	53200	893.35	894.1	0.000284	7.52	9927.82	706.99	0.24
3.65	0.133% (750-yr)	58100	895.92	896.59	0.000235	7.22	11821.97	766.14	0.22
3.65	0.1% (1000-yr)	60800	896.3	897	0.000244	7.42	12113.39	774.84	0.23
3.65	0.04% (2500-yr)	72800	901.35	901.94	0.000182	7.05	16301.71	860	0.2
3.764	10% (10-yr)	17200	879.93	880.35	0.000308	5.24	3284.85	202.64	0.23
3.764	2% (50-yr)	30400	886.14	886.75	0.000301	6.42	5462.79	523.84	0.24
3.764	1% (100-yr)	36800	888.47	889.14	0.000294	6.78	6760.42	588.02	0.24
3.764	0.5% (200-yr)	43500	890.7	891.4	0.000286	7.08	8134.4	646.02	0.24
3.764	0.2% (500-yr)	53200	893.53	894.27	0.000277	7.45	10060.52	711.3	0.24
3.764	0.133% (750-yr)	58100	896.07	896.73	0.00023	7.17	11939.14	769.65	0.22
3.764	0.1% (1000-yr)	60800	896.46	897.15	0.000239	7.36	12236.97	778.5	0.23
3.764	0.04% (2500-yr)	72800	901.47	902.05	0.000179	7.01	16402.6	860	0.2
3.874	10% (10-yr)	17200	880.1	880.54	0.000317	5.29	3249.41	201.8	0.23
3.874	2% (50-yr)	30400	886.3	886.94	0.000317	6.55	5172.14	461.56	0.24
3.874	1% (100-yr)	36800	888.63	889.32	0.000308	6.9	6382.27	604.1	0.25
3.874	0.5% (200-yr)	43500	890.86	891.57	0.000293	7.14	7959.37	767.11	0.24
3.874	0.2% (500-yr)	53200	893.73	894.44	0.000271	7.35	10243.8	824.53	0.24
3.874	0.133% (750-yr)	58100	896.26	896.87	0.000218	6.96	12398.1	875.22	0.22
3.874	0.1% (1000-yr)	60800	896.66	897.29	0.000225	7.13	12747.87	883.18	0.22
3.874	0 04% (2500-yr)	72800	901.66	902.16	0.000161	6.64	17385.96	950	0.19
3.984	10% (10-yr)	17200	880.28	880.72	0.000327	5.35	3215.23	200.98	0.24
3.984	2% (50-yr)	30400	886.49	887.13	0.000319	6.54	5252.47	495.56	0.25
3.984	1% (100-yr)	36800	888.81	889.5	0.000312	6.91	6491.46	563.28	0.25
3.984	0.5% (200-yr)	43500	891.02	891.74	0.000302	7.21	7805.79	620	0.25
3.984	0.2% (500-yr)	53200	893.85	894.62	0.000291	7.57	9561.77	620	0.25
3.984	0.133% (750-yr)	58100	896.33	897.03	0.000244	7.32	11102.42	620	0 23
3.984	0.1% (1000-yr)	60800	896.73	897.46	0.000253	7.52	11347.75	620	0.23
3.984	0.04% (2500-yr)	72800	901.66	902.31	0.000198	7.3	14402.34	620	0.21
4.097	10% (10-yr)	17200	880.46	880.94	0.000365	5.56	3091.54	195	0.25
4.097	2% (50-yr)	30400	886.64	887.38	0.000441	6.9	4402.72	231.33	0.28
4.097	1% (100-yr)	36800	888.92	889.78	0.000476	7.44	4948.75	246.57	0.29
4.097	0.5% (200-yr)	43500	891.08	892.05	0.000498	7.92	5522.39	506.68	0.3
4.097	0.2% (500-yr)	53200	893.85	894.94	0.000486	8.42	7894.16	1188.25	0.3
4.097	0 133% (750-yr)	58100	896.34	897.29	0.000385	8.01	11333	1543.36	0.28
4.097	0.1% (1000-yr)	60800	896.74	897.72	0.000394	8.19	11929.05	1543.36	0.28
4.097	0.04% (2500-yr)	72800	901.77	902.45	0.000248	7.28	20005.67	1569.36	0.23
4.0985		Bridge							
4.1	10% (10-yr)	17200	880.51	880.98	0.000362	5.55	3100.16	195.24	0.25

HEC-RAS River Station	Profile	Q Total (cfs)	Water Surface Elevation (ft)	Energy Grade Elevation (ft)	Energy Grade Slope (ft/ft)	Average Channel Velocity (ft/s)	Flow Area (sq ft)	Top Width (ft)	Channel Froude #
4.1	2% (50-yr)	30400	886.72	887.45	0.000436	6.88	4420.49	231.88	0.28
4.1	1% (100-yr)	36800	889.01	889.87	0.00047	7.4	4971.42	247.04	0.29
4.1	0.5% (200-yr)	43500	891.15	892.12	0.000493	7.89	5563.75	545.23	0.3
4.1	0.2% (500-yr)	53200	893.96	895.02	0.000478	8.37	8021.85	1212.3	0.3
4.1	0.133% (750-yr)	58100	896.47	897.4	0.000377	7.95	11519.84	1543.36	0.27
4.1	0.1% (1000-yr)	60800	896.81	897.77	0.00039	8.16	12028.12	1543.36	0.28
4.1	0.04% (2500-yr)	72800	901.89	902.57	0.000243	7.23	20204.04	1569.36	0.23
4.178	10% (10-yr)	17200	880.63	881.16	0.000414	5.83	2950.81	193.6	0.26
4.178	2% (50-yr)	30400	886.88	887.64	0.000438	7.04	4881.52	652.03	0.28
4.178	1% (100-yr)	36800	889.25	890.05	0.000407	7.33	6450.27	668.52	0.28
4.178	0.5% (200-yr)	43500	891.49	892.31	0.000381	7.56	7962.51	681.95	0.27
4.178	0.2% (500-yr)	53200	894.37	895.22	0.000354	7.87	9953.82	696	0.27
4.178	0.133% (750-yr)	58100	896.78	897.55	0.000294	7.6	11631.37	696	0.25
4.178	0.1% (1000-yr)	60800	897.13	897.94	0.000307	7.82	11873.77	696	0.25
4.178	0.04% (2500-yr)	72800	901.96	902.68	0.000235	7.57	15236.22	696	0.23
4.287	10% (10-yr)	17200	880.85	881.42	0.00047	6.06	2837.5	191.06	0.28
4.287	2% (50-yr)	30400	887.14	887.9	0.000462	7.11	5734.73	1209.19	0.29
4.287	1% (100-yr)	36800	889.6	890.29	0.000384	7.03	8757.57	1244.12	0.27
4.287	0.5% (200-yr)	43500	891.92	892.53	0.000324	6.92	11677.34	1276.96	0.25
4.287	0.2% (500-yr)	53200	894.88	895.43	0.000271	6.84	15522.56	1318.7	0.23
4.287	0.133% (750-yr)	58100	897.27	897.72	0.000211	6.39	18677.65	1318.7	0.21
4.287	0.1% (1000-yr)	60800	897.65	898.12	0.000217	6.53	19179.57	1318.7	0.21
4.287	0.04% (2500-yr)	72800	902.46	902.82	0.00015	6.01	25522.75	1318.7	0.18
4.396	10% (10-yr)	17200	881.13	881.69	0.000463	6.03	2851.66	191.52	0.28
4.396	2% (50-yr)	30400	887.39	888.17	0.000463	7.14	5538.85	1207.3	0.29
4.396	1% (100-yr)	36800	889.81	890.52	0.000392	7.1	8492.66	1242.35	0.27
4.396	0.5% (200-yr)	43500	892.08	892.73	0.000334	7.01	11361.79	1275.48	0.25
4.396	0.2% (500-yr)	53200	895.01	895.59	0.000281	6.95	15164.1	1318.7	0.24
4.396	0.133% (750-yr)	58100	897.37	897.85	0.000219	6.49	18276.62	1318.7	0.21
4.396	0.1% (1000-yr)	60800	897.76	898.25	0.000225	6.64	18782.48	1318.7	0.22
4.396	0.04% (2500-yr)	72800	902.53	902.91	0.000156	6.1	25080.35	1318.7	0.18
4.554	10% (10-yr)	16500	881.57	882.05	0.00037	5.55	2974.95	192.68	0.25
4.554	2% (50-yr)	28400	887.87	888.52	0.00037	6.54	4998.51	797.61	0.26
4.554	1% (100-yr)	34100	890.15	890.82	0.000341	6.75	6846.25	819.21	0.25
4.554	0.5% (200-yr)	40100	892.34	893	0.000314	6.89	8657.24	839.84	0.25
4.554	0.2% (500-yr)	48600	895.19	895.85	0.000282	7.04	11096.93	868.04	0.24
4.554	0.133% (750-yr)	53500	897.48	898.07	0.000237	6.82	13085.72	868.7	0.22
4.554	0.1% (1000-yr)	56000	897.86	898.48	0.000245	6.99	13417.58	868.7	0.23
4.554	0.04% (2500-yr)	67000	902.57	903.1	0.000184	6.67	17506.2	868.7	0.2
4.712	10% (10-yr)	16500	881.9	882.35	0.000349	5.35	3084.37	202.74	0.24
4.712	2% (50-yr)	28400	888.26	888.81	0.000307	6.11	5913.77	597.17	0.24
4.712	1% (100-yr)	34100	890.51	891.09	0.000291	6.38	7271.27	608.81	0.24
4.712	0.5% (200-yr)	40100	892.64	893.26	0.000279	6.63	8582.24	619.86	0.23
4.712	0.2% (500-yr)	48600	895.43	896.08	0.000266	6.94	10334.24	635.71	0.23

HEC-RAS River Station	Profile	Q Total (cfs)	Water Surface Elevation (ft)	Energy Grade Elevation (ft)	Energy Grade Slope (ft/ft)	Average Channel Velocity (ft/s)	Flow Area (sq ft)	Top Width (ft)	Channel Froude #
4.712	0.133% (750-yr)	53500	897.66	898.28	0.000234	6.86	11755	639.61	0.22
4.712	0.1% (1000-yr)	56000	898.05	898.7	0.000243	7.06	12001.54	640.28	0.23
4.712	0.04% (2500-yr)	67000	902.68	903.28	0.000195	6.95	14977.51	643.7	0.21
4.869	10% (10-yr)	16500	882.14	882.74	0.000494	6.24	2642.52	176.48	0.28
4.869	2% (50-yr)	28400	888.39	889.2	0.000464	7.31	4260.48	398.99	0.29
4.869	1% (100-yr)	34100	890.6	891.48	0.000447	7.7	5193.46	444.7	0.29
4.869	0.5% (200-yr)	40100	892.71	893.64	0.00043	8.02	6172.49	477.66	0.29
4.869	0.2% (500-yr)	48600	895.47	896.45	0.000405	8.37	7524.75	498.68	0.28
4.869	0.133% (750-yr)	53500	897.68	898.61	0.000353	8.23	8634.7	504.21	0.27
4.869	0.1% (1000-yr)	56000	898.07	899.04	0.000366	8.46	8828.77	505.17	0.27
4.869	0.04% (2500-yr)	67000	902.68	903.56	0.000286	8.24	11174.79	510	0.25
4.907	10% (10-yr)	16500	882.24	882.84	0.000481	6.22	2654.09	174.52	0.28
4.907	2% (50-yr)	28400	888.46	889.31	0.000525	7.38	3845.85	208.34	0.3
4.907	1% (100-yr)	34100	890.64	891.61	0.000557	7.91	4311.16	220.14	0.31
4.907	0.5% (200-yr)	40100	892.69	893.79	0.000572	8.4	4775.86	232.86	0.32
4.907	0.2% (500-yr)	48600	895.37	896.63	0.000574	9.01	5424.43	251.9	0.33
4.907	0.133% (750-yr)	53500	897.52	898.8	0.000516	9.06	5986.41	270.11	0.32
4.907	0.1% (1000-yr)	56000	897.89	899.24	0.000539	9.35	6085.37	273.2	0.32
4.907	0.04% (2500-yr)	67000	902.42	903.77	0.000437	9.38	7563.36	345.1	0.3
4.9105		Bridge							
4.914	10% (10-yr)	16500	882.29	882.88	0.000477	6.2	2662.69	174.79	0.28
4.914	2% (50-yr)	28400	888.54	889.38	0.00052	7.35	3861.71	208.76	0.3
4.914	1% (100-yr)	34100	890.73	891.69	0.000551	7.87	4330.92	220.63	0.31
4.914	0.5% (200-yr)	40100	892.79	893.88	0.000564	8.36	4799.99	233.53	0.32
4.914	0.2% (500-yr)	48600	895.49	896.74	0.000564	8.97	5454.9	252.92	0.33
4.914	0.133% (750-yr)	53500	897.64	898.9	0.000508	9.02	6018.34	271.11	0.31
4.914	0.1% (1000-yr)	56000	898	899.34	0.000531	9.31	6115.48	274.13	0.32
4.914	0.04% (2500-yr)	67000	903.69	904.9	0.000377	8.95	7999.01	347.83	0.28
4.942	10% (10-yr)	16500	882.37	882.96	0.000474	6.15	2683.99	177.87	0.28
4.942	2% (50-yr)	28400	888.67	889.46	0.00044	7.19	4374.3	404.84	0.28
4.942	1% (100-yr)	34100	890.92	891.77	0.000422	7.55	5339.72	451.44	0.28
4.942	0.5% (200-yr)	40100	893.08	893.97	0.000404	7.85	6351.52	479.78	0.28
4.942	0.2% (500-yr)	48600	895.91	896.84	0.000379	8.18	7742.71	499.77	0.28
4.942	0.133% (750-yr)	53500	898.12	899	0.000332	8.06	8855.13	505.3	0.26
4.942	0.1% (1000-yr)	56000	898.52	899.44	0.000343	8.28	9057.22	506.3	0.27
4.942	0.04% (2500-yr)	67000	904.23	905	0.000238	7.74	11967.44	510	0.23
5.108	10% (10-yr)	16500	882.81	883.35	0.000422	5.9	2795.83	180.75	0.26
5.108	2% (50-yr)	28400	889.1	889.83	0.000402	6.94	4457.57	405.57	0.27
5.108	1% (100-yr)	34100	891.35	892.13	0.000383	7.26	5447.64	472.66	0.27
5.108	0.5% (200-yr)	40100	893.51	894.31	0.000363	7.51	6514.1	507.1	0.27
5 108	0.2% (500-yr)	48600	896.33	897.16	0.000337	7.78	7968.58	527.13	0.26
5.108	0.133% (750-yr)	53500	898.5	899.29	0.000297	7.67	9163.79	575.89	0.25
5.108	0.1% (1000-yr)	56000	898.92	899.74	0.000306	7.87	9406.14	585.28	0.25

HEC-RAS River Station	Profile	Q Total (cfs)	Water Surface Elevation (ft)	Energy Grade Elevation (ft)	Energy Grade Slope (ft/ft)	Average Channel Velocity (ft/s)	Flow Area (sq ft)	Top Width (ft)	Channel Froude #
5.108	0.04% (2500-yr)	67000	904.55	905.2	0.000207	7.25	12827.8	609.6	0.21
5.274	10% (10-yr)	16500	883.19	883.73	0.000436	5.88	2805.36	187.43	0.27
5.274	2% (50-yr)	28400	889.5	890.2	0.000425	6.76	4611.28	500.59	0.27
5.274	1% (100-yr)	34100	891.78	892.47	0.000382	6.92	5887.25	611.65	0.27
5.274	0.5% (200-yr)	40100	893.95	894.63	0.000342	6.99	7323.5	706.24	0.26
5.274	0.2% (500-yr)	48600	896.82	897.46	0.000294	7	9524.35	831.21	0.24
5.274	0.133% (750-yr)	53500	898.98	899.54	0.000244	6.73	11413.51	917.63	0.22
5.274	0.1% (1000-yr)	56000	899.42	900	0.000248	6.86	11826.4	935.46	0.23
5.274	0.04% (2500-yr)	67000	904.98	905.38	0.000149	5.99	17149.52	958.6	0.18
5.386	10% (10-yr)	16500	883.46	883.99	0.000427	5.84	2827.08	188.25	0.27
5.386	2% (50-yr)	28400	889.78	890.45	0.000409	6.66	4724.14	598.09	0.27
5.386	1% (100-yr)	34100	892.01	892.7	0.000374	6.87	5787.73	724.74	0.26
5.386	0.5% (200-yr)	40100	894.15	894.85	0.000347	7.05	6817.72	827.96	0.26
5.386	0.2% (500-yr)	48600	896.94	897.66	0.000316	7.26	8195.53	964.3	0.25
5.386	0.133% (750-yr)	53500	899.05	899.73	0.000276	7.14	9242.71	1059.12	0.24
5.386	0.1% (1000-yr)	56000	899.49	900.2	0.000283	7.31	9461.1	1078.9	0.24
5.386	0.04% (2500-yr)	67000	904.94	905.54	0.000196	6.84	12171.96	1108.6	0.21
5.499	10% (10-yr)	16500	883.77	884.23	0.000372	5.42	3045.41	207.28	0.25
5.499	2% (50-yr)	28400	890.07	890.68	0.000346	6.26	4747.6	341.81	0.25
5.499	1% (100-yr)	34100	892.24	892.91	0.000339	6.65	5504.17	356.03	0.25
5.499	0.5% (200-yr)	40100	894.32	895.06	0.000333	7.02	6259.21	369.66	0.26
5.499	0.2% (500-yr)	48600	897.07	897.88	0.000324	7.44	7293.62	380	0.26
5.499	0.133% (750-yr)	53500	899.13	899.94	0.000295	7.47	8077.54	380	0.25
5.499	0.1% (1000-yr)	56000	899.57	900.42	0.000305	7.67	8242.97	380	0.25
5.499	0.04% (2500-yr)	67000	904.94	905.72	0.00023	7.47	10284.66	380	0.23
5.605	10% (10-yr)	16500	883.98	884.44	0.000383	5.47	3015.41	206.38	0.25
5.605	2% (50-yr)	28400	890.26	890.88	0.000357	6.32	4692.48	339.82	0.25
5.605	1% (100-yr)	34100	892.43	893.11	0.000349	6.71	5444.98	354.93	0.26
5.605	0.5% (200-yr)	40100	894.5	895.25	0.000342	7.08	6196.31	368.55	0.26
5.605	0.2% (500-yr)	48600	897.24	898.07	0.000332	7.51	7226.5	380	0.26
5.605	0.133% (750-yr)	53500	899.29	900.11	0.000302	7.53	8004.18	380	0.25
5.605	0.1% (1000-yr)	56000	899.73	900.59	0.000312	7.74	8171.75	380	0.26
5.605	0.04% (2500-yr)	67000	905.06	905.86	0.000236	7.53	10197.62	380	0.23
5.711	10% (10-yr)	16500	884.16	884.69	0.000434	5.83	2829.76	193.26	0.27
5.711	2% (50-yr)	28400	890.4	891.13	0.000431	6.86	4189.87	275	0.28
5.711	1% (100-yr)	34100	892.54	893.37	0.000427	7.34	4865.22	342.65	0.28
5.711	0.5% (200-yr)	40100	894.6	895.51	0.000419	7.74	5586.35	356.57	0.28
5.711	0.2% (500-yr)	48600	897.33	898.32	0.000405	8.19	6578.74	369	0.28
5.711	0.133% (750-yr)	53500	899.36	900.34	0.000367	8.21	7328.63	369	0.27
5.711	0.1% (1000-yr)	56000	899.8	900.84	0.000379	8.43	7491.8	369	0.28
5.711	0.04% (2500-yr)	67000	905.1	906.05	0.000282	8.16	9448.49	369	0.25
5.749	10% (10-yr)	16500	884.26	884.78	0.000425	5.78	2855.41	194.7	0.27
5.749	2% (50-yr)	28400	890.5	891.22	0.000441	6.8	4175.06	228.26	0.28

HEC-RAS River Station	Profile	Q Total (cfs)	Water Surface Elevation (ft)	Energy Grade Elevation (ft)	Energy Grade Slope (ft/ft)	Average Channel Velocity (ft/s)	Flow Area (sq ft)	Top Width (ft)	Channel Froude #
5.749	1% (100-yr)	34100	892.63	893.46	0.000467	7.3	4673.63	239.72	0.29
5.749	0.5% (200-yr)	40100	894.67	895.61	0.000472	7.76	5170.62	250.72	0.3
5.749	0.2% (500-yr)	48600	897.35	898.43	0.000467	8.34	5824.5	265.05	0.3
5.749	0.133% (750-yr)	53500	899.35	900.46	0.000433	8.48	6310.78	275.6	0.29
5.749	0.1% (1000-yr)	56000	899.78	900.96	0.000449	8.73	6416.43	277.9	0.3
5.749	0.04% (2500-yr)	67000	905.07	906.15	0.000345	8.39	8440.74	410	0.27
5.7585		Bridge							
5.768	10% (10-yr)	16500	884.29	884.8	0.000423	5.77	2860.6	194.84	0.27
5.768	2% (50-yr)	28400	890.54	891.25	0.000439	6.79	4183.24	228.45	0.28
5.768	1% (100-yr)	34100	892.67	893.49	0.000464	7.28	4683.63	239.95	0.29
5.768	0.5% (200-yr)	40100	894.72	895.65	0.000469	7.74	5182.04	250.97	0.3
5.768	0.2% (500-yr)	48600	898.35	899.35	0.000407	8.01	6067.9	270.33	0.28
5.768	0.133% (750-yr)	53500	900.79	901.76	0.000361	8.03	6662.53	289.75	0.27
5.768	0.1% (1000-yr)	56000	901.38	902.42	0.000369	8.23	6806.02	336.23	0.27
5.768	0.04% (2500-yr)	67000	906.44	907.41	0.000293	7.97	9001.66	410	0.25
5.795	10% (10-yr)	16500	884.35	884.86	0.000419	5.76	2865.37	194.24	0.26
5.795	2% (50-yr)	28400	890.6	891.31	0.000416	6.79	4244.89	282.89	0.27
5.795	1% (100-yr)	34100	892.75	893.56	0.000412	7.25	4937.29	344.06	0.28
5.795	0.5% (200-yr)	40100	894.83	895.72	0.000404	7.65	5667.29	358.1	0.28
5.795	0.2% (500-yr)	48600	898.53	899.41	0.00034	7.74	7022.51	369	0.26
5.795	0.133% (750-yr)	53500	901	901.85	0.000295	7.64	7936.27	369	0.25
5.795	0.1% (1000-yr)	56000	901.61	902.49	0.000299	7.8	8160.84	369	0.25
5.795	0.04% (2500-yr)	67000	906.61	907.45	0.000239	7.73	10005.55	369	0.23
5.962	10% (10-yr)	16500	884.67	885.31	0.000519	6.42	2568.35	171.06	0.29
5.962	2% (50-yr)	28400	890.88	891.79	0.000538	7.64	3728.56	225.19	0.31
5.962	1% (100-yr)	34100	893	894.04	0.00054	8.22	4283.66	298.02	0.31
5.962	0.5% (200-yr)	40100	895.05	896.21	0.000535	8.7	4931.64	329.56	0.32
5.962	0.2% (500-yr)	48600	898.69	899.84	0.000452	8.81	6182.73	349	0.3
5.962	0.133% (750-yr)	53500	901.13	902.22	0.000391	8.68	7035.46	349	0.28
5.962	0.1% (1000-yr)	56000	901.74	902.87	0.000395	8.85	7247.62	349	0 29
5.962	0.04% (2500-yr)	67000	906.7	907.76	0.000313	8.72	8977.94	349	0.26
6	10% (10-yr)	16500	884.78	885.41	0.000511	6.4	2578.26	170.56	0.29
6	2% (50-yr)	28400	890.99	891.89	0.000547	7.63	3723.3	198.07	0.31
6	1% (100-yr)	34100	893.11	894.16	0.000584	8.21	4153.07	207.46	0.32
6	0.5% (200-yr)	40100	895.14	896.33	0.000616	8.75	4583.66	216.46	0.34
6	0.2% (500-yr)	48600	898.7	899.97	0.00055	9.05	5400.41	247.32	0.32
6	0.133% (750-yr)	53500	901.1	902.36	0.000485	9 04	5994.17	263.82	0.31
6	0.1% (1000-yr)	56000	901.69	903.02	0.000492	9.25	6145.93	267.93	0.31
6	0.04% (2500-yr)	67000	906.64	907.89	0.000382	9.11	8067.65	386	0.28
6.003		Bridge							
6.006	10% (10-yr)	16500	884.85	885.48	0.000504	6.37	2590.73	170.88	0.29
6 006	2% (50-yr)	28400	891.09	891 99	0.000539	7.59	3743.91	198.53	0.31

HEC-RAS River Station	Profile	Q Total (cfs)	Water Surface Elevation (ft)	Energy Grade Elevation (ft)	Energy Grade Slope (ft/ft)	Average Channel Velocity (ft/s)	Flow Area (sq ft)	Top Width (ft)	Channel Froude #
6.006	1% (100-yr)	34100	893.23	894.27	0.000574	8.16	4178.49	208	0.32
6.006	0.5% (200-yr)	40100	895.28	896.46	0.000605	8.69	4614.11	217.08	0.33
6.006	0.2% (500-yr)	48600	899.71	900.87	0.000497	8.65	5648.1	254.29	0.31
6.006	0.133% (750-yr)	53500	902.43	903.55	0.000426	8.52	6443.52	386	0.29
6.006	0.1% (1000-yr)	56000	903.07	904.24	0.000429	8.69	6691.41	386	0.29
6.006	0.04% (2500-yr)	67000	907.59	908.72	0.00035	8.69	8435.08	386	0.27
6.029	10% (10-yr)	16500	884.91	885.54	0.000512	6.4	2580.08	170.96	0.29
6.029	2% (50-yr)	28400	891.16	892.05	0.000512	7.6	3791.83	245.87	0.3
6.029	1% (100-yr)	34100	893.31	894.33	0.000513	8.15	4392.95	307.69	0.31
6.029	0.5% (200-yr)	40100	895.4	896.53	0.000506	8.61	5065.09	333.43	0.31
6.029	0.2% (500-yr)	48600	899.92	900.94	0.000381	8.38	6628.83	349	0.28
6.029	0.133% (750-yr)	53500	902.66	903.61	0.000322	8.19	7585.44	349	0.26
6.029	0.1% (1000-yr)	56000	903.31	904.3	0.000325	8.35	7812.79	349	0.26
6.029	0.04% (2500-yr)	67000	907.79	908.78	0.000279	8.45	9375.54	349	0.25
6.186	10% (10-yr)	16500	885.36	885.96	0.000476	6.23	2647.94	173.37	0.28
6.186	2% (50-yr)	28400	891.62	892.47	0.000489	7.43	3855.31	240.5	0.3
6.186	1% (100-yr)	34100	893.77	894.76	0.000491	7.99	4439.26	301.14	0.3
6.186	0.5% (200-yr)	40100	895.86	896.94	0.000487	8.45	5105.47	332.95	0.31
6.186	0.2% (500-yr)	48600	900.25	901.26	0.000375	8.3	6625.51	349	0.28
6.186	0.133% (750-yr)	53500	902.93	903.88	0.000319	8.14	7562.43	349	0.26
6.186	0.1% (1000-yr)	56000	903.58	904.57	0.000322	8.29	7790.8	349	0.26
6.186	0.04% (2500-yr)	67000	908.02	909.01	0.000278	8.41	9338.74	349	0.25
6.346	10% (10-yr)	16500	885.76	886.39	0.000523	6.37	2589.61	175.3	0.29
6.346	2% (50-yr)	28400	892.05	892.91	0.000557	7.43	3821.21	216.47	0.31
6.346	1% (100-yr)	34100	894.22	895.2	0.000559	7.93	4334.22	261.58	0.32
6.346	0.5% (200-yr)	40100	896.29	897.38	0.000546	8.38	4950.45	325.6	0.32
6.346	0.2% (500-yr)	48600	900.57	901.59	0.000414	8.24	6427.05	349	0.29
6.346	0.133% (750-yr)	53500	903.2	904.17	0.000349	8.07	7345.97	349	0.27
6.346	0.1% (1000-yr)	56000	903.86	904.86	0.000351	8.22	7575.28	349	0.27
6.346	0.04% (2500-yr)	67000	908.26	909.25	0.000298	8.31	9109.27	349	0.25
6.505	10% (10-yr)	16500	886.26	886.84	0.000555	6.13	2691.92	203.57	0.3
6.505	2% (50-yr)	28400	892.65	893.36	0.000486	6.81	4278.6	302.2	0.29
6.505	1% (100-yr)	34100	894.86	895.64	0.000468	7.15	4990.52	339.83	0.29
6.505	0.5% (200-yr)	40100	896.97	897.81	0.000443	7.47	5724.58	357.09	0.29
6.505	0.2% (500-yr)	48600	901.13	901.92	0.000336	7.34	7263.99	375.7	0.26
6.505	0.133% (750-yr)	53500	903.69	904.45	0.000284	7.2	8227.6	375.7	0.24
6.505	0.1% (1000-yr)	56000	904.36	905.14	0.000286	7.33	8477.84	375.7	0.24
6.505	0.04% (2500-yr)	67000	908.71	909.5	0.000243	7.43	10111.25	375.7	0.23
6.663	10% (10-yr)	16500	886.71	887.3	0.000531	6.13	2689.6	195.79	0.29
6.663	2% (50-yr)	28400	893.04	893.79	0.000514	6.93	4129.76	290.79	0.3
6.663	1% (100-yr)	34100	895.24	896.06	0.000496	7.29	4831.55	339.89	0.3
6.663	0.5% (200-yr)	40100	897.32	898.21	0.000471	7.63	5557.13	356.94	0.3
6.663	0.2% (500-yr)	48600	901.39	902.23	0.00036	7.51	7061.5	375.7	0.27
6.663	0.133% (750-yr)	53500	903.91	904.71	0.000305	7.37	8009.05	375.7	0.25

HEC-RAS River Station	Profile	Q Total (cfs)	Water Surface Elevation (ft)	Energy Grade Elevation (ft)	Energy Grade Slope (ft/ft)	Average Channel Velocity (ft/s)	Flow Area (sq ft)	Top Width (ft)	Channel Froude #
6.663	0.1% (1000-yr)	56000	904.58	905.4	0.000305	7.5	8259.5	375.7	0.25
6.663	0.04% (2500-yr)	67000	908.89	909.72	0.000259	7.59	9879.71	375.7	0.24
6.815	10% (10-yr)	16500	887.15	887.68	0.000417	5.82	2833.78	185.94	0.26
6.815	2% (50-yr)	28400	893.43	894.17	0.000428	6.9	4188.51	301.17	0.28
6.815	1% (100-yr)	34100	895.6	896.43	0.000422	7.36	4902.14	343.24	0.28
6.815	0.5% (200-yr)	40100	897.66	898.57	0.000416	7.76	5627.13	360.13	0.28
6.815	0.2% (500-yr)	48600	901.64	902.52	0.000336	7.75	7105.87	375.7	0.26
6.815	0.133% (750-yr)	53500	904.12	904.96	0.000291	7.64	8037.85	375.7	0.25
6.815	0.1% (1000-yr)	56000	904.79	905.65	0.000293	7.78	8288.39	375.7	0.25
6.815	0.04% (2500-yr)	67000	909.07	909.94	0.000254	7.9	9895.3	375.7	0.24
6.967	10% (10-yr)	16500	887.5	888	0.000389	5.67	2908.14	188.25	0.25
6.967	2% (50-yr)	28400	893.8	894.5	0.000397	6.74	4315.67	316.52	0.27
6.967	1% (100-yr)	34100	895.97	896.76	0.000394	7.2	5043.93	346.68	0.27
6.967	0.5% (200-yr)	40100	898.03	898.9	0.00039	7.6	5775.15	363.54	0.27
6.967	0.2% (500-yr)	48600	901.94	902.78	0.00032	7.63	7232.75	375.7	0.25
6.967	0.133% (750-yr)	53500	904.38	905.19	0.000281	7.55	8149.23	375.7	0.24
6.967	0.1% (1000-yr)	56000	905.04	905.89	0.000283	7.68	8400.46	375.7	0.24
6.967	0.04% (2500-yr)	67000	909.29	910.14	0.000247	7.83	9993.97	375.7	0.23
7.119	10% (10-yr)	16500	887.69	888.49	0.000646	7.21	2288.1	148	0.32
7.119	2% (50-yr)	28400	893.9	895.05	0.000716	8.63	3292.14	175.18	0.35
7.119	1% (100-yr)	34100	896.01	897.35	0.000745	9.29	3695.1	232	0.36
7.119	0.5% (200-yr)	40100	898	899.51	0.000744	9.88	4261.11	335.04	0.37
7.119	0.2% (500-yr)	48600	901.88	903.3	0.000589	9.78	5662.87	374	0.34
7.119	0.133% (750-yr)	53500	904.32	905.63	0.000497	9.53	6577.46	374	0.31
7.119	0.1% (1000-yr)	56000	904.99	906.33	0.000496	9.67	6827.53	374	0.31
7.119	0.04% (2500-yr)	67000	909.24	910.52	0.000409	9.61	8418.08	374	0.29
7.271	10% (10-yr)	16500	888.24	888.99	0.000586	6.96	2370.86	150 43	0.31
7.271	2% (50-yr)	28400	894.53	895.61	0.000654	8.34	3403.58	177.94	0.34
7.271	1% (100-yr)	34100	896.67	897.92	0.000668	8.99	3860.28	266.26	0.35
7.271	0.5% (200-yr)	40100	898.69	900.08	0.000665	9.53	4493.42	340.07	0.35
7.271	0.2% (500-yr)	48600	902.41	903.76	0.000547	9.55	5820.5	374	0.33
7.271	0.133% (750-yr)	53500	904.76	906 03	0.00047	9.36	6700.32	374	0.31
7.271	0.1% (1000-yr)	56000	905.43	906.72	0 00047	9.5	6949.96	374	0.31
7.271	0.04% (2500-yr)	67000	909.6	910 84	0.000394	9.5	8508.74	374	0.29
7.309	10% (10-yr)	16500	888.37	889.11	0.000573	6.91	2388.86	150.51	0.31
7.309	2% (50-yr)	28400	894.67	895.74	0.000641	8.3	3422.94	177.53	0.33
7.309	1% (100-yr)	34100	896.82	898.06	0.000691	8.94	3813.31	186.72	0 35
7.309	0.5% (200-yr)	40100	898.81	900.23	0.000739	9.56	4194.6	195.27	0.36
7.309	0.2% (500-yr)	48600	902.42	903.93	0.000696	9.86	4933.72	230.05	0.36
7.309	0.133% (750-yr)	53500	904.7	906.21	0.000633	9.88	5442.7	295.89	0.35
7.309	0.1% (1000-yr)	56000	905.34	906.92	0 000637	10.08	5590.93	337.72	0.35
7.309	0.04% (2500-yr)	67000	909.48	911.02	0.000525	10.1	7258.6	374	0.32
7.312		Bridge							

HEC-RAS River Station	Profile	Q Total (cfs)	Water Surface Elevation (ft)	Energy Grade Elevation (ft)	Energy Grade Slope (ft/ft)	Average Channel Velocity (ft/s)	Flow Area (sq ft)	Top Width (ft)	Channel Froude #
7.315	10% (10-yr)	16500	888.45	889.19	0.000564	6.87	2401.89	150.88	0.3
7.315	2% (50-yr)	28400	894.81	895.86	0.000629	8.24	3446.6	178.1	0.33
7.315	1% (100-yr)	34100	896.97	898.2	0.000676	8.87	3843.12	187.4	0.35
7.315	0.5% (200-yr)	40100	899	900.39	0.000722	9.48	4231.22	196.08	0.36
7.315	0.2% (500-yr)	48600	902.54	904.03	0.000686	9.81	4959.73	232.28	0.36
7.315	0.133% (750-yr)	53500	906.26	907.57	0.000512	9.24	6050.74	374	0.31
7.315	0.1% (1000-yr)	56000	906.97	908.32	0.000509	9.38	6319.08	374	0.31
7.315	0.04% (2500-yr)	67000	910.89	912.25	0.000442	9.55	7782.36	374	0.3
7.345	10% (10-yr)	16500	888.49	889.31	0.000643	7.24	2279.54	144.14	0.32
7.345	2% (50-yr)	28400	894.84	896	0.000722	8.63	3290.73	174.46	0.35
7.345	1% (100-yr)	34100	897.01	898.34	0.000747	9.26	3711.95	246.62	0.36
7.345	0.5% (200-yr)	40100	899.06	900.53	0.000737	9.8	4332.47	338.99	0.36
7.345	0.2% (500-yr)	48600	902.72	904.14	0.000602	9.8	5658.06	374	0.34
7.345	0.133% (750-yr)	53500	906.53	907.66	0.000419	8.95	7080.32	374	0.29
7.345	0.1% (1000-yr)	56000	907.26	908.42	0.000416	9.06	7354.02	374	0.29
7.345	0.04% (2500-yr)	67000	911.17	912.33	0.000366	9.2	8818.38	374	0.28
7.534	10% (10-yr)	16500	889.13	889.98	0.000682	7.41	2226.78	142.1	0.33
7.534	2% (50-yr)	28400	895.55	896.75	0.00075	8.78	3235.36	172.05	0.36
7.534	1% (100-yr)	34100	897.75	899.12	0.000787	9.41	3632.06	205.95	0.37
7.534	0.5% (200-yr)	40100	899.77	901.31	0.000783	10	4165.23	321.8	0.37
7.534	0.2% (500-yr)	48600	903.28	904.81	0.000658	10.11	5405.59	374	0.35
7.534	0.133% (750-yr)	53500	906.9	908.14	0.000466	9.3	6759.17	374	0.3
7.534	0.1% (1000-yr)	56000	907.62	908.89	0.000462	9.41	7031.59	374	0.3
7.534	0.04% (2500-yr)	67000	911.49	912.74	0.000403	9.53	8477.8	374	0.29
7.724	10% (10-yr)	16500	889.82	890.66	0.000667	7.34	2249.06	144.22	0.33
7.724	2% (50-yr)	28400	896.32	897.48	0.000718	8.66	3278.27	172.64	0.35
7.724	1% (100-yr)	34100	898.56	899.89	0.000748	9.28	3683.39	208.82	0.36
7.724	0.5% (200-yr)	40100	900.58	902.08	0.000748	9.88	4210.05	313.09	0.37
7.724	0.2% (500-yr)	48600	903.93	905.46	0.00065	10.1	5381.96	374	0.35
7.724	0.133% (750-yr)	53500	907.34	908.62	0.000476	9.39	6659.11	374	0.31
7.724	0.1% (1000-yr)	56000	908.07	909.36	0.000472	9.5	6929.73	374	0.31
7.724	0.04% (2500-yr)	67000	911.87	913.16	0.000414	9.65	8353.21	374	0.29
7.914	10% (10-yr)	16500	890.49	891.33	0.000676	7.34	2248.68	146.72	0.33
7.914	2% (50-yr)	28400	897.05	898.2	0.000708	8.59	3305.04	175.41	0.35
7.914	1% (100-yr)	34100	899.32	900.63	0.000717	9.18	3749.88	243.11	0.36
7.914	0.5% (200-yr)	40100	901.36	902.82	0.000711	9.74	4351.22	337.38	0.36
7.914	0 2% (500-yr)	48600	904.62	906.1	0.000624	9.97	5508.29	374	0.35
7.914	0.133% (750-yr)	53500	907.83	909.09	0.00047	9.36	6709.98	374	0.31
7.914	0.1% (1000-yr)	56000	908.55	909.83	0.000466	9.47	6979.02	374	0.31
7.914	0.04% (2500-yr)	67000	912.29	913.58	0.000412	9.64	8378.53	374	0.29
8.103	10% (10-yr)	15900	891.56	892.11	0.00084	5.93	2683.53	200.23	0.29
8.103	2% (50-yr)	27100	898.35	898.98	0.000765	6.4	4235.69	263.4	0.28
8.103	1% (100-yr)	32500	900.75	901.41	0.000723	6.58	5633.88	960.27	0.28

HEC-RAS River Station	Profile	Q Total (cfs)	Water Surface Elevation (ft)	Energy Grade Elevation (ft)	Energy Grade Slope (ft/ft)	Average Channel Velocity (ft/s)	Flow Area (sq ft)	Top Width (ft)	Channel Froude #
8.103	0.5% (200-yr)	38100	902.92	903.57	0.000625	6.62	7748.88	990.09	0.26
8.103	0.2% (500-yr)	46000	906.16	906.74	0.000481	6.43	11022.87	1018.11	0.24
8.103	0.133% (750-yr)	51100	909.1	909.58	0.000356	5.99	14029.11	1025	0.21
8.103	0.1% (1000-yr)	53500	909.84	910.31	0.000346	6.02	14783.78	1025	0.21
8.103	0.04% (2500-yr)	64000	913.56	914	0.000285	5.96	18597.25	1025	0.19
8.3	10% (10-yr)	15900	892.42	892.86	0.000609	5.3	3002.52	208.71	0.25
8.3	2% (50-yr)	27100	899.12	899.67	0.000565	5.99	4527.44	355.32	0.25
8.3	1% (100-yr)	32500	901.47	902.06	0.000527	6.21	6260.18	888.42	0.24
8.3	0.5% (200-yr)	38100	903.55	904.14	0.00048	6.32	8174.41	949.86	0.23
8.3	0.2% (500-yr)	46000	906.66	907.19	0.000395	6.25	11348.1	1097.29	0.22
8.3	0.133% (750-yr)	51100	909.48	909.91	0.000297	5.82	14583.95	1161	0.19
8.3	0.1% (1000-yr)	53500	910.22	910.64	0.000288	5.82	15434.43	1161	0.19
8.3	0.04% (2500-yr)	64000	913.9	914.27	0.000232	5.66	19709.31	1161	0.17
8.497	10% (10-yr)	15900	893.05	893.59	0.00075	5.92	2686.65	181.42	0.27
8.497	2% (50-yr)	27100	899.67	900.39	0.000735	6.77	4006.27	621.3	0.28
8.497	1% (100-yr)	32500	902.02	902.67	0.000618	6.7	6711.56	890.4	0.26
8.497	0.5% (200-yr)	38100	904.06	904.69	0.000553	6.75	8614.72	972.46	0.25
8.497	0.2% (500-yr)	46000	907.09	907.64	0.000444	6.57	11635.91	1017.31	0.23
8.497	0.133% (750-yr)	51100	909.81	910.25	0.000339	6.14	14443.24	1049.24	0.2
8.497	0.1% (1000-yr)	53500	910.53	910.97	0.00033	6.16	15202.99	1057.71	0.2
8.497	0.04% (2500-yr)	64000	914.15	914.54	0.000272	6.04	19098.32	1093.24	0.19
8.694	10% (10-yr)	15900	893.78	894.62	0.00112	7.37	2156.06	138.93	0.33
8.694	2% (50-yr)	27100	900.31	901.46	0.00115	8.63	3144.9	489.53	0.35
8.694	1% (100-yr)	32500	902.49	903.61	0.001029	8.76	5798.88	1585.51	0.33
8.694	0.5% (200-yr)	38100	904.54	905.42	0.00081	8.25	9194.66	1708.52	0.3
8.694	0.2% (500-yr)	46000	907.53	908.1	0.000531	7.24	14369.31	1739.82	0.25
8.694	0.133% (750-yr)	51100	910.21	910.58	0.00035	6.26	19050.37	1762.37	0.2
8.694	0.1% (1000-yr)	53500	910.93	911.28	0.000328	6.17	20330.27	1768.49	0.2
8.694	0.04% (2500-yr)	64000	914.53	914.78	0.000235	5.62	26740.49	1798.81	0.17
8.891	10% (10-yr)	15900	895.01	895.63	0.000808	6.32	2515.84	162.71	0.28
8.891	2% (50-yr)	27100	901.64	902.48	0.000786	7.34	3726.01	1006.11	0.29
8.891	1% (100-yr)	32500	903.73	904.48	0.000676	7.28	7896.99	2221.99	0.27
8.891	0.5% (200-yr)	38100	905.49	906.09	0.000552	6.92	11875.07	2289	0.25
8.891	0.2% (500-yr)	46000	908.13	908.52	0.000382	6.18	18020.01	2377.19	0.21
8.891	0.133% (750-yr)	51100	910.59	910.85	0.000254	5.35	23960.51	2444.19	0.18
8.891	0.1% (1000-yr)	53500	911.29	911.53	0.000237	5.25	25680.68	2463.25	0.17
8.891	0.04% (2500-yr)	64000	914.79	914.95	0.000164	4.71	34453.42	2558.24	0.14
9.088	10% (10-yr)	15900	895.87	896.26	0.000448	5.02	3167.71	186	0.21
9.088	2% (50-yr)	27100	902.58	903.13	0.000482	5.99	4546.18	1157	0.23
9.088	1% (100-yr)	32500	904.53	905.06	0.000444	6.05	8761.06	1921.68	0.22
9.088	0.5% (200-yr)	38100	906.08	906.57	0.000413	6.1	11754.67	1949.3	0.22
9.088	0.2% (500-yr)	46000	908.46	908.86	0.000337	5.86	16455.79	1991.91	0.2
9.088	0.133% (750-yr)	51100	910.8	911.09	0.000247	5.31	21144.42	2028.68	0.17
9.088	0.1% (1000-yr)	53500	911.48	911.76	0.000235	5.26	22533.2	2038.5	0.17

HEC-RAS River Station	Profile	Q Total (cfs)	Water Surface Elevation (ft)	Energy Grade Elevation (ft)	Energy Grade Slope (ft/ft)	Average Channel Velocity (ft/s)	Flow Area (sq ft)	Top Width (ft)	Channel Froude #
9.088	0.04% (2500-yr)	64000	914.9	915.12	0.000176	4.89	29597.69	2087.72	0.15
9.274	10% (10-yr)	15400	896.31	896.8	0.000594	5.59	2756.62	168.86	0.24
9.274	2% (50-yr)	25900	903.02	903.68	0.000565	6.52	4025.43	1601.73	0.25
9.274	1% (100-yr)	30800	904.99	905.48	0.000437	6.08	9736.74	1916.64	0.22
9.274	0.5% (200-yr)	36000	906.51	906.95	0.000395	6.03	12687.74	1956.1	0.21
9.274	0.2% (500-yr)	43400	908.82	909.17	0.000319	5.75	17260.66	2003.84	0.19
9.274	0.133% (750-yr)	48300	911.05	911.31	0.000236	5.21	21765.02	2030.84	0.17
9.274	0.1% (1000-yr)	50600	911.72	911.97	0.000225	5.16	23132.74	2049.12	0.17
9.274	0.04% (2500-yr)	60500	915.08	915.27	0.000166	4.76	30074.46	2079.94	0.15
9.46	10% (10-yr)	15400	896.91	897.33	0.000493	5.22	2951.51	174.51	0.22
9.46	2% (50-yr)	25900	903.61	904.19	0.000475	6.16	4438.62	1506.83	0.23
9.46	1% (100-yr)	30800	905.4	905.89	0.000409	6.01	9333.61	1867.42	0.22
9.46	0.5% (200-yr)	36000	906.87	907.33	0.000382	6.04	12093.86	1873.04	0.21
9.46	0.2% (500-yr)	43400	909.1	909.48	0.000322	5.86	16274.65	1881.51	0.2
9.46	0.133% (750-yr)	48300	911.25	911.55	0.000246	5.39	20339.01	1889.72	0.17
9.46	0.1% (1000-yr)	50600	911.91	912.19	0.000236	5.35	21584.8	1892.22	0.17
9.46	0.04% (2500-yr)	60500	915.22	915.44	0.000179	5	27871.93	1900.74	0.15
9.647	10% (10-yr)	15400	897.38	897.86	0.000542	5.53	2785.11	160.13	0.23
9.647	2% (50-yr)	25900	904.05	904.73	0.000561	6.62	3946.4	2043.15	0.25
9.647	1% (100-yr)	30800	905.81	906.32	0.000444	6.19	10170.54	2288.68	0.22
9.647	0.5% (200-yr)	36000	907.29	907.72	0.000394	6.07	13607	2370.63	0.21
9.647	0.2% (500-yr)	43400	909.48	909.8	0.000311	5.69	18877.94	2417.76	0.19
9.647	0.133% (750-yr)	48300	911.56	911.79	0.000228	5.11	23919.21	2428.29	0.16
9.647	0.1% (1000-yr)	50600	912.21	912.43	0.000215	5.03	25496.95	2431.57	0.16
9.647	0.04% (2500-yr)	60500	915.46	915.61	0.000154	4.56	33420.98	2440.73	0.14
9.732	10% (10-yr)	15400	897.45	898.3	0.001037	7.39	2084.51	119.42	0.31
9.732	2% (50-yr)	25900	904	905.24	0.001106	8.94	2898.67	2032.75	0.33
9.732	1% (100-yr)	30800	905.89	906.71	0.000861	7.98	8554.51	2276.91	0.29
9.732	0.5% (200-yr)	36000	907.43	908.05	0.000709	7.49	12142.71	2403.71	0.27
9.732	0.2% (500-yr)	43400	909.65	910.04	0.000504	6.61	17623.57	2486.81	0.23
9.732	0.133% (750-yr)	48300	911.7	911.96	0.00034	5.7	22818.78	2604.29	0.19
9.732	0.1% (1000-yr)	50600	912.35	912.58	0.000313	5.55	24517.18	2657.69	0.18
9.732	0.04% (2500-yr)	60500	915.57	915.72	0.000203	4.8	33464.09	2840.74	0.15
9.734501		Bridge							
9.737	10% (10-yr)	15400	897.49	898.33	0.001031	7.37	2088.88	119.48	0.31
9.737	2% (50-yr)	25900	904.54	905.72	0.001024	8.73	2966.79	2066.27	0.32
9.737	1% (100-yr)	30800	906.3	907	0.000761	7.56	9479.97	2317.03	0.28
9.737	0.5% (200-yr)	36000	907.72	908.28	0.000642	7.19	12853.05	2429.68	0.26
9.737	0.2% (500-yr)	43400	909.75	910.13	0.000488	6.52	17875.25	2487.27	0.22
9.737	0.133% (750-yr)	48300	911.79	912.03	0.000332	5.65	23036.38	2611.67	0.19
9.737	0.1% (1000-yr)	50600	912.42	912.65	0.000307	5.51	24716.59	2663.52	0.18
9.737	0.04% (2500-yr)	60500	915.62	915.76	0.000201	4.78	33588.92	2840.74	0.15

HEC-RAS River Station	Profile	Q Total (cfs)	Water Surface Elevation (ft)	Energy Grade Elevation (ft)	Energy Grade Slope (ft/ft)	Average Channel Velocity (ft/s)	Flow Area (sq ft)	Top Width (ft)	Channel Froude #
9.87	10% (10-yr)	15400	898.37	898.92	0.000648	5.96	2582.15	145.49	0.25
9.87	2% (50-yr)	25900	905.8	906.26	0.000457	5.86	9518.56	2740.81	0.22
9.87	1% (100-yr)	30800	907.03	907.43	0.000424	5.83	12929.25	2814.95	0.21
9.87	0.5% (200-yr)	36000	908.31	908.65	0.000376	5.68	16573.89	2883.7	0.2
9.87	0.2% (500-yr)	43400	910.16	910.42	0.000305	5.36	21963.58	2931.73	0.18
9.87	0.133% (750-yr)	48300	912.06	912.24	0.000221	4.78	27556.37	2965.58	0.16
9.87	0.1% (1000-yr)	50600	912.67	912.84	0.000207	4.68	29382.28	2976.55	0.15
9.87	0.04% (2500-yr)	60500	915.78	915.89	0.000143	4.17	38711.77	3033.55	0.13

A-2.3 SHUNGANUNGA CREEK

A-2.3.1 INTRODUCTION

As part of the feasibility study, hydrologic and hydraulic analyses were conducted on Shunganunga Creek in Topeka, Kansas. To determine the discharges within the Oakland Levee flood protection works, a watershed analysis was completed using the SWMM (Storm Water Management Model) computer software developed by the U.S. Environmental Protection Agency. The hydraulic investigation was completed to calculate water surface profiles along the Oakland Levee Unit from the mouth of Shunganunga Creek to the 10th Street Bridge. To accomplish this, the HEC-RAS (River Analysis System) computer software developed by the Hydrologic Engineering Center, U.S. Army Corps of Engineers was used. The hydraulic model was developed using 1997 survey data supplemented with 1995 four-foot aerial contour maps supplied by the City of Topeka.

A-2.3.2 PURPOSE

The purpose of this investigation is to develop Shunganunga water surface profiles from the Kansas River to the upstream limit of the flood reduction works reflecting the base (or existing) conditions. The resulting hydraulic model will be used to evaluate a series of alternatives for improving the integrity of the existing flood control system.

A-2.3.3 HYDROLOGY

To determine the discharges along Shunganunga Creek, a computer model was created for the basin using the SWMM (Storm Water Management Model) developed by the U.S. Environmental Protection Agency. Using hypothetical rainfall events, discharges were determined for the 0.2, 0.5, 1, 2, 4, 10, and 50-percent exceedance (500, 200, 100, 50, 25, 10, and 2-yr) flood events at ten different locations within the basin. The following sections describe the components of the hydrologic model: basin topography, development of watershed boundaries, loss rates, rainfall-runoff transformation, routing, and hypothetical rainfall. The last two sections show the resulting discharges used in the feasibility study and the hydrologic uncertainty.

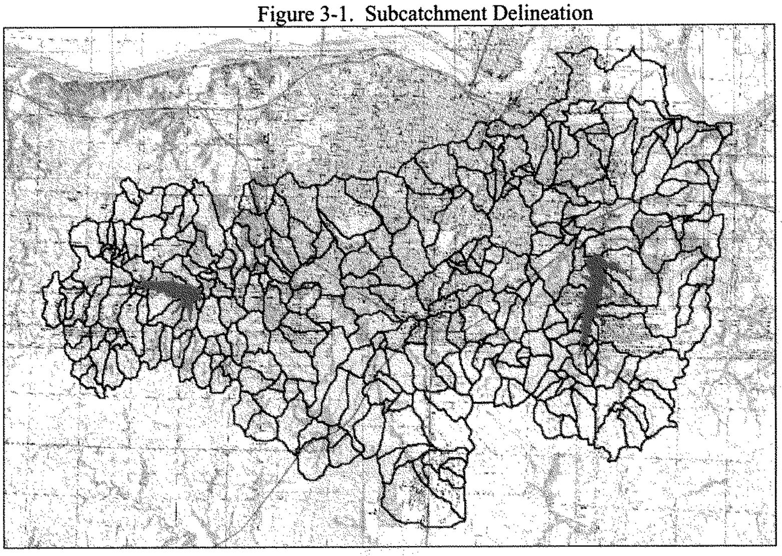
Basin Topography

Shunganunga Creek is a right bank tributary of the Kansas River flowing through Shawnee County, Kansas. The total drainage area of the basin is approximately 75.7 square miles of which 22.5 square miles lie within the city limits of Topeka. The basin is about 20 miles long and 7 miles wide at its widest point. . The land is flat in the lower part of the basin and hilly in the headwater areas. There are four detention dams within the basin. In 1935, Lake Shawnee on Deer Creek, a tributary within the Shunganunga drainage basin, was constructed. However, no provision was made for floodwater storage in this lake. After the disastrous flood of 1951, two more detention basins were constructed. In 1952 and 1953, Burnett Dam on Shunganunga Creek and South Branch Dam on South Branch Shunganunga Creek were constructed. In 1962, Sherwood Lake was constructed upstream from Burnett Dam.

Watershed Boundaries

The watershed was delineated into 299 subcatchments based on surface topography. To complete this task, the computer program HEC-PrePro was used. HEC-PrePro is a developing script for use in ArcView. It is capable of delineating a watershed based on the Digital Elevation Models (DEM) and a given subbasin resolution. Surface topography was obtained from USGS 30-meter DEM's. Figure 1 shows the subcatchment delineation.

Figure 3-1. Subcatchment Delineation



Loss Rates

Loss rates define how much rainfall will be lost to the ground. In this study, the Green-Ampt method was used. This method is dependent on soil characteristics such as initial loss, volume moisture deficit, wetting front suction, and hydraulic conductivity. The soil data for Shawnee County was obtained from the city of Topeka. In the Shunganunga basin, the soils are primarily clay and clay loams with relatively low hydraulic conductivity values.

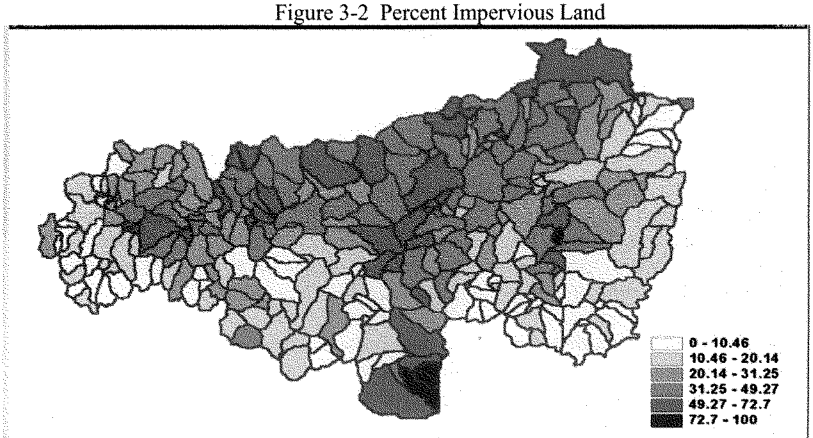
Another important parameter for determining loss rates is the percentage of impervious ground cover such as rooftops and pavement. Percent impervious values were determined from parcel mapping that included land use data. Each land use type was assigned a percent impervious value according to Table 3-1.

Table 3-1 Landuse Percent Impervious Values

Landuse	Fraction Impervious
Agricultural	0.00
Commercial	0.90
Commercial-Office	0.90
Hotel-Motel	0.60
Industrial	0.70
Institutional	0.88
Mobile Home	0.50
Multi-Family (3+)	0.40
None	0.27
Not Codified	0.27
Other Resid. N.E.C.	0.35
Recreational/Open Space	0.15
Single-Family	0.30
Transport-Utility	0.85
Two-Family	0.35
Vacant	0.05
Surface Water	1.00

Parcel polygons were divided according to subcatchment boundaries. Then, for each subcatchment, a composite percent impervious value was calculated based on all the land use parcels it contained. The resulting subcatchment percent impervious values are indicated in Figure 2.

Figure 3-2 Percent Impervious Land



Rainfall-Runoff Transformation

To determine the amount of runoff that results from a particular rainfall event, the Kinematic Wave Routing method was used. This method requires a main channel with one or two overland flow planes defined for each subcatchment. The discharge is calculated using Manning's equation and parameters such as slope, roughness, area, and channel shape and size. Wide, shallow flow is assumed for the overland flow planes. The pervious Manning's roughness coefficient was taken as 0.20, and the impervious Manning's roughness coefficient was taken as 0.014.

Routing

To route the hydrograph from the upstream subcatchments downstream, SWMM EXTRAN was used. EXTRAN is an extremely powerful hydraulic computational engine, which works by finding a complete solution to the St. Venant equations. Consequently, it is capable of simulating backwater effects. EXTRAN is capable of simulating virtually any hydraulic phenomenon including pressurized flow, reverse flow, etc. EXTRAN was chosen for this portion of the model primarily for its ability to simulate the storage and discharge of water in the two dry basins (Burnett Dam and South Branch Dam) within watershed.

The routing component of the model transports the runoff from the individual subareas downstream to the creek and on to the Kansas River. This component of the model consists of a network of channels, or links, which are an attempt to approximate the collection and transport of surface runoff through the Shunganunga Creek tributaries and convey it downstream. Figure 3 on the following page shows the model with the routing network overlaid on the subcatchment boundaries.

The channel links were represented by trapezoidal channels. The majority of the creek's tributaries were represented by channels with bottom widths of 3 feet and side slopes scaled off the USGS quad maps. These channels were given a Manning's roughness value of 0.04. The creek itself was modeled as a trapezoidal channel with a bottom width of roughly 30 feet, 3:1 side slopes, and a roughness of 0.03. This portion of the model was only necessary to propagate peak flows downstream. The creek's actual hydraulic response will be simulated in the HEC-RAS model.

All channel segments in the routing model must start and end at junctions. EXTRAN requires ground and invert elevations at each of these junctions. The junction invert elevations were calculated with ArcView's 3D Spatial Analyst extension. This software package used the USGS DEM's to compute the ground elevations at each node location. These elevations were then assigned to the node invert elevation values in the routing model. The node ground elevations were arbitrarily assigned a value of 30 feet above the inverts, thus giving the channels a maximum flow depth of 30 feet. This depth was never fully utilized.

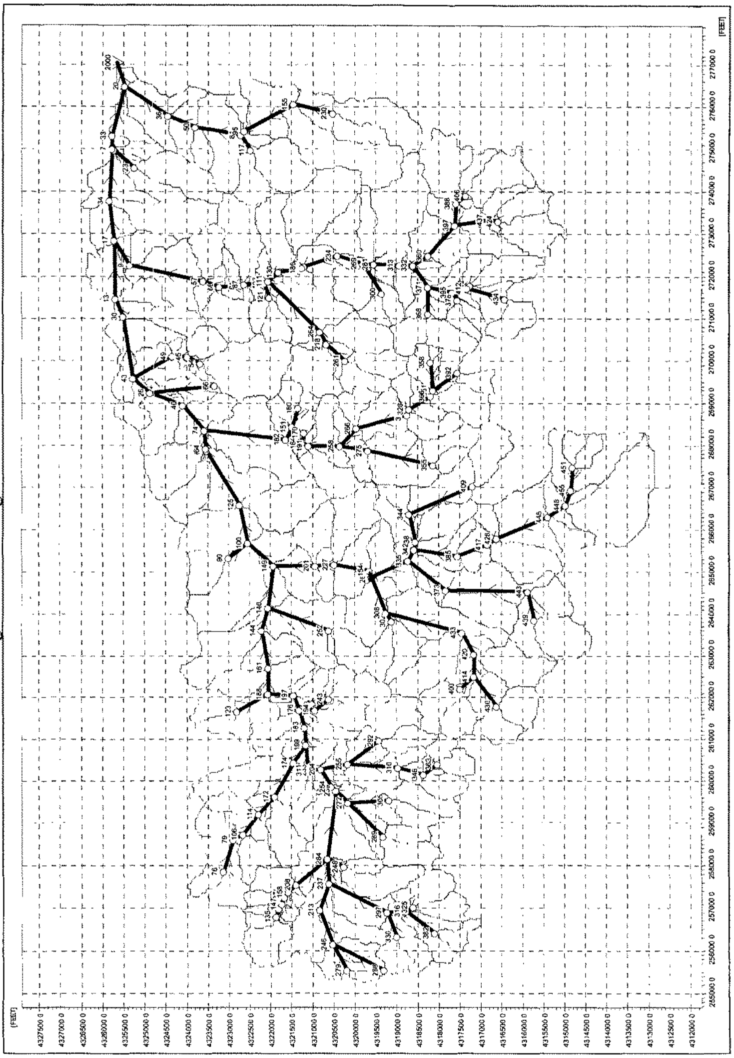
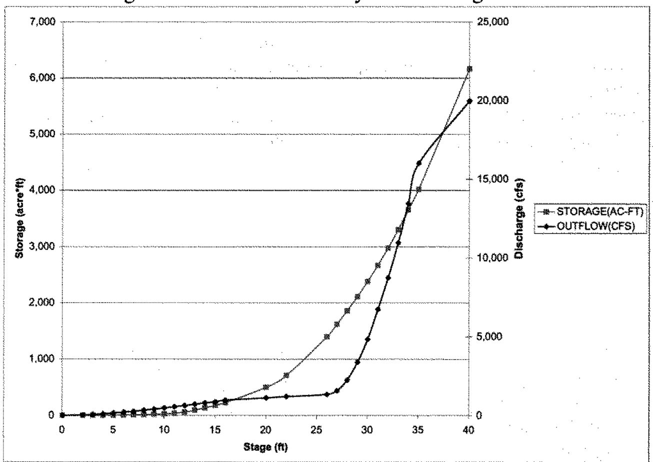


Figure 3-3 Routing Model Schematic

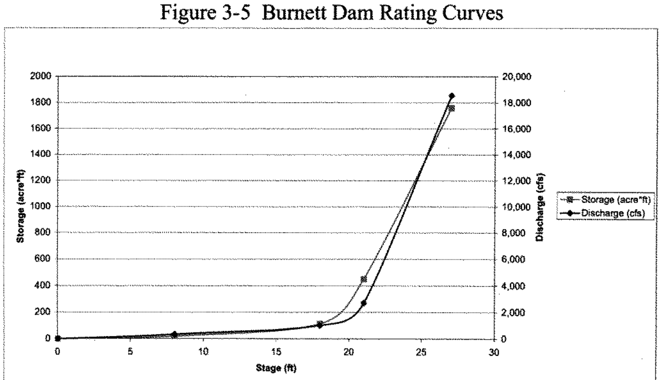
A rating curve of the South Branch dry basin (Figure 4) was taken from the report prepared by White, Martin & Associates in 1993. This curve provided the stage vs. area and discharge vs. stage relationships required to simulate the behavior of this basin.

Figure 3-4 South Branch Dry Basin Rating Curves



For the Burnett dry basin, little information was provided. Therefore the stage vs. area relationship was developed from the USGS contours. For this basin, the dam spillway was assumed to operate like that of the South Branch dam and the rating curve shown in Figure 5 was developed.

Figure 3-5 Burnett Dam Rating Curves



The stage-area relationships were input directly into the EXTRAN model as variable area storage junctions. The discharge spillways were approximated in the model as variable speed pumps whose discharge rates were controlled by the water level in the storage basins. Pump discharge rates vs. water depths were set to approximate the spillways' discharge rating curves.

Hypothetical Rainfall

Finally, synthetic input rainfall hyetographs were developed. These rainfall hyetographs were developed for a range of design storm recurrence intervals ranging from 2 to 500 years. The hyetographs were developed by first selecting 24-hour rainfall totals from the IDF curves (Figure 6). These rainfall totals were then distributed into hourly rainfall volumes according to the SCS Type II rainfall distribution (Figure 7) to develop the synthetic rainfall hyetographs shown in Figure 8.

Figure 3-6 Rainfall IDF Curves

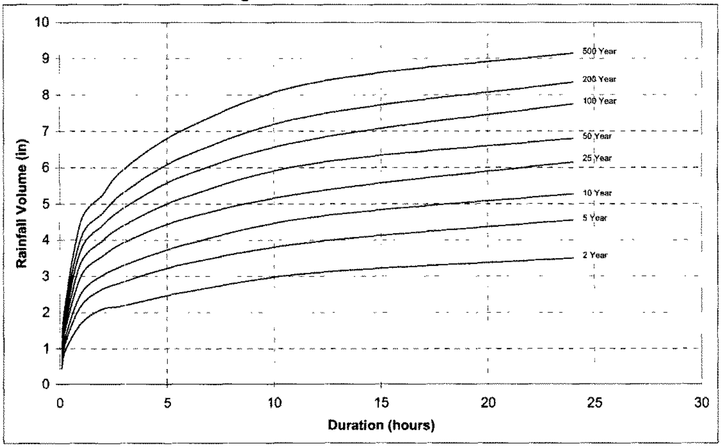


Figure 3-7 SCS Type II Rainfall

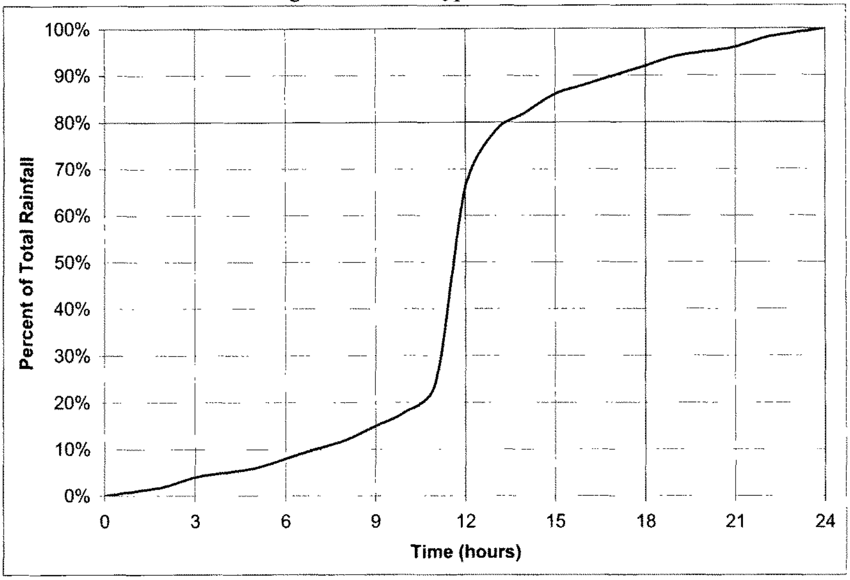
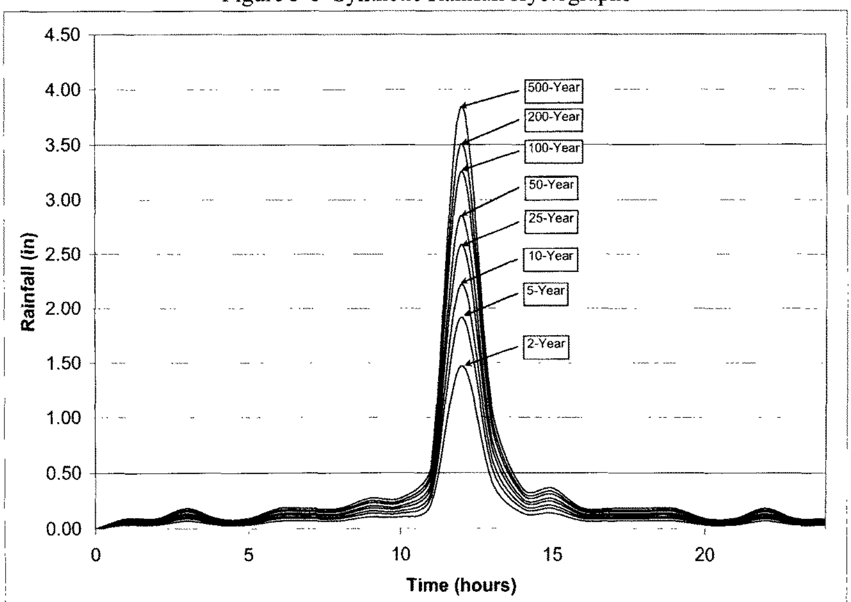


Figure 3-8 Synthetic Rainfall Hyetographs



Feasibility Discharges

By simulating the hypothetical rainfall with the SWMM program, the discharges were determined for the 0.2, 0.5, 1, 2, 4, 10, and 50-percent exceedance (500, 200, 100, 50, 25, 10, and 2-yr) flood events at ten different locations within the basin. The points were consolidated into eight flow change locations in the hydraulic HEC-RAS computer model. The results are shown in Table 3-2.

Table 3-2 Flow Frequency as developed with the SWMM model

Percent Chance of Exceedance	Return Interval (yr)	Discharge (cfs)							
		Station 27054	Station 23003	Station 19198	Station 13895	Station 9689	Station 5659	Station 3210	Station 368
0.2	500	19,400	20,600	21,000	31,100	31,700	32,600	33,500	36,500
0.5	200	17,200	18,200	18,600	27,500	28,000	29,000	29,900	32,100
1	100	15,600	16,500	16,800	24,800	25,300	25,900	26,400	28,900
2	50	13,100	13,900	14,100	20,700	21,000	21,500	22,000	23,900
4	25	11,400	12,100	12,300	17,800	18,100	18,500	18,900	20,600
10	10	9390	9910	10,100	14,500	14,700	15,000	15,400	16,700
20	5	7740	8150	8290	11,800	12,000	12,200	12,500	13,600
50	2	5530	5770	5860	8310	8400	8520	8760	9400

In the Shawnee County, Kansas Flood Insurance Study (FIS) of 1993, the discharges for this entire reach of study for the 10, 50, 100, and 500-year flood events are 10,210 cfs, 17,100 cfs, 20,780 cfs, and 30,750 cfs respectively. At the mouth, the discharges calculated with the SWMM model are higher, and therefore more conservative, than the FIS discharges.

Since flood events above the 0.2% chance exceedance (500-year) event need to be considered in this study, the discharge-frequency curves were extended up to the 0.04% chance exceedance (2500-year) event. To accomplish this, a straight-line extrapolation was used on a log-probability plot of the discharge-frequency events at HEC-RAS river station 3210 (see Plate A2-3-1). The discharges at the other locations were determined by multiplying the results at station 3210 with the average ratio of the known discharges at the area of interest to the discharges at station 3210. Table 3-3 summarizes all of the discharges used on Shunganunga Creek for the existing conditions model.

Table 3-3 Summary of Feasibility Flood Discharges

Percent Chance of Exceedance	Return Interval (yr)	Discharge (cfs)							
		Station 27054	Station 23003	Station 19198	Station 13895	Station 9689	Station 5659	Station 3210	Station 368
0.04	2500	25,200	26,600	27,100	39,400	40,000	41,000	42,000	45,600
0.1	1000	22,200	23,500	23,900	34,700	35,300	36,100	37,000	40,100
0.133	750	21,300	22,500	22,900	33,300	33,800	34,600	35,500	38,500
0.2	500	19,400	20,600	21,000	31,100	31,700	32,600	33,500	36,500
0.5	200	17,200	18,200	18,600	27,500	28,000	29,000	29,900	32,100
1	100	15,600	16,500	16,800	24,800	25,300	25,900	26,400	28,900
2	50	13,100	13,900	14,100	20,700	21,000	21,500	22,000	23,900
10	10	9,390	9,910	10,100	14,500	14,700	15,000	15,400	16,700

Hydrologic Uncertainty

In the past, the Corps of Engineers used freeboard as a factor of safety in designing levees to account for uncertainties in discharge, stage, and other engineering parameters such as geotechnical and structural. Now, the Corps of Engineers has adopted a new methodology called Risk Based Analysis (RBA) for formulating flood risk management projects. This method considers all of the same engineering parameters, but accounts for the uncertainties directly in the analysis in lieu of using freeboard. Using RBA, the project's performance will be expressed as the average return period in years of the largest flood that can be accommodated by the plan under study, with a conditional non-exceedance probability of 90%. The concept of freeboard is no longer used.

To use RBA, the hydrologic uncertainty must be characterized. This information is entered into the computer program HEC-FDA (Flood Damage Analysis), which uses Monte Carlo algorithms to quantify the uncertainties. The uncertainty bands used in this program are based on the effective record lengths used to develop the flow frequency estimates. According to Table 4-5 in EM 1110-2-1619 "Risk Based Analysis for Flood Reduction Studies", the equivalent record length is 15 years for Shunganunga Creek since discharges were estimated with a rainfall-runoff-routing model using textbook parameters.

HEC-FDA calculates the uncertainty either analytically or graphically. For an analytical computation the log Pearson Type III statistics are inputted directly. A graphical approach is used on regulated streams, when the stream gage records are small or incomplete, or when partial duration data is used. For Shunganunga Creek, the discharge-probability curve was defined graphically. HEC-FDA uses the procedures outlined in ETL 1110-2-537 "Uncertainty Estimates for Nonanalytic Frequency Curves" to calculate the error limit curves using order statistics. This is related as standard deviations of the discharge estimate. For the HEC-FDA analysis, an arbitrary index point was selected at HEC-RAS river station 16621 (between Rice and Golden Avenue). Table 3-4 shows the hydrologic uncertainty results at this station.

Table 3-4 Hydrologic Uncertainty on Shunganunga Creek at HEC-RAS river station 16621

Exceedance Probability	Discharge (cfs)	Confidence Limit Curves (standard error) Discharge (cfs)			
		-2 SD	-1 SD	+1 SD	+2 SD
0.999	2260	1370	1760	2900	3720
0.99	2740	1790	2210	3390	4200
0.95	3330	2320	2780	3990	4780
0.9	3730	2680	3160	4390	5170
0.8	4310	3220	3730	4980	5760
0.7	4820	3680	4210	5510	6310
0.5	5860	4560	5170	6640	7530
0.3	7274	5480	6310	8380	9660
0.2	8290	6090	7110	9670	11,290
0.1	10,100	7020	8420	12,110	14,530
0.04	12,300	7990	9910	15,260	18,940
0.02	14,100	8690	11,070	17,960	22,870
0.01	16,800	9650	12,730	22,170	29,260
0.004	18,600	10,240	13,800	25,070	33,800
0.002	21,000	10,970	15,180	29,050	40,190
0.001	23,532	11,700	16,600	33,370	47,320

A-2.3.4 HYDRAULICS

The hydraulic analysis for this report centered on the development of the HEC-RAS computer model for the study reach of Shunganunga Creek at Topeka, Kansas. For this analysis, version 3.0.1 of the HEC-RAS (River Analysis System) developed by the Hydrologic Engineering Center was used. The computer model was calibrated using known water surface elevations and the corresponding discharge. Once calibrated, a series of steady flow water surface profiles were created based on the flood discharges in Table 3-3 above.

Original Design Water Surface Elevations

The elevation of the crown of the existing levee was determined by selecting a design water surface elevation and then adding freeboard to account for uncertainties. For the Oakland Levee Unit the freeboard was three feet. The original design discharges assumed a Kansas River discharge above Soldier Creek of 314,000 cfs and 364,000 cfs below the confluence. The design discharge on Shunganunga creek was 40,000 cfs at the mouth and 27,000 cfs upstream of Deer Creek, which is located at HEC-RAS river station 13895.

Geometric Data

The computer model required cross section geometry along the length of the study reach (see Plate A2-3-2). The information used to create the cross-section geometry was obtained from two sources. The U.S. Army Corps of Engineers provided 1997 cross-section surveys of the channel that covered the entire length of the study reach. The City of Topeka provided four-foot contours, from 1995 aerial mapping that covered the entire study area. In order for the model to more accurately compute friction losses, some of the surveyed sections were copied and modified based on aerial photographs and on-site inspection.

Based on field investigation and review of aerial photography, appropriate Manning's "n" coefficients were selected for each cross section. Values from 0.030 to 0.035 were selected for the channel throughout the entire study reach. Overbank "n" values ranged from 0.040 for well maintained grassy areas to 0.15 for heavily treed areas with dense undergrowth. Higher values of "n" were also used to reduce flow or block out flow in overbanks that were either very wide or contained trees or other obstructions. For the side slopes of the levees, "n" values from 0.035 to 0.045 were used.

The bridge data was obtained from engineering drawings provided by: Kansas Department of Transportation, City of Topeka, Shawnee County, and the Burlington Northern Santa Fe Railroad. The plans for the railroad bridge near the mouth of Shunganunga Creek were not available. The bridge was modeled using plans from a similar bridge upstream of the study limits along with contour data. The plan specifications were used to obtain pier widths and deck thickness, and spot elevations along the railroad track were used to determine the high chord elevation of the bridge deck and embankment. This approximation was deemed satisfactory since this bridge does not significantly affect the water surface profile along the levee during the flood events this study focuses on.

For the cross-sections that did not have a field survey, levee heights were approximated using the "Topeka Flood Protection Project Operation and Maintenance Manual". There is a well-maintained levee/berm on the right side of Shunganunga Creek, across from the Oakland Levee Unit. It is continuous from the raised Interstate 70 profile, just upstream of the study boundary, through the Branner Street Bridge. Though this levee/berm does not appear pronounced on the contour map, its presence and consistency were verified by on-site inspection.

The lower portion of the study reach, downstream of the levee unit, required some unusual modeling. During the 4% chance and larger events, water is lost over the railroad tracks to the left of the channel. To capture this loss, the railroad berm upstream of Goodell Bridge was modeled as a lateral weir. HEC-RAS calculates the amount of flow spilling over the lateral weir and reduces the downstream flow accordingly. On the cross-sections between Goodell Bridge and the Railroad Bridge, a high ineffective flow area was added at the railroad berm. Therefore, flow to the left of the berm was not considered as contributing flow to the stream. To account for the lateral flow that would be spilling over the berm, the left side of the railroad bridge in the model was coded with the berm elevations. Essentially, the cross-section at the bridge accounted for the lateral flow over the railroad berm between the two bridges.

<u>Starting Water Surface Elevation</u>

Due to the limited amount of gage data available, it was difficult to correlate the peak on Shunganunga Creek with the coincident water surface elevation on the Kansas River. Three different profiles were created on Shunganunga Creek following the illustration of Figure 11-1 in EM 1110-2-1415 "Engineering and Design – Hydrologic Frequency Analysis". Plate A2-3-3 shows the Shunganunga Creek profiles. The first profile assumed 100-year discharges on both Shunganunga and the Kansas River. The second profile assumed a 2-year water surface elevation on the Kansas River with a 100-yr discharge on Shunganunga Creek. The third profile assumed a 100-year starting water surface elevation on the Kansas River and a 2-year discharge on Shunganunga Creek. As shown in Plate A2-4-3, the majority of the levee is dominated by the discharge on Shunganunga Creek and not the Kansas River starting water surface elevation. Furthermore, upstream of the Rice Bridge at river station 11056, the difference between the first two profiles is diminished to less than half a foot. Since the water surface profile for the majority of the levee is not primarily dependent on the starting water surface elevation, a simplified coincident analysis was used to determine starting water surface elevations.

To simplify the coincident analysis, an empirical table from the Hydraulic Manual from the Texas Department of Highways was used. This relationship is shown in Plate A2-3-4. The empirical table relates annual events based on the relative sizes of the two watersheds up to the 100-year frequency event. Table 3-5 shows the application of the empirical table to the coincident Kansas River flow during a Shunganunga flood event. Above the 100-year frequency events, the Kansas River frequency was estimated. The starting water surface elevation was determined from a rating curve on the Kansas River hydraulic model.

Table 3-5 Coincident Kansas River Discharge And Shunganunga Starting Water Surface Elevation

Shunganunga Creek		Coincident Kansas River		Shunganunga Starting Water Surface Elevation (ft)
Percent Chance of Exceedance	Return Interval (yr)	Percent Chance of Exceedance	Return Interval (yr)	
0.04	2500	0.133	750	877.22
0.1	1000	0.2	500	873.43
0.133	750	0.2	500	873.43
0.2	500	1	100	871.6
0.5	200	2	50	869.01
1	100	10	10	863.02
2	50	20	5	859.4
10	10	50	2	854.14

Calibration

There was limited data available to calibrate the model. Shunganunga Creek only had two short periods with an operating gage. Other than gage readings, no highwater marks with a corresponding discharge could be found. Therefore, the model was calibrated using data from a U.S.G.S. gage that was located at the upstream face of Rice Bridge from May 1980 to September 1981. Other data from a gage located further upstream, from June 1994 to August 1996, were disregarded due to the fact that they were not taken near a surveyed cross section. That is, the geometry at the gage location could not be reproduced accurately enough to calibrate to the relatively low flows recorded by the gage. The calibration discharges were entered as a constant flow throughout the entire length of the model with the downstream boundary condition set to "normal depth."

The calibration of the backwater program to known water surface elevations was accomplished by adjusting the Manning's "n" values for the channel until the profile matches the gage data. In this case, the calibration resulted in "n" values of 0.03 to 0.035 in the channel along the entire study reach.

Table 3-6 presents the results of the calibration. It lists the discharges and water surface elevations from the U.S.G.S. gage data and compares these to the computed water surface profile elevations. Figure 4 shows the calibration discharge profiles and the calibration points.

Table 3-6 Shunganunga Calibration Data

Discharge (cfs)	U.S.G.S. Elevation (ft)	HEC-RAS Model Elevation (ft)
5920	865.24	865.40
2880	860.10	860.95
1280	857.47	857.36
Note: Comparison at HEC-RAS Sta. 12549		

The calibrated backwater model matched the observed stage readings fairly well. However, only one point was used to calibrate the model at three fairly low discharges. Although this is not an ideal calibration, it was the best possible with the limited data available

Shunganunga Creek Existing Condition (Base) Profile

Once the model was calibrated, the existing conditions water surface profiles were generated using the discharges of Table 3-6 above. Plate A2-3-5 shows the 50% non-exceedance probability profiles for the 10, 2, 1, 0.5, 0.2, 0.133, 0.1, and 0.04-percent chance (10, 50, 100, 200, 500, 750, 1000, and 2500-year) flood events. The tabular data is presented in Table 3-7, located at the end of this section.

The HEC-RAS model indicates that the Oakland Levee Unit does not overtop until the water surface elevation reaches the 50% non-exceedance probability stage for the 0.04% chance exceedance (2500-year) event. Discretion should be used when applying profiles higher than the top of the levee. The model used a confined cross sectional area from levee to levee. Essentially, overbank flow beyond the levee height was not taken into consideration. This assumption was made to avoid trying to predict where a levee would fail. Within the Topeka levee systems, there are many different combinations of failure scenarios that could physically occur. Potentially, each could produce a different overbank flow path. HEC-RAS is a one-dimensional steady state model. It is beyond the limitations for HEC-RAS to predict the overbank flow scenarios or to model multi-dimensional flow. Profiles for the rare frequency events that exceed the top of levee are highly speculative and would not necessarily match what would physically happen. These events were produced to formulate frequency-stage curves for economic analyses in the HEC-FDA computer program.

Hydraulic Uncertainty

Uncertainties in computed stage result from two main sources: natural variations in the river and modeling errors. Natural variations include uncertainties in physical factors such as bed forms, debris and other obstructions, channel scour or deposition, sediment transport, and waves. Modeling uncertainty includes factors such as inexact geometry and loss coefficients, variation in hydraulic roughness with season, and error in setting high water marks (EM 1110-2-1619).

In Risk Based Analysis, the stage uncertainty is express as standard deviation (in feet). The total standard deviation depends on the standard deviation based on natural variations and the standard deviation based on model errors according to the formula below:

$$\text{Total Standard Deviation} = \sqrt{S_{natural}^{2} + S_{model}^{2}}$$

where $S_{natural}$ = standard deviation based on natural variations
S_{model} = standard deviation based on modeling uncertaities

For a ungaged reached, $S_{natural}$ is estimated using Figure 5-3 of the Corps of Engineers Engineering Manual 1110-2-1619 "Risk-Based Analysis for Flood Damage Reduction Studies". This graph shows the stream slope versus the standard deviation of uncertainty for 112 rivers. Based on the graph, $S_{natural}$ for Shunganunga Creek was taken as 0.5 feet.

Table 5-2 in EM 1110-2-1619 quantifies S_{model} based on the quality of topographic data and the reliability of the Manning's n-value. A standard deviation of 1.5 feet was chosen since some of the cross-sections were based on topographical mapping and the Manning's n-values were assumed to have "poor" reliability (due to the limited amount of calibration data available).

Once $S_{natural}$ and S_{model} are known, a total standard deviation can be computed. For this study a total standard deviation of 1.58 ft was computed for the entire discharge set.

A-2.3.5 SUMMARY

First, a hydrologic analysis was completed to determine the expected discharges at the flood reduction works based upon a SWMM computer model of the Shunganunga basin. A hydraulic investigation was conducted on Shunganunga Creek using the HEC-RAS computer software developed by the Hydrologic Engineering Center, U.S. Army Corps of Engineers. The program was used to calculate water surface profiles on approximately the first five miles of Shunganunga Creek adjacent to the Oakland Levee Unit in Topeka, Kansas. The model was calibrated using data from a U.S.G.S. gage that was located at the upstream face of Rice Bridge from May 1980 to September 1981. The 50% non-exceedance probability water surface profiles were then generated for eight different discharge events. These include the 10, 2, 1, 0.5, 0.2, 0.133, 0.1, and 0.04-percent chance (10, 50, 100, 200, 500, 750, 1000, and 2500-year) flood events. The model shows that the existing levees are not overtopped until the 0.04% chance exceedance (2500-year) flood event (with a 50% chance of non-exceedance). Finally, the uncertainty in both stage and discharge were calculated.

Table 3-7 Shunganunga Creek Existing Conditions Water Surface Profiles

HEC-RAS River Station	Profile	Q Total (cfs)	Water Surface Elevation (ft)	Energy Grade Elevation (ft)	Average Channel Velocity (ft/s)	Flow Area (sq ft)	Top Width Width (ft)	Channel Froude #
5	10% 10yr	16700	854.14	856.63	12.92	1541.14	705.03	0.75
5	2% 50yr	23800	859.4	860.58	9.65	3530.66	1250.98	0.45
5	1% 100yr	25900	863.02	863.71	7.62	4972.07	1519.68	0.32
5	0.5% 200yr	23800	869.01	869.26	4.77	7357.16	1687.6	0.17
5	0.2% 500yr	24200	871.6	871.62	1.94	24319.7	1697.8	0.07
5	0.133% 750yr	23500	873.43	873.45	1.61	29763.05	1705.36	0.05
5	0.1% 1000yr	24800	873.43	873.45	1.7	29763.05	1705.36	0.06
5	0.04% 2500yr	20600	877.22	877.23	1.14	36254.5	1720.31	0.04
191	10% 10yr	16700	854	857.87	15.79	1057.66	118.25	0.93
191	2% 50yr	23800	858.13	861.61	15.05	1670.38	669.46	0.75
191	1% 100yr	25900	862.24	864.27	11.75	2586.21	1403.43	0.51
191	0.5% 200yr	23800	868.71	869.45	7.31	4039.2	1479.96	0.27
191	0.2% 500yr	24200	871.55	871.66	3.64	19477.22	1547.21	0.13
191	0.133% 750yr	23500	873.4	873.47	3.07	23462.45	1588.38	0.1
191	0.1% 1000yr	24800	873.39	873.47	3.24	23456.93	1588.31	0.11
191	0.04% 2500yr	20600	877.21	877.24	2.16	29790.3	1773.99	0.07
200				Railroad Bridge				
209	10% 10yr	16700	857.96	859.85	11.05	1511	128.15	0.57
209	2% 50yr	23800	860.98	863.37	12.42	1947.82	909.15	0.58
209	1% 100yr	25900	867.08	868.33	9.13	3129.94	1343.41	0.36
209	0.5% 200yr	23800	871.22	871.4	4.3	15656.38	1370.34	0.15
209	0.2% 500yr	24200	872.96	873.1	3 82	18050.37	1380.04	0.13
209	0.133% 750yr	23500	873 94	874.04	3.48	19395.49	1389.46	0.12
209	0.1% 1000yr	24800	874	874.12	3.65	19489.56	1390.01	0.12
209	0.04% 2500yr	20600	877.24	877.29	2.48	24080.31	1440.25	0.08
368	10% 10yr	16700	858.35	860.16	10.8	1546.93	129.12	0.55
368	2% 50yr	23800	861.36	863.67	12.21	1965.42	152.87	0.56
368	1% 100yr	25900	867.16	868.45	9.24	3036.07	215.16	0.36
368	0.5% 200yr	23800	870.87	871.59	6.99	3904.76	253.03	0.25
368	0.2% 500yr	24200	872.65	873.26	6.49	4371.04	271.18	0.23
368	0.133% 750yr	23500	873.66	874.18	6 02	4650.28	278.51	0.21
368	0.1% 1000yr	24800	873.7	874.27	6.33	4660.92	278.64	0.22
368	0.04% 2500yr	20600	877.08	877.37	4.52	5626.28	294.73	0.14
1575	10% 10yr	15400	860.77	862.03	9.03	1710.43	141.87	0.44

HEC-RAS River Station	Profile	Q Total (cfs)	Water Surface Elevation (ft)	Energy Grade Elevation (ft)	Average Channel Velocity (ft/s)	Flow Area (sq ft)	Top Width Width (ft)	Channel Froude #
1575	2% 50yr	21900	864.03	865.45	9.78	2664.81	362.71	0.43
1575	1% 100yr	23400	868.45	869.16	7.28	4348.31	397.95	0.28
1575	0.5% 200yr	21600	871.54	871.92	5.45	5640.15	440.77	0.2
1575	0.2% 500yr	21200	873.24	873.51	4.72	6974.86	875.3	0.17
1575	0.133% 750yr	20500	874.17	874.39	4.26	7792.07	879.17	0.15
1575	0.1% 1000yr	21700	874.26	874.5	4.47	7873.28	879.55	0.15
1575	0.04% 2500yr	17000	877.38	877.46	2.79	10642.32	907.75	0.09
2414	10% 10yr	15400	861.52	863.35	11.2	1702.19	271.42	0.52
2414	2% 50yr	21900	864.7	866.58	11.87	2696.59	368.06	0.49
2414	1% 100yr	23400	868.73	869.62	8.75	4305.45	416.75	0.33
2414	0.5% 200yr	21600	871.69	872.13	6.4	5548.84	424.91	0.23
2414	0.2% 500yr	21200	873.33	873.65	5.59	6253.14	432.89	0.19
2414	0.133% 750yr	20500	874.24	874.5	5.13	6647.16	443.2	0.17
2414	0.1% 1000yr	21700	874.33	874.63	5.38	6690.83	447.39	0.18
2414	0.04% 2500yr	17000	877.4	877.51	3.42	9441.58	1379.53	0.11
2704	10% 10yr	15400	861.99	863.79	11.06	1682.85	253.25	0.5
2704	2% 50yr	21900	865.07	866.97	11.87	2526.08	405.68	0.49
2704	1% 100yr	23400	868.78	869.85	9.36	3763.17	529.89	0.35
2704	0.5% 200yr	21600	871.69	872.24	6.96	4879.47	564.95	0.25
2704	0.2% 500yr	21200	873.33	873.74	6.08	5539.2	575.25	0.21
2704	0.133% 750yr	20500	874.23	874.57	5.56	5906.21	579.72	0.19
2704	0.1% 1000yr	21700	874.33	874.7	5.83	5945.95	580.2	0.2
2704	0.04% 2500yr	17000	877.4	877.55	3.82	7205.12	595.49	0.12
2809	10% 10yr	15400	862.25	863.95	10.81	1747.54	255.91	0.49
2809	2% 50yr	21900	865.31	867.11	11.6	2636.32	353.74	0.48
2809	1% 100yr	23400	868.91	869.92	9.17	4010.39	400	0.35
2809	0.5% 200yr	21600	871.76	872.28	6.8	5151.06	400	0.24
2809	0.2% 500yr	21200	873.38	873.76	5.94	5798.75	400	0.2
2809	0.133% 750yr	20500	874.27	874.59	5.45	6156.44	400	0.18
2809	0.1% 1000yr	21700	874.38	874.72	5.71	6197.04	400	0.19
2809	0.04% 2500yr	17000	877.41	877.55	3.76	7409.56	400	0.12
2827				Goodell Bridge				
2845	10% 10yr	15400	863.32	864.52	9.11	2145.65	296.89	0.4
2845	2% 50yr	21900	866.34	867.64	9.92	3179.64	370.09	0.4
2845	1% 100yr	23400	869.31	870.18	8.39	4344.73	401.12	0.31

HEC-RAS River Station	Profile	Q Total (cfs)	Water Surface Elevation (ft)	Energy Grade Elevation (ft)	Average Channel Velocity (ft/s)	Flow Area (sq ft)	Top Width Width (ft)	Channel Froude #
2845	0.5% 200yr	21600	871.92	872.4	6.43	5400.54	408.7	0.23
2845	0.2% 500yr	21200	873.48	873.85	5.68	6043.09	412.39	0.2
2845	0.133% 750yr	20500	874.36	874.66	5.23	6403.26	414.44	0.18
2845	0.1% 1000yr	21700	874.47	874.8	5.48	6448.88	414.7	0.18
2845	0.04% 2500yr	17000	877.44	877.59	3.65	7693.05	419.55	0.12
2964	10% 10yr	15400	863.47	864.64	8.98	2191.75	297.77	0.39
2964	2% 50yr	21900	866.44	867.75	9.91	3101.16	315.4	0.4
2964	1% 100yr	23400	869.34	870.25	8.54	4055.6	335.72	0.32
2964	0.5% 200yr	21800	871.91	872.45	6.7	4928.43	343.23	0.24
2964	0.2% 500yr	21400	873.47	873.89	5.99	5465.74	346.89	0.21
2964	0.133% 750yr	20800	874.34	874.69	5.56	5768.17	348.94	0.19
2964	0.1% 1000yr	21900	874.44	874.84	5.83	5805.81	349.2	0.2
2964	0.04% 2500yr	17500	877.43	877.6	3.99	6856.46	354.09	0.13
3210	10% 10yr	15400	863.8	864.85	8.62	2411.6	368.87	0.37
3210	2% 50yr	21900	866.85	867.96	9.32	3630.42	422.16	0.37
3210	1% 100yr	23800	869.62	870.39	8.05	4804.99	424.31	0.3
3210	0.5% 200yr	23200	872.03	872.52	6.6	5828.89	426.18	0.23
3210	0.2% 500yr	23600	873.53	873.94	6.1	6470.31	427.33	0.21
3210	0.133% 750yr	23600	874.38	874.74	5.79	6830.88	427.98	0.2
3210	0.1% 1000yr	24800	874.49	874.88	6.05	6879.65	428.07	0.2
3210	0.04% 2500yr	22400	877.41	877.63	4.65	8132.69	430.58	0.15
4150		Lateral Weir - Spill over Railroad						
4428	10% 10yr	15000	864.71	865.8	8.64	2228.01	536.62	0.37
4428	2% 50yr	21500	867.84	868.8	8.84	4153.44	669.57	0.35
4428	1% 100yr	25900	870.21	870.95	8.24	5768.5	688.07	0.3
4428	0.5% 200yr	29000	872.36	872.92	7.5	7259.07	701.66	0.27
4428	0.2% 500yr	32600	873.77	874.3	7.46	8259.72	711.48	0.26
4428	0.133% 750yr	34600	874.57	875.08	7.42	8828.66	717	0.25
4428	0.1% 1000yr	36100	874.7	875.25	7.66	8925.57	717.93	0.26
4428	0.04% 2500yr	41000	877.47	877.91	7.14	10943.65	748.76	0.23
5659	10% 10yr	15000	865.85	866.62	7.46	2918.14	529.24	0.31
5659	2% 50yr	21500	868.77	869.52	7.92	4534.2	582.46	0.31
5659	1% 100yr	25900	870.84	871.52	7.85	5794.42	621.24	0.29
5659	0.5% 200yr	29000	872.77	873.38	7.61	7083.53	796.61	0.27
5659	0.2% 500yr	32600	874.13	874.75	7.84	8284.29	999.1	0.27

HEC-RAS River Station	Profile	Q Total (cfs)	Water Surface Elevation (ft)	Energy Grade Elevation (ft)	Average Channel Velocity (ft/s)	Flow Area (sq ft)	Top Width Width (ft)	Channel Froude #
5659	0.133% 750yr	34600	874.91	875.5	7.71	9081.41	1018.54	0.26
5659	0.1% 1000yr	36100	875.07	875.69	7.92	9242.9	1021.26	0.27
5659	0.04% 2500yr	41000	877.77	878.22	7.11	12078.05	1084.84	0.23
6926	10% 10yr	14700	866.44	867.43	8.21	2053.9	178.72	0.34
6926	2% 50yr	21000	869.1	870.49	9.85	2627.1	302.24	0.38
6926	1% 100yr	25300	871	872.46	10.36	3405.35	515.43	0.38
6926	0.5% 200yr	28000	872.92	874.15	9.84	4583.9	673.82	0.35
6926	0.2% 500yr	31700	874.32	875.48	9.86	5547.97	706.47	0.34
6926	0.133% 750yr	33800	875.07	876.2	9.85	6087.76	724.12	0.34
6926	0.1% 1000yr	35300	875.23	876.42	10.14	6206.07	727.86	0.34
6926	0.04% 2500yr	40000	877.88	878.74	9.16	8347.7	894.61	0.3
7069	10% 10yr	14700	866.54	867.52	8.15	2073.27	180.18	0.34
7069	2% 50yr	21000	869.24	870.6	9.75	2670.95	318.17	0.38
7069	1% 100yr	25300	871.16	872.58	10.23	3488.35	533.09	0.38
7069	0.5% 200yr	28000	873.04	874.24	9.73	4665.38	676.64	0.34
7069	0.2% 500yr	31700	874.43	875.57	9.77	5626.72	709.07	0.34
7069	0.133% 750yr	33800	875.18	876.28	9.76	6164.04	726.54	0.33
7069	0.1% 1000yr	35300	875.35	876.5	10.05	6288.05	730.45	0.34
7069	0.04% 2500yr	40000	877.95	878.8	9.11	8413.49	898.91	0.29
7091				Oakland Expressway				
7113	10% 10yr	14700	867.19	868.14	8.04	2098.88	168.57	0.33
7113	2% 50yr	21000	869.85	871.24	9.83	2602.33	223.52	0.38
7113	1% 100yr	25300	871.29	872.88	10.72	3297.25	679.74	0.4
7113	0.5% 200yr	28000	873.12	874.41	10.05	4609.11	755.95	0.36
7113	0.2% 500yr	31700	874.49	875.67	9.99	5670.85	785.19	0.35
7113	0.133% 750yr	33800	875.23	876.36	9.91	6265.26	824.4	0.34
7113	0.1% 1000yr	35300	875.42	876.59	10.17	6419.16	847.72	0.35
7113	0.04% 2500yr	40000	878.07	878.87	8.97	8903.09	995.94	0.29
7338	10% 10yr	14700	867.34	868.27	7.96	2125.2	169.63	0.33
7338	2% 50yr	21000	870.06	871.41	9.71	2651.05	265.71	0.37
7338	1% 100yr	25300	871.53	873.07	10.56	3294.67	691	0.39
7338	0.5% 200yr	28000	873.22	874.57	10.2	4166.19	761.35	0.36
7338	0.2% 500yr	31700	874.52	875.86	10.4	4853.85	785.54	0.36
7338	0.133% 750yr	33800	875.22	876.56	10.48	5240.24	823.24	0.36

HEC-RAS River Station	Profile	Q Total (cfs)	Water Surface Elevation (ft)	Energy Grade Elevation (ft)	Average Channel Velocity (ft/s)	Flow Area (sq ft)	Top Width Width (ft)	Channel Froude #
7338	0.1% 1000yr	35300	875.4	876.8	10.79	5341.68	845.26	0.37
7338	0.04% 2500yr	40000	877.97	879.06	9.95	7089.58	994.42	0.32
8114	10% 10yr	14700	867.79	868.75	8.11	2146.51	202.48	0.34
8114	2% 50yr	21000	870.75	871.96	9.38	2861.39	393.73	0.36
8114	1% 100yr	25300	872.27	873.67	10.2	3271.32	728.1	0.38
8114	0.5% 200yr	28000	873.74	875.09	10.18	3883.79	867.89	0.37
8114	0.2% 500yr	31700	875	876.38	10.5	4583.09	1018.68	0.37
8114	0.133% 750yr	33800	875.69	877.07	10.61	4987.83	1146.58	0.37
8114	0.1% 1000yr	35300	875.89	877.34	10.91	5104.84	1172.8	0.37
8114	0.04% 2500yr	40000	878.3	879.49	10.29	6512.62	1278.03	0.34
9323	10% 10yr	14700	868.67	869.62	8.11	2094.98	180.53	0.34
9323	2% 50yr	21000	871.69	872.94	9.46	2674.92	202.93	0.36
9323	1% 100yr	25300	873.25	874.76	10.48	3031.95	271.66	0.39
9323	0.5% 200yr	28000	874.62	876.13	10.6	3374.96	339.11	0.38
9323	0.2% 500yr	31700	875.84	877.46	11.11	3685.62	398.66	0.39
9323	0.133% 750yr	33800	876.49	878.18	11.4	3853.7	985.17	0.4
9323	0.1% 1000yr	35300	876.72	878.51	11.74	3913.77	1002.69	0.41
9323	0.04% 2500yr	40000	878.83	880.58	11.8	4477.14	1107.64	0.39
9503	10% 10yr	14700	868.64	869.99	9.72	1740.5	187.65	0.45
9503	2% 50yr	21000	871.69	873.3	10.81	2270.61	219.84	0.46
9503	1% 100yr	25300	873.29	875.13	11.63	2547.97	247.12	0.47
9503	0.5% 200yr	28000	874.62	876.5	11.8	2778.88	258.43	0.46
9503	0.2% 500yr	31700	875.8	877.87	12.45	2982.72	268.82	0.47
9503	0.133% 750yr	33800	876.42	878.61	12.8	3090.98	728.1	0.48
9503	0.1% 1000yr	35300	876.64	878.96	13.21	3128.69	801.25	0.49
9503	0.04% 2500yr	40000	878.67	881.06	13.43	3481.63	1200.27	0.48
9520				Croco Bridge				
9537	10% 10yr	14700	868.79	870.49	11	1704.62	157.02	0.47
9537	2% 50yr	21000	871.88	874.07	12.73	2210.85	197.3	0.5
9537	1% 100yr	25300	873.52	876.02	13.75	2492.14	216.3	0.52
9537	0 5% 200yr	28000	878.9	880.49	11.25	3417.93	659.91	0.38
9537	0.2% 500yr	31700	879.22	881.2	12.54	3473.75	708.89	0.42
9537	0.133% 750yr	33800	879.35	881.57	13.28	3495.93	728.35	0.45
9537	0.1% 1000yr	35300	879.43	881.83	13.82	3509.63	740.36	0.46

HEC-RAS River Station	Profile	Q Total (cfs)	Water Surface Elevation (ft)	Energy Grade Elevation (ft)	Average Channel Velocity (ft/s)	Flow Area (sq ft)	Top Width Width (ft)	Channel Froude #
9537	0.04% 2500yr	40000	879.42	882.5	15.67	3506.74	737.83	0.53
9689	10% 10yr	14700	869.1	870.76	10.89	1768.77	186.15	0.46
9689	2% 50yr	21000	872.41	874.38	12.2	2446.79	227.07	0.47
9689	1% 100yr	25300	874.07	876.35	13.24	2874.33	288.93	0.5
9689	0.5% 200yr	28000	879.52	880.71	10.15	4878.45	783.06	0.34
9689	0.2% 500yr	31700	880.07	881.47	11.09	5093.13	1008.54	0.37
9689	0.133% 750yr	33800	880.37	881.88	11.6	5207.37	1019.93	0.38
9689	0.1% 1000yr	35300	880.67	882.19	11.74	7017.58	1031.69	0.39
9689	0.04% 2500yr	40000	881.28	882.99	12.59	7660.43	1056.24	0.41
11056	10% 10yr	14500	871.36	872.04	6.83	2662.29	295.35	0.27
11056	2% 50yr	20700	874.9	875.7	7.68	3762.74	319.11	0.28
11056	1% 100yr	24800	876.8	877.77	8.51	4507.06	513.25	0.3
11056	0.5% 200yr	27500	880.83	881.44	7.17	6686.97	665.6	0.23
11056	0.2% 500yr	31100	881.62	882.31	7.7	7123.39	672.5	0.25
11056	0.133% 750yr	33300	882.04	882.78	8.02	7355.01	674.91	0.26
11056	0.1% 1000yr	34700	882.33	883.1	8.2	7517.43	676.6	0.26
11056	0.04% 2500yr	39400	883.13	884.01	8.86	7958.18	681.19	0.28
11935	10% 10yr	14500	871.83	872.5	6.86	2492.66	182.67	0.27
11935	2% 50yr	20700	875.31	876.23	8.11	3227.62	240.07	0.29
11935	1% 100yr	24800	877.27	878.32	8.76	3788.64	402.29	0.3
11935	0.5% 200yr	27500	881.04	881.82	7.81	4986.78	552.68	0.25
11935	0.2% 500yr	31100	881.84	882.75	8.46	5249.43	562.34	0.27
11935	0.133% 750yr	33300	882.27	883.25	8.85	5390.44	567.48	0.28
11935	0.1% 1000yr	34700	882.57	883.6	9.08	5488.71	571.04	0.29
11935	0.04% 2500yr	39400	883.38	884.59	9.9	5761.23	581.52	0.31
12191	10% 10yr	14500	871.93	872.66	7.07	2390.86	176.23	0.28
12191	2% 50yr	20700	875.44	876.4	8.27	3051.11	199.71	0.3
12191	1% 100yr	24800	877.4	878.51	8.95	3461.33	235	0.31
12191	0.5% 200yr	27500	881.08	881.98	8.24	4289.26	419.69	0.27
12191	0.2% 500yr	31100	881.87	882.94	8.96	4470.6	441.46	0.29
12191	0.133% 750yr	33300	882.3	883.46	9.4	4566.89	452.64	0.3
12191	0.1% 1000yr	34700	882.59	883.82	9.66	4633.47	460.37	0.31
12191	0.04% 2500yr	39400	883.39	884.85	10.57	4816.37	481.6	0.33
12209				Rice Bridge				

HEC-RAS River Station	Profile	Q Total (cfs)	Water Surface Elevation (ft)	Energy Grade Elevation (ft)	Average Channel Velocity (ft/s)	Flow Area (sq ft)	Top Width Width (ft)	Channel Froude #
12227	10% 10yr	14500	872.7	873.44	7.24	2429.73	182.65	0.28
12227	2% 50yr	20700	876.16	877.14	8.51	3087.45	208.42	0.3
12227	1% 100yr	24800	878.1	879.22	9.19	3502.35	236.78	0.32
12227	0.5% 200yr	27500	881.74	882.64	8.38	4333.78	425.44	0.27
12227	0.2% 500yr	31100	882.54	883.59	9.11	4517.33	443.34	0.29
12227	0.133% 750yr	33300	882.97	884.12	9.55	4615.65	452.93	0.3
12227	0.1% 1000yr	34700	883.26	884.47	9.81	4683.18	459.51	0.31
12227	0.04% 2500yr	39400	884.07	885.52	10.72	4869.7	477.7	0.33
12549	10% 10yr	14500	872.85	873.64	7.43	2381.86	185.2	0.29
12549	2% 50yr	20700	876.32	877.36	8.71	3089.87	225.18	0.31
12549	1% 100yr	24800	878.29	879.48	9.37	3566.26	257.86	0.32
12549	0.5% 200yr	27500	881.85	882.81	8.63	4608.04	336.46	0.28
12549	0.2% 500yr	31100	882.68	883.79	9.35	4893.76	358.76	0.3
12549	0.133% 750yr	33300	883.12	884.33	9.79	5055.58	370.8	0.31
12549	0.1% 1000yr	34700	883.43	884.69	10.03	5170.7	377.72	0.32
12549	0.04% 2500yr	39400	884.28	885.74	10.87	5500.22	395.53	0.34
13895	10% 10yr	14500	873.71	874.64	8.22	2128.8	170.64	0.33
13895	2% 50yr	20700	877.24	878.47	9.59	2942.07	385.76	0.36
13895	1% 100yr	24800	879.3	880.55	9.96	3766.73	419.03	0.36
13895	0.5% 200yr	27500	882.64	883.54	8.76	5460.88	637.06	0.29
13895	0.2% 500yr	31100	883.66	884 59	9.11	6117.04	650.43	0.3
13895	0.133% 750yr	33300	884.23	885.18	9.32	6486.53	658.09	0.3
13895	0.1% 1000yr	34700	884.6	885.56	9.42	6734.52	663.44	0.31
13895	0.04% 2500yr	39400	885.68	886.69	9.84	7458.06	679.09	0.31
14931	10% 10yr	10100	874 88	875.28	5.55	2255.6	201.96	0.22
14931	2% 50yr	14100	878.71	879.14	6	3229.46	278.62	0.22
14931	1% 100yr	16800	880.76	881.19	6.18	4120.88	758.67	0.21
14931	0.5% 200yr	18600	883.69	883.95	5.21	6981.71	1049.71	0.17
14931	0.2% 500yr	21000	884.76	885.01	5.25	8115.65	1077.23	0.17
14931	0.133% 750yr	22900	885.36	885.61	5.38	8765.21	1095.43	0.17
14931	0.1% 1000yr	23900	885.74	886	5.39	9191.14	1105.66	0.17
14931	0.04% 2500yr	27100	886.89	887.13	5.47	10479.87	1151.52	0.17
16621	10% 10yr	10100	875.51	876.01	6.16	2014.92	175.63	0.25
16621	2% 50yr	14100	879.26	879.81	6.63	2696.36	198.95	0.25
16621	1% 100yr	16800	881.26	881.9	7.29	4535 26	1557.08	0.26

HEC-RAS River Station	Profile	Q Total (cfs)	Water Surface Elevation (ft)	Energy Grade Elevation (ft)	Average Channel Velocity (ft/s)	Flow Area (sq ft)	Top Width Width (ft)	Channel Froude #
16621	0.5% 200yr	18600	884.03	884.35	5.73	9607.96	1952.64	0.19
16621	0.2% 500yr	21000	885.09	885.38	5.65	11696.78	1966.2	0.19
16621	0.133% 750yr	22900	885.7	885.98	5.72	12901.02	1985.35	0.19
16621	0.1% 1000yr	23900	886.09	886.36	5.71	13671.77	2004.87	0.19
16621	0.04% 2500yr	27100	887.23	887.48	5.69	15971.79	2026.1	0.18
17813	10% 10yr	10100	876.08	876.86	7.8	1734.05	229.57	0.34
17813	2% 50yr	14100	879.82	880.46	7.48	2713.46	291.32	0.3
17813	1% 100yr	16800	882.06	882.46	6.68	7034.95	2122.56	0.25
17813	0.5% 200yr	18600	884.44	884.65	5.36	12211.96	2216.07	0.19
17813	0.2% 500yr	21000	885.47	885.66	5.33	14503.46	2244.95	0.19
17813	0.133% 750yr	22900	886.07	886.26	5.41	15854.2	2261.8	0.19
17813	0.1% 1000yr	23900	886.45	886.64	5.41	16714.46	2272.35	0.18
17813	0.04% 2500yr	27100	887.57	887.75	5.42	19286.67	2302.61	0.18
18194	10% 10yr	10100	876.39	877.19	7.82	1622.88	171.48	0.34
18194	2% 50yr	14100	879.97	880.77	8.09	2278.63	197	0.32
18194	1% 100yr	16800	882.06	882.75	7.93	5736.92	1833.77	0.3
18194	0.5% 200yr	18600	884.45	884.8	6.22	10321.55	1998.7	0.22
18194	0.2% 500yr	21000	885.49	885.79	6.12	12406.26	2042.07	0.21
18194	0.133% 750yr	22900	886.09	886.39	6.2	13642.18	2081.84	0.21
18194	0.1% 1000yr	23900	886.47	886.76	6.17	14437.5	2095.95	0.21
18194	0.04% 2500yr	27100	887.58	887.88	6.43	16866	2271.15	0.22
18212				Golden Bridge				
18230	10% 10yr	10100	876.61	877.27	7.3	1774.18	171.47	0.3
18230	2% 50yr	14100	880.13	880.83	7.81	2582.83	1454 61	0.3
18230	1% 100yr	16800	882.24	882.77	7.39	5875.59	1680.7	0.27
18230	0.5% 200yr	18600	884.47	884.83	6.45	9963.19	1955.14	0.22
18230	0.2% 500yr	21000	885.5	885.82	6.37	11992.6	1987.32	0.22
18230	0.133% 750yr	22900	886.1	886.42	6.45	13197.42	2020.31	0.22
18230	0.1% 1000yr	23900	886.48	886.79	6.43	13966.09	2028.49	0.22
18230	0.04% 2500yr	27100	887.58	887.91	6.78	16279.8	2177.15	0.22
18571	10% 10yr	10100	876.81	877.57	7.72	1641.31	156.75	0.32
18571	2% 50yr	14100	880.28	881.11	8.35	2647.34	1618.22	0.32
18571	1% 100yr	16800	882.45	882.95	7.24	6541.98	1901.85	0.26
18571	0.5% 200yr	18600	884.73	884.94	5.38	11067.61	2066.32	0.19
18571	0.2% 500yr	21000	885.75	885.92	5.17	13183.79	2090.43	0.18

HEC-RAS River Station	Profile	Q Total (cfs)	Water Surface Elevation (ft)	Energy Grade Elevation (ft)	Average Channel Velocity (ft/s)	Flow Area (sq ft)	Top Width Width (ft)	Channel Froude #
18571	0.133% 750yr	22900	886.35	886.52	5.16	14453.18	2104.77	0.17
18571	0.1% 1000yr	23900	886.73	886.89	5.1	15243.36	2113.64	0.17
18571	0.04% 2500yr	27100	887.87	888.01	4.96	17677.3	2138.34	0.16
19198	10% 10yr	10100	877.31	877.99	7.31	1807.41	166.19	0.31
19198	2% 50yr	14100	880.72	881.51	8.12	2777.42	873.29	0.31
19198	1% 100yr	16800	882.54	883.36	8.53	4233.19	1253.64	0.31
19198	0.5% 200yr	18600	884.73	885.18	6.97	7849.84	1516.3	0.25
19198	0.2% 500yr	21000	885.73	886.14	6.9	9404.35	1568.97	0.24
19198	0.133% 750yr	22900	886.34	886.73	6.97	10356.21	1598.58	0.24
19198	0.1% 1000yr	23900	886.71	887.09	6.96	10956.01	1618.17	0.24
19198	0.04% 2500yr	27100	887.85	888.2	6.9	12833.69	1668.9	0.23
19815	10% 10yr	9900	877.59	878.35	7.56	1614.8	153.27	0.31
19815	2% 50yr	13900	880.99	881.86	8.27	2191.9	190.46	0.32
19815	1% 100yr	16500	882.8	883.71	8.62	2603.59	251.82	0.32
19815	0.5% 200yr	18200	884.89	885.39	7.16	8092.17	1656.25	0.25
19815	0.2% 500yr	20600	885.87	886.35	7.26	9740.76	1708.5	0.25
19815	0.133% 750yr	22500	886.46	886.95	7.44	10760.9	1741.17	0.25
19815	0.1% 1000yr	23500	886.82	887.3	7.47	11401.01	1760.67	0.25
19815	0.04% 2500yr	26600	887.95	888.41	7.53	13408.86	1810.78	0.25
20002	10% 10yr	9900	877.7	878.46	7.54	1600.38	145.56	0.31
20002	2% 50yr	13900	881.08	881.97	8.36	2135.17	179.36	0.32
20002	1% 100yr	16500	882.87	883.82	8.77	2535.33	248.76	0.32
20002	0.5% 200yr	18200	884.98	885.45	7.02	8384.17	1726.04	0.25
20002	0.2% 500yr	20600	885.99	886.42	7.03	10076.79	1762.57	0.24
20002	0.133% 750yr	22500	886.58	887.02	7.2	11214.94	1821.19	0.25
20002	0.1% 1000yr	23500	886.94	887.36	7.22	11870.09	1841.06	0.24
20002	0.04% 2500yr	26600	888.05	888.46	7.28	13986.99	1987.05	0.24
20020				Pedestrian Bridge				
20039	10% 10yr	9900	877.78	878.54	7.52	1606.08	146.19	0.31
20039	2% 50yr	13900	881.14	882.03	8.35	2139.49	179.24	0.32
20039	1% 100yr	16500	882.96	883.89	8.73	2544.67	246.33	0.32
20039	0.5% 200yr	18200	885.03	885.5	7.05	7811.32	1732.43	0.25
20039	0.2% 500yr	20600	886.03	886.46	7.02	10299.84	1799.24	0.24
20039	0.133% 750yr	22500	886.63	887.06	7.16	11386.36	1840.48	0.24

HEC-RAS River Station	Profile	Q Total (cfs)	Water Surface Elevation (ft)	Energy Grade Elevation (ft)	Average Channel Velocity (ft/s)	Flow Area (sq ft)	Top Width Width (ft)	Channel Froude #
20039	0.1% 1000yr	23500	886.99	887.41	7.19	12048.84	1884.34	0.24
20039	0.04% 2500yr	26600	888.12	888.51	7.22	14220.97	1996.72	0.24
20230	10% 10yr	9900	877.87	878.65	7.61	1580.64	146.54	0.32
20230	2% 50yr	13900	881.24	882.15	8.43	2126.56	185.12	0.32
20230	1% 100yr	16500	883.06	884	8.76	2551.64	254.45	0.32
20230	0.5% 200yr	18200	885.04	885.59	7.44	6373.31	1881.8	0.26
20230	0.2% 500yr	20600	886.12	886.53	6.92	10833.86	1954.06	0.24
20230	0.133% 750yr	22500	886.72	887.12	7.02	12020	1985.04	0.24
20230	0.1% 1000yr	23500	887.09	887.48	7.02	12747.42	2003.76	0.24
20230	0.04% 2500yr	26600	888.21	888.57	6.99	15043.04	2065.89	0.23
20776	10% 10yr	9900	878.12	879.04	8.21	1488.69	142.04	0.36
20776	2% 50yr	13900	881.48	882.52	8.97	2005.69	843.13	0.35
20776	1% 100yr	16500	883.24	884.39	9.57	2561.3	1686.15	0.36
20776	0.5% 200yr	18200	884.87	886.02	9.69	3692.68	2105	0.35
20776	0.2% 500yr	20600	886.14	886.79	8.15	10646.27	2178.26	0.29
20776	0.133% 750yr	22500	886.76	887.37	8.17	12000.38	2209.9	0.29
20776	0.1% 1000yr	23500	887.13	887.71	8.11	12828.12	2229.28	0.28
20776	0.04% 2500yr	26600	888.28	888.78	7.91	15416.66	2285.43	0.27
21730	10% 10yr	9900	878.81	879.89	8.8	1359.43	149.56	0.41
21730	2% 50yr	13900	882.09	883.3	9.54	1955.31	235.64	0.4
21730	1% 100yr	16500	883.89	885.13	9.85	2483.46	1305.04	0.4
21730	0.5% 200yr	18200	885.67	886.64	9.06	3281.7	2058.22	0.35
21730	0.2% 500yr	20600	886.57	887.2	8.06	8488.28	2097.26	0.3
21730	0.133% 750yr	22500	887.21	887.77	7.9	9828.39	2124.27	0.29
21730	0.1% 1000yr	23500	887.57	888.09	7.78	10597.35	2138.48	0.29
21730	0.04% 2500yr	26600	888.69	889.11	7.41	13033.03	2186.81	0.27
21939	10% 10yr	9900	879.13	880.1	8.43	1450.44	158.62	0.39
21939	2% 50yr	13900	882.47	883.49	8.89	2021.2	181.4	0.37
21939	1% 100yr	16500	884.3	885.31	9.13	3294.82	1700.93	0.37
21939	0.5% 200yr	18200	886.11	886.78	7.98	6615.22	1911.85	0.31
21939	0.2% 500yr	20600	886.62	887.32	8.38	7586.09	1933.63	0.32
21939	0.133% 750yr	22500	887.22	887.89	8.41	8770.53	1989.71	0.31
21939	0.1% 1000yr	23500	887.57	888.21	8.35	9474.54	2004.91	0.31
21939	0 04% 2500yr	26600	888.68	889.23	8.09	11734.48	2061	0.29

HEC-RAS River Station	Profile	Q Total (cfs)	Water Surface Elevation (ft)	Energy Grade Elevation (ft)	Average Channel Velocity (ft/s)	Flow Area (sq ft)	Top Width Width (ft)	Channel Froude #
21962				4th Street Bridge				
21985	10% 10yr	9900	879.24	880.19	8.34	1468.31	159.56	0.39
21985	2% 50yr	13900	882.61	883.6	8.8	2045.46	182.24	0.37
21985	1% 100yr	16500	884.46	885.43	8.99	3570.62	1782.86	0.36
21985	0.5% 200yr	18200	886.23	886.87	7.84	6845.53	1917.04	0.3
21985	0.2% 500yr	20600	886.75	887.42	8.22	7840.33	1939.29	0.31
21985	0.133% 750yr	22500	887.34	887.98	8.27	9008.75	1994.87	0.31
21985	0.1% 1000yr	23500	887.69	888.3	8.21	9702.06	2009.8	0.3
21985	0.04% 2500yr	26600	888.77	889.3	7.99	11920.57	2064.5	0.29
22032	10% 10yr	9900	879.29	880.24	8.07	1369.65	144.85	0.4
22032	2% 50yr	13900	882.63	883.65	8.53	1885.13	164.06	0.38
22032	1% 100yr	16500	884.42	885.5	8.87	2187.92	1438.35	0.37
22032	0.5% 200yr	18200	885.93	887.04	9.02	2465.98	1942.87	0.36
22032	0.2% 500yr	20600	886.61	887.52	8.69	6717.69	1991.95	0.34
22032	0.133% 750yr	22500	887.21	888.08	8.71	7927.47	2017.97	0.34
22032	0.1% 1000yr	23500	887.56	888.39	8.66	8636.97	2033.09	0.34
22032	0.04% 2500yr	26600	888.67	889.38	8.43	10906.26	2080.89	0.32
22062	10% 10yr	9900	879.51	880.29	7.29	1512.58	146.15	0.35
22062	2% 50yr	13900	882.8	883.69	7.92	2024.89	165.05	0.34
22062	1% 100yr	16500	884.58	885.54	8.33	2327.08	1500.66	0.34
22062	0.5% 200yr	18200	886.37	887.1	7.64	6350.58	1981.56	0.3
22062	0.2% 500yr	20600	886.72	887.55	8.25	7056.84	1996.87	0.32
22062	0.133% 750yr	22500	887.3	888.11	8.34	8215.65	2021.75	0.32
22062	0.1% 1000yr	23500	887.64	888.42	8.33	8893.41	2036.18	0.31
22062	0.04% 2500yr	26600	888.7	889.4	8.21	11092.37	2082.45	0.3
22195	10% 10yr	9900	879.62	880.39	7.25	1534.75	147.98	0.34
22195	2% 50yr	13900	882.89	883.78	7.93	2052.75	168.85	0.34
22195	1% 100yr	16500	884.69	885.63	8.29	2733.47	1356.4	0.34
22195	0.5% 200yr	18200	886.36	887.21	8.02	3944.19	1903.04	0.31
22195	0.2% 500yr	20600	886.67	887.69	8.86	4168.77	1914.79	0.34
22195	0.133% 750yr	22500	887.17	888.29	9.31	4533.33	1933.83	0.35
22195	0.1% 1000yr	23500	887.46	888.61	9.51	4745.39	1944.89	0.36
22195	0.04% 2500yr	26600	888.4	889.65	10.03	5432.52	1980.77	0.37
23003	10% 10yr	9900	880.12	881.28	9.33	1289.33	140.42	0.43

HEC-RAS River Station	Profile	Q Total (cfs)	Water Surface Elevation (ft)	Energy Grade Elevation (ft)	Average Channel Velocity (ft/s)	Flow Area (sq ft)	Top Width Width (ft)	Channel Froude #
23003	2% 50yr	13900	883.34	884.57	9.88	1778.64	163.91	0.41
23003	1% 100yr	16500	885.17	886.35	10.03	2738.54	1110.11	0.4
23003	0.5% 200yr	18200	886.81	887.76	9.37	4302.05	1531.97	0.36
23003	0.2% 500yr	20600	887.22	888.35	10.27	4718.26	1639.55	0.39
23003	0.133% 750yr	22500	887.61	889.1	11.52	5151.96	1915.11	0.43
23003	0.1% 1000yr	23500	887.98	889.4	11.44	5602.65	1938.33	0.42
23003	0.04% 2500yr	26600	889.15	890.34	11	7040.76	2058.6	0.4
23632	10% 10yr	9400	881.07	882.19	9.05	1248.36	134.99	0.42
23632	2% 50yr	13100	884.14	885.38	9.79	1695.9	164.23	0.41
23632	1% 100yr	15600	885.77	887.19	10.58	2043.96	263.15	0.42
23632	0.5% 200yr	17200	887.19	888.51	10.39	2487.45	1418.12	0.4
23632	0.2% 500yr	19400	887.69	889.19	11.2	2682.74	1906.28	0.43
23632	0.133% 750yr	21300	888.34	890	11.82	3033.55	2850.43	0.44
23632	0.1% 1000yr	22200	888.67	890.26	11.75	3244.27	2889.13	0.44
23632	0.04% 2500yr	25200	889.72	891.12	11.49	3907.16	2956.5	0.42
23801	10% 10yr	9400	881.35	882.37	8.7	1301.02	133.79	0.4
23801	2% 50yr	13100	884.4	885.54	9.42	1741.5	155.02	0.39
23801	1% 100yr	15600	886.15	887.36	9.83	2022.52	165.83	0.39
23801	0.5% 200yr	17200	887.46	888.65	9.88	2244.19	1450.17	0.38
23801	0.2% 500yr	19400	887.91	889.35	10.85	2324.58	1902.19	0.41
23801	0.133% 750yr	21300	888.62	890.17	11.31	2453.46	2719.9	0.42
23801	0.1% 1000yr	22200	888.8	890.43	11.64	2485.73	2818.21	0.43
23801	0.04% 2500yr	25200	889.54	891.41	12.55	2621.07	2942.38	0.46
23832				Branner Bridge				
23863	10% 10yr	9400	881.64	882.73	8.96	1308.07	135.2	0.41
23863	2% 50yr	13100	884.65	885.91	9.86	1746.15	158.52	0.41
23863	1% 100yr	15600	886.25	887.65	10.51	2015.14	178.15	0.42
23863	0.5% 200yr	17200	887.55	888.95	10.61	2256.79	1546.71	0.41
23863	0.2% 500yr	19400	888.03	889.69	11.59	2352.13	2548.44	0.44
23863	0.133% 750yr	21300	888.75	890.52	12.06	2497.59	2735.17	0.45
23863	0.1% 1000yr	22200	888.94	890.81	12.4	2535.86	2764.89	0.46
23863	0.04% 2500yr	25200	889.72	891.85	13.35	2693.86	2841.02	0.49
23998	10% 10yr	9400	881.76	882.85	8.94	1325.3	136.03	0.4
23998	2% 50yr	13100	884.76	886.03	9.9	1762.92	159.81	0.41
23998	1% 100yr	15600	886.35	887.78	10.57	2033.05	179.38	0.42

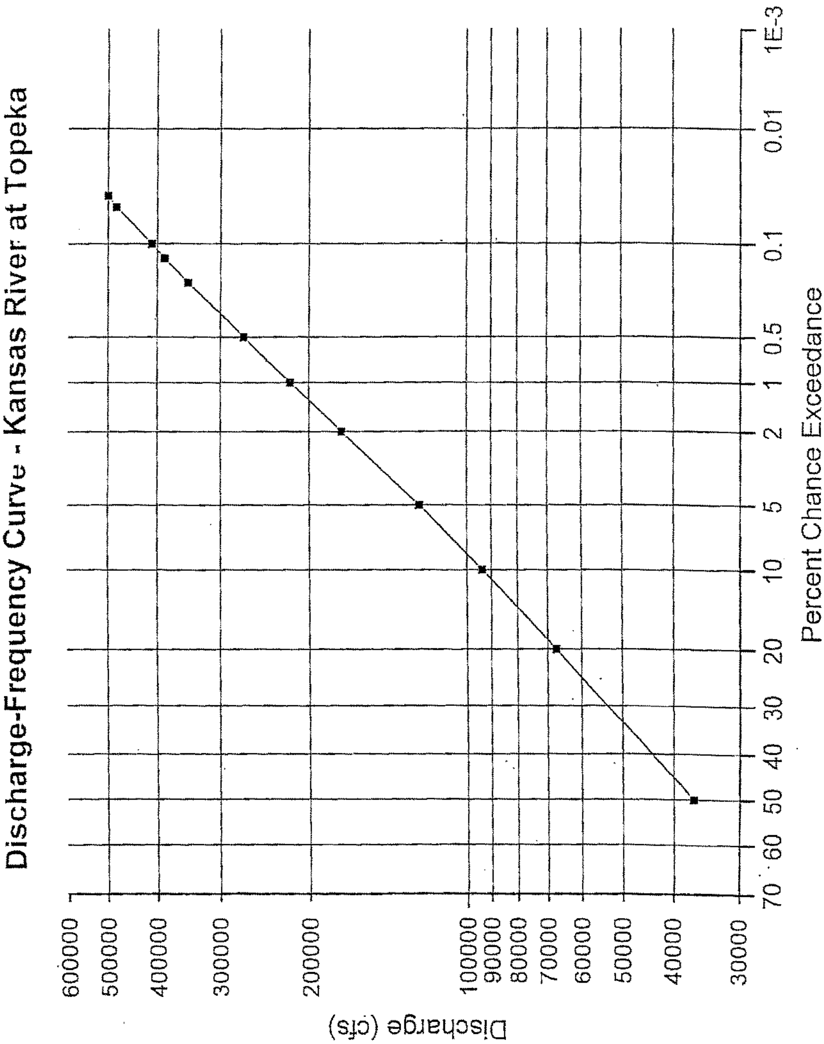
HEC-RAS River Station	Profile	Q Total (cfs)	Water Surface Elevation (ft)	Energy Grade Elevation (ft)	Average Channel Velocity (ft/s)	Flow Area (sq ft)	Top Width Width (ft)	Channel Froude #
23998	0.5% 200yr	17200	887.63	889.07	10.7	2273.5	1608.33	0.41
23998	0.2% 500yr	19400	888.13	889.83	11.69	2371.83	2569.6	0.44
23998	0.133% 750yr	21300	888.83	890.68	12.28	2515.67	2752.55	0.46
23998	0.1% 1000yr	22200	889.01	890.97	12.65	2555.06	2771.07	0.47
23998	0.04% 2500yr	25200	889.74	892.05	13.79	2716.43	2843.45	0.51
24276	10% 10yr	9400	881.89	883.3	10.26	1137.82	126.68	0.48
24276	2% 50yr	13100	884.88	886.42	11.02	1545.36	146.44	0.47
24276	1% 100yr	15600	886.5	888.15	11.55	1792.51	382.28	0.47
24276	0.5% 200yr	17200	887.78	889.41	11.59	1999.49	1714.04	0.45
24276	0.2% 500yr	19400	888.31	890.22	12.59	2088.02	2495.63	0.49
24276	0.133% 750yr	21300	889.03	891.08	13.14	2210.5	2645.98	0.5
24276	0.1% 1000yr	22200	889.23	891.39	13.5	2245.02	2656.48	0.51
24276	0.04% 2500yr	25200	890.03	892.5	14.52	2385.7	2768.65	0.54
24317				6th Street Bridge				
24358	10% 10yr	9400	882.37	883.65	9.84	1183.64	129.84	0.45
24358	2% 50yr	13100	885.3	886.71	10.62	1591.65	148.98	0.45
24358	1% 100yr	15600	886.98	888.48	11.07	1852.5	1025.45	0.45
24358	0.5% 200yr	17200	888.27	889.75	11.1	2063.46	2489.82	0.43
24358	0.2% 500yr	19400	888.94	890.63	11.91	2177.62	2565.27	0.46
24358	0.133% 750yr	21300	889.75	891.54	12.36	2316.85	2682.2	0.46
24358	0.1% 1000yr	22200	890.02	891.89	12.64	2363.56	2766.07	0.47
24358	0.04% 2500yr	25200	891.03	893 1	13.4	2543.15	2907.28	0.49
24516	10% 10yr	9400	882.57	883 86	9.88	1199.31	129.55	0.45
24516	2% 50yr	13100	885.45	886.91	10.77	1596.2	146.33	0.45
24516	1% 100yr	15600	887.11	888.68	11.3	1847.55	156.07	0.45
24516	0.5% 200yr	17200	888.37	889.94	11.39	2048.94	163.03	0.44
24516	0.2% 500yr	19400	889.04	890.84	12.26	2159	166.15	0.47
24516	0.133% 750yr	21300	889.83	891.76	12.77	2292	170.69	0.48
24516	0.1% 1000yr	22200	890.1	892.12	13.09	2338.65	172.65	0.49
24516	0.04% 2500yr	25200	891.09	893.36	13.98	2512.21	179.15	0.51
25468	10% 10yr	9400	883.74	885.27	10.92	1105.32	128.21	0.5
25468	2% 50yr	13100	886.55	888.21	11.73	1490.45	146.54	0.49
25468	1% 100yr	15600	888.19	889.93	12.18	1739.74	157.07	0.49
25468	0.5% 200yr	17200	889.38	891.1	12.22	1930.47	163.79	0.48
25468	0.2% 500yr	19400	890.18	892.09	12.98	2062 98	168.31	0.5

HEC-RAS River Station	Profile	Q Total (cfs)	Water Surface Elevation (ft)	Energy Grade Elevation (ft)	Average Channel Velocity (ft/s)	Flow Area (sq ft)	Top Width Width (ft)	Channel Froude #
25468	0.133% 750yr	21300	891.02	893.03	13.4	2206.99	173.08	0.5
25468	0.1% 1000yr	22200	891.33	893.41	13.66	2260.7	174.82	0.51
25468	0.04% 2500yr	25200	892.45	894.71	14.35	2460.09	180.66	0.52
26024	10% 10yr	9400	885.03	886.11	9.42	1290	148.6	0.47
26024	2% 50yr	13100	887.78	888.97	10.13	1720.21	166	0.45
26024	1% 100yr	15600	889.39	890.66	10.55	1996.37	176.91	0.45
26024	0.5% 200yr	17200	890.49	891.78	10.68	2196.14	184.4	0.44
26024	0.2% 500yr	19400	891.4	892.81	11.27	2365.88	190.53	0.45
26024	0.133% 750yr	21300	892.21	893.76	11.89	2525.17	208.37	0.47
26024	0.1% 1000yr	22200	892.52	894.16	12.24	2591.97	219.86	0.48
26024	0.04% 2500yr	25200	893.78	895.49	12.64	2876.23	228.42	0.48
26165	10% 10yr	9400	885.4	886.29	8.71	1413.92	160.39	0.43
26165	2% 50yr	13100	888.15	889.14	9.36	1874.92	176.6	0.42
26165	1% 100yr	15600	889.76	890.82	9.77	2168.4	187.66	0.41
26165	0.5% 200yr	17200	890.85	891.93	9.91	2377.74	195.2	0.41
26165	0.2% 500yr	19400	891.79	892.97	10.45	2563.5	201.74	0.42
26165	0.133% 750yr	21300	892.69	893.94	10.77	2748.77	207.65	0.42
26165	0.1% 1000yr	22200	893.07	894.34	10.94	2826.74	210.04	0.42
26165	0.04% 2500yr	25200	894.23	895.67	11.71	3077.67	228.59	0.44
26339	10% 10yr	9400	885.65	886.49	8.48	1453.47	161.63	0.41
26339	2% 50yr	13100	888.36	889.32	9.19	1913.26	178.08	0.41
26339	1% 100yr	15600	889.97	890.99	9.61	2207.4	189.08	0.4
26339	0.5% 200yr	17200	891.05	892.09	9.77	2416.01	196.57	0.4
26339	0.2% 500yr	19400	892	893.14	10.3	2605.15	203.18	0.41
26339	0.133% 750yr	21300	892.9	894.11	10.62	2791.9	208.98	0.41
26339	0.1% 1000yr	22200	893.28	894.52	10.79	2870.9	211.38	0.42
26339	0.04% 2500yr	25200	894.52	895.85	11.24	3138.28	239.23	0.42
26382				10th Street Bridge				
26425	10% 10yr	9400	886.02	886.68	7.19	1682.71	178.36	0.33
26425	2% 50yr	13100	888.75	889.51	7.89	2189.11	192.32	0.34
26425	1% 100yr	15600	890.37	891.19	8.3	2506.53	213.5	0.34
26425	0.5% 200yr	17200	891.46	892.29	8.44	2726.67	239.93	0.33
26425	0.2% 500yr	19400	892.44	893.36	8.87	2930.2	251.39	0.34
26425	0.133% 750yr	21300	893.37	894.34	9.15	3123.14	254.98	0.35

HEC-RAS River Station	Profile	Q Total (cfs)	Water Surface Elevation (ft)	Energy Grade Elevation (ft)	Average Channel Velocity (ft/s)	Flow Area (sq ft)	Top Width Width (ft)	Channel Froude #
26425	0.1% 1000yr	22200	893.76	894.76	9.3	3204.55	256.49	0.35
26425	0.04% 2500yr	25200	895.04	896.12	9.74	3474.3	261.44	0.35
		0						
26593	10% 10yr	9400	886.17	886.78	6.95	1708.78	179.11	0.32
26593	2% 50yr	13100	888.9	889.61	7.61	2217.83	193.08	0.32
26593	1% 100yr	15600	890.48	891.28	8.22	2533.24	217.03	0.33
26593	0.5% 200yr	17200	891.54	892.38	8.51	2777.97	241.41	0.34
26593	0.2% 500yr	19400	892.54	893.45	8.9	3027.01	251.76	0.34
26593	0.133% 750yr	21300	893.49	894 43	9.07	3268.73	255.45	0.34
26593	0.1% 1000yr	22200	893.91	894.85	9 16	3374.7	257.05	0.34
26593	0.04% 2500yr	25200	895.23	896.22	9.46	3718 61	262.18	0.34
		0						
26772	10% 10yr	9400	886.27	886.88	6.95	1682.84	178.7	0.32
26772	2% 50yr	13100	889	889.71	7.66	2200.18	203.2	0.33
26772	1% 100yr	15600	890.61	891.38	8.08	2541.61	221.68	0.33
26772	0.5% 200yr	17200	891.7	892.49	8.23	2792.38	235.2	0.32
26772	0.2% 500yr	19400	892.72	893.56	8.59	3034.61	241.88	0.33
26772	0.133% 750yr	21300	893.66	894.53	8.78	3264.66	245.9	0.33
26772	0.1% 1000yr	22200	894.06	894.95	8.89	3364.3	247.62	0.33
26772	0.04% 2500yr	25200	895.38	896.33	9.2	3695.21	253.26	0.33
		0						
27054	10% 10yr	9400	886.39	887.06	7.25	1615.54	177.75	0.34
27054	2% 50yr	13100	889.11	889.88	7.88	2129.91	197.07	0.34
27054	1% 100yr	15600	890.73	891.54	8.19	2454.14	203.41	0.33
27054	0.5% 200yr	17200	891.83	892.65	8.3	2679.62	207.7	0.33
27054	0.2% 500yr	19400	892.83	893.73	8.73	2890.48	213.45	0.34
27054	0.133% 750yr	21300	893.76	894.7	9.01	3090.9	219.11	0.34
27054	0.1% 1000yr	22200	894.16	895.13	9.15	3178.52	221.54	0.34
27054	0.04% 2500yr	25200	896.11	896.48	6.69	6734.73	2104.36	0.24

CHAPTER A-2

PLATES



Discharge-Frequency Curve - Kansas River at Topeka
Discharge (cfs)
600000
500000
400000
300000
200000
100000
90000
80000
70000
60000
50000
40000
30000
Percent Chance Exceedance
70
60
50
40
30
20
10
5
2
1
0.5
0.1
0.01
1E-3

Plate A2-1-1

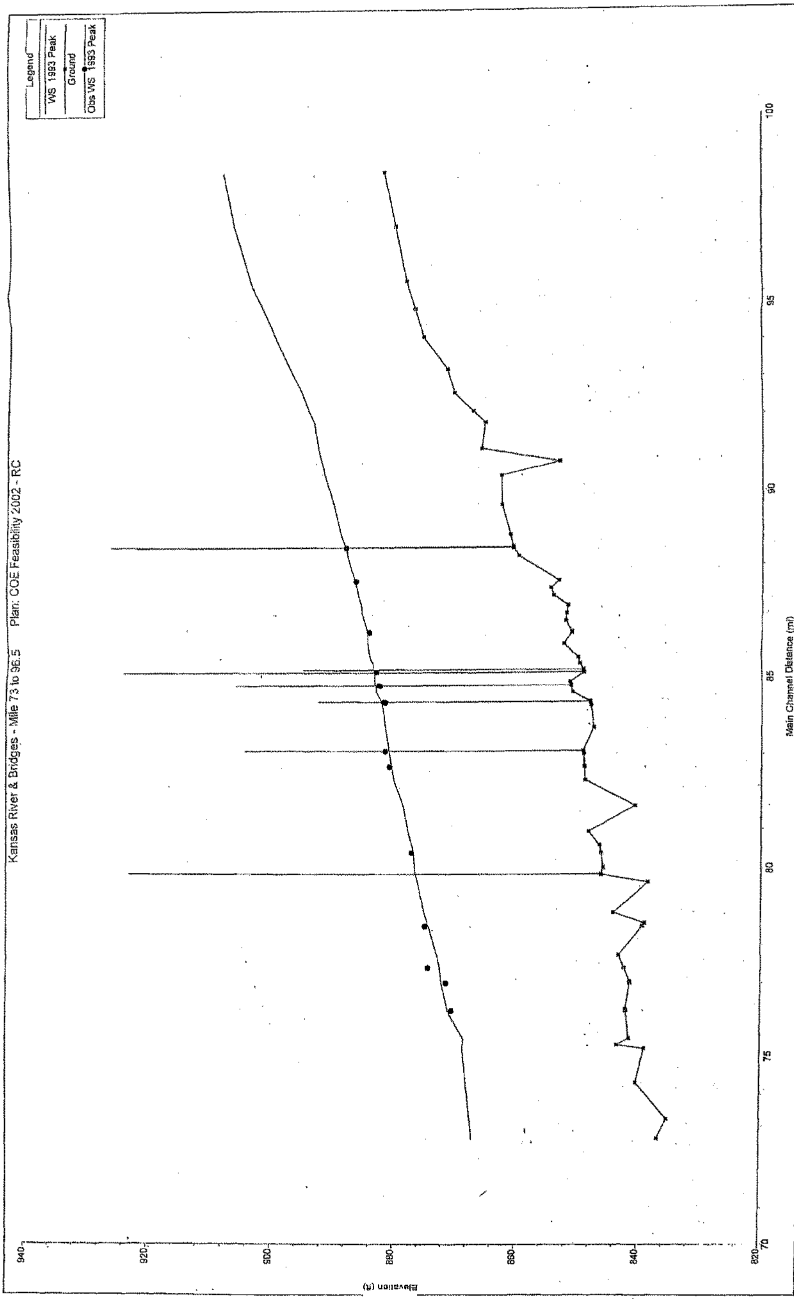

Kansas River & Bridges - Mile 73 to 96.5   Plan: COE Feasibility 2002 - RC
Legend
WS 1993 Peak
Ground
Obs WS 1993 Peak
Elevation (ft)
940
920
900
880
860
840
820
Main Channel Distance (mi)
70
75
80
85
90
95
100

Plate A2-1-2

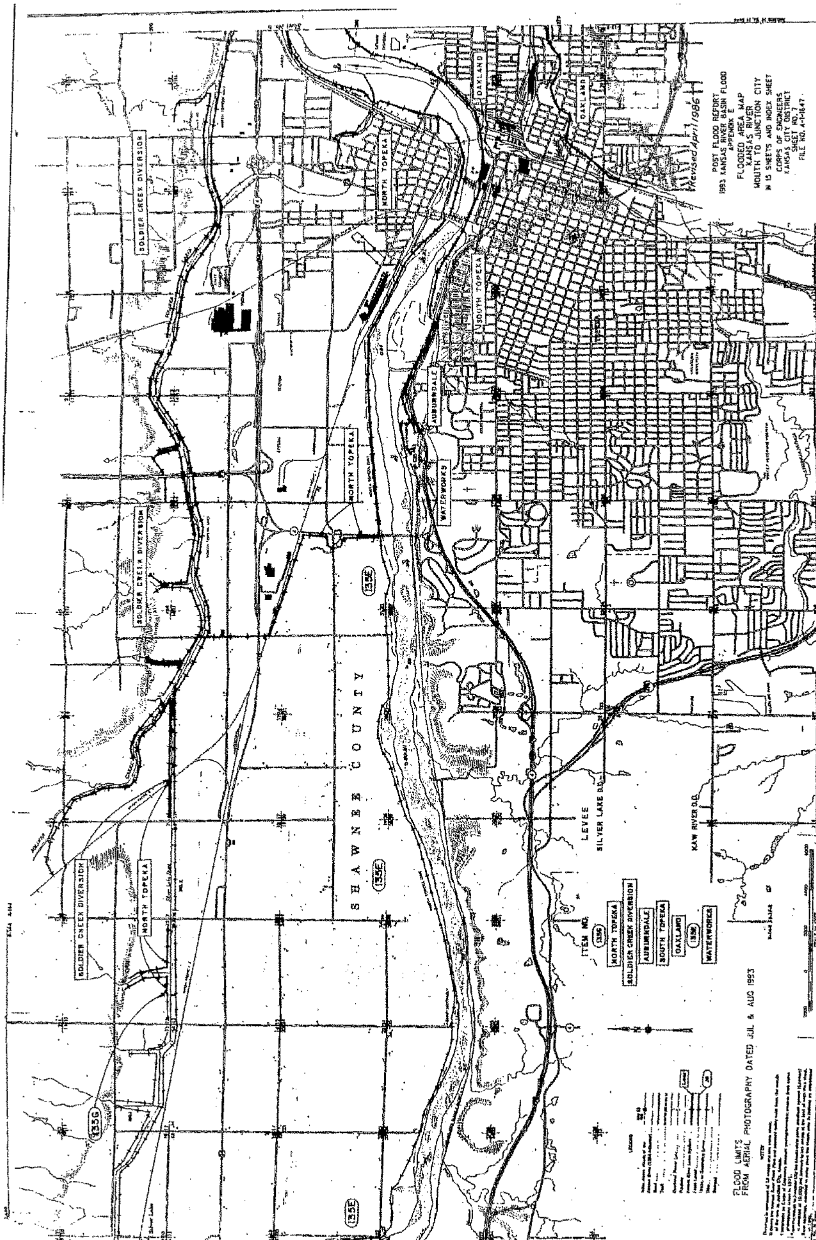
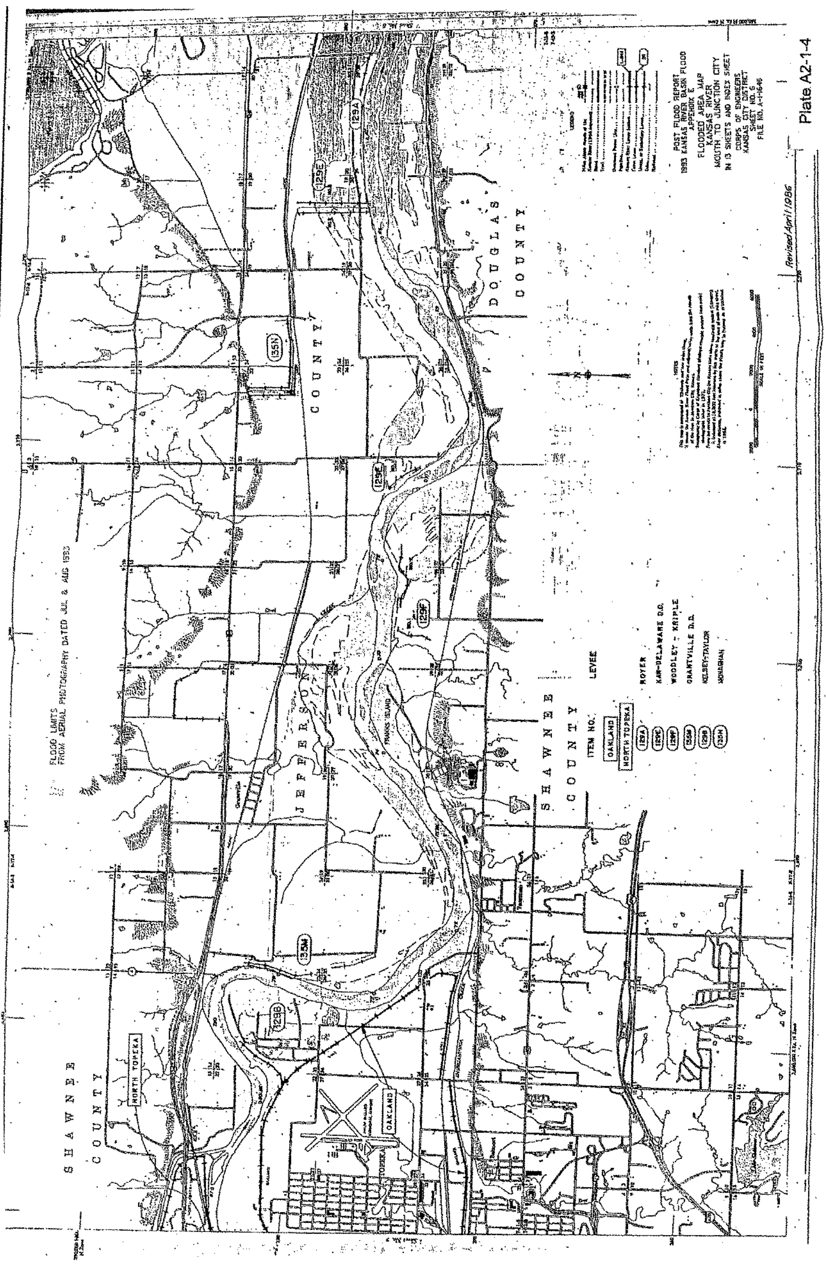

POST FLOOD REPORT
1993 KANSAS RIVER BASIN FLOOD
APPENDIX E
FLOODED AREA MAP
KANSAS RIVER
MOUTH TO JUNCTION CITY
IN 15 SHEETS AND INDEX SHEET
CORPS OF ENGINEERS
KANSAS CITY DISTRICT
SHEET NO. 7
Revised April 1986
FLOOD LIMITS
FROM AERIAL PHOTOGRAPHY DATED JUL & AUG 1993
ITEM NO.
135E
NORTH TOPEKA
SOLDIER CREEK DIVERSION
AUBURNDALE
SOUTH TOPEKA
OAKLAND
135C
WATERWORKS
SHAWNEE COUNTY
135G
LEVEE
SILVER LAKE D.D.
KAW RIVER D.D.

Plate A2-1-3


FLOOD LIMITS
FROM AERIAL PHOTOGRAPHY DATED JUL & AUG 1993
SHAWNEE COUNTY
JEFFERSON COUNTY
DOUGLAS COUNTY
SHAWNEE COUNTY
NORTH TOPEKA
OAKLAND
TOPEKA
FRANKS ISLAND
129A
129B
129E
129F
135M
135N
ITEM NO.
LEVEE
OAKLAND
NORTH TOPEKA
129A ROYER
129E KAW-DELAWARE D.D.
129F WOODLEY - KRIPLE
135M GRANTVILLE D.D.
129B KELSEY-TAYLOR
135N MCMAHAN
POST FLOOD REPORT
1993 KANSAS RIVER BASIN FLOOD
APPENDIX E
FLOODED AREA MAP
KANSAS RIVER
MOUTH TO JUNCTION CITY
IN 13 SHEETS AND INDEX SHEET
CORPS OF ENGINEERS
KANSAS CITY DISTRICT
SHEET NO. 6
Revised April 1986
Plate A2-1-4

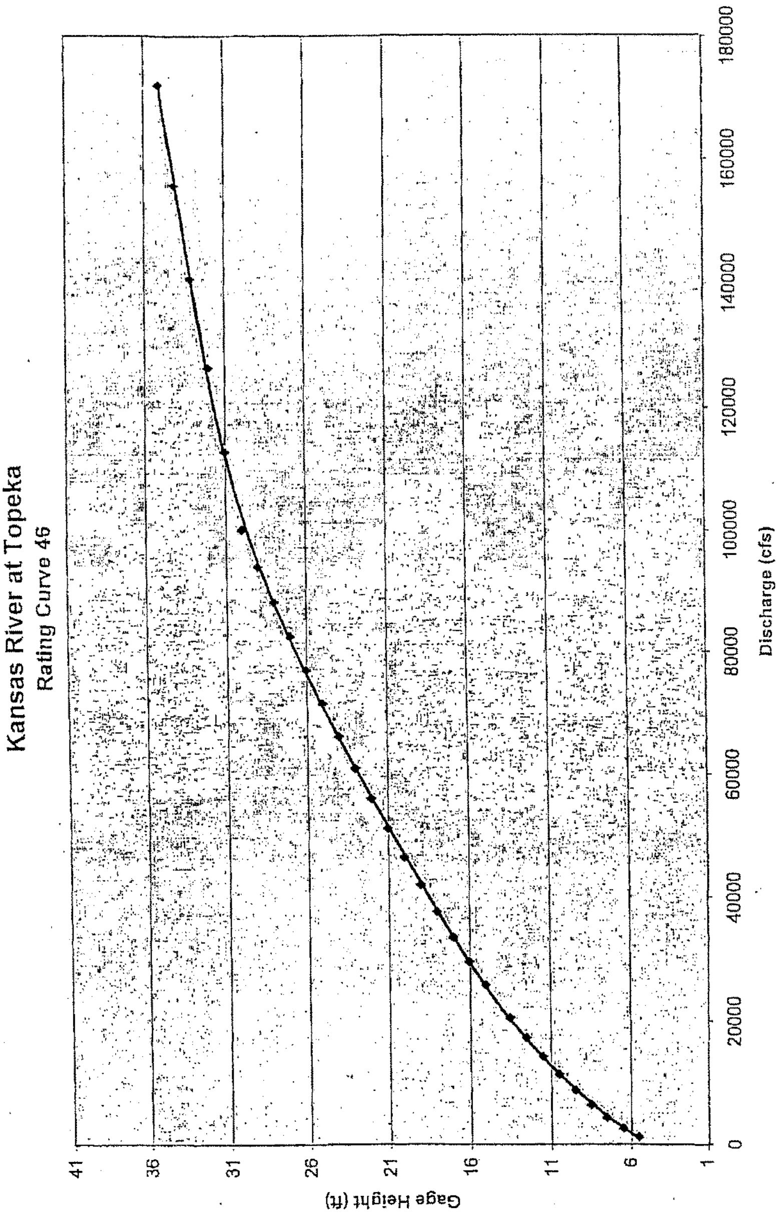

Kansas River at Topeka
Rating Curve 46
Gage Height (ft)
41
36
31
26
21
16
11
6
1
Discharge (cfs)
0
20000
40000
60000
80000
100000
120000
140000
160000
180000

Plate A2-1-5

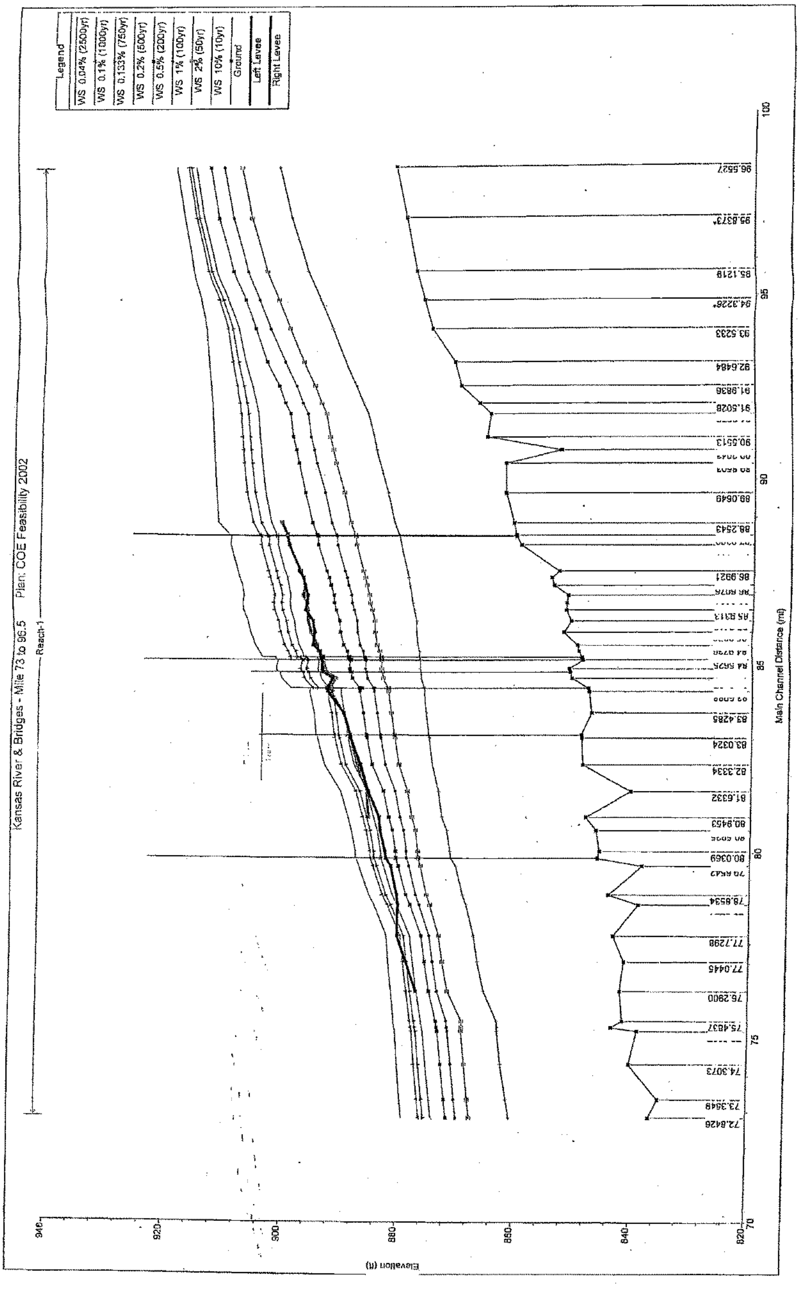

Kansas River & Bridges - Mile 73 to 96.5 Plan: COE Feasibility 2002
Reach-1
Legend
WS 0.04% (2500yr)
WS 0.1% (1000yr)
WS 0.133% (750yr)
WS 0.2% (500yr)
WS 0.5% (200yr)
WS 1% (100yr)
WS 2% (50yr)
WS 10% (10yr)
Ground
Left Levee
Right Levee
Elevation (ft)
Main Channel Distance (mi)
96.5527
95.8373*
95.1219
94.3226*
93.5233
92.6484
91.9836
91.5028
90.5513
89.0649
88.2543
86.9921
85.8113
84.5625
83.4285
83.0324
82.3334
81.6332
80.9453
80.0369
78.8534
77.7298
77.0445
76.2900
75.4837
74.3073
73.3549
72.8426
940
920
900
880
860
840
820
70
75
80
85
90
95
100

Plate A2-1-6

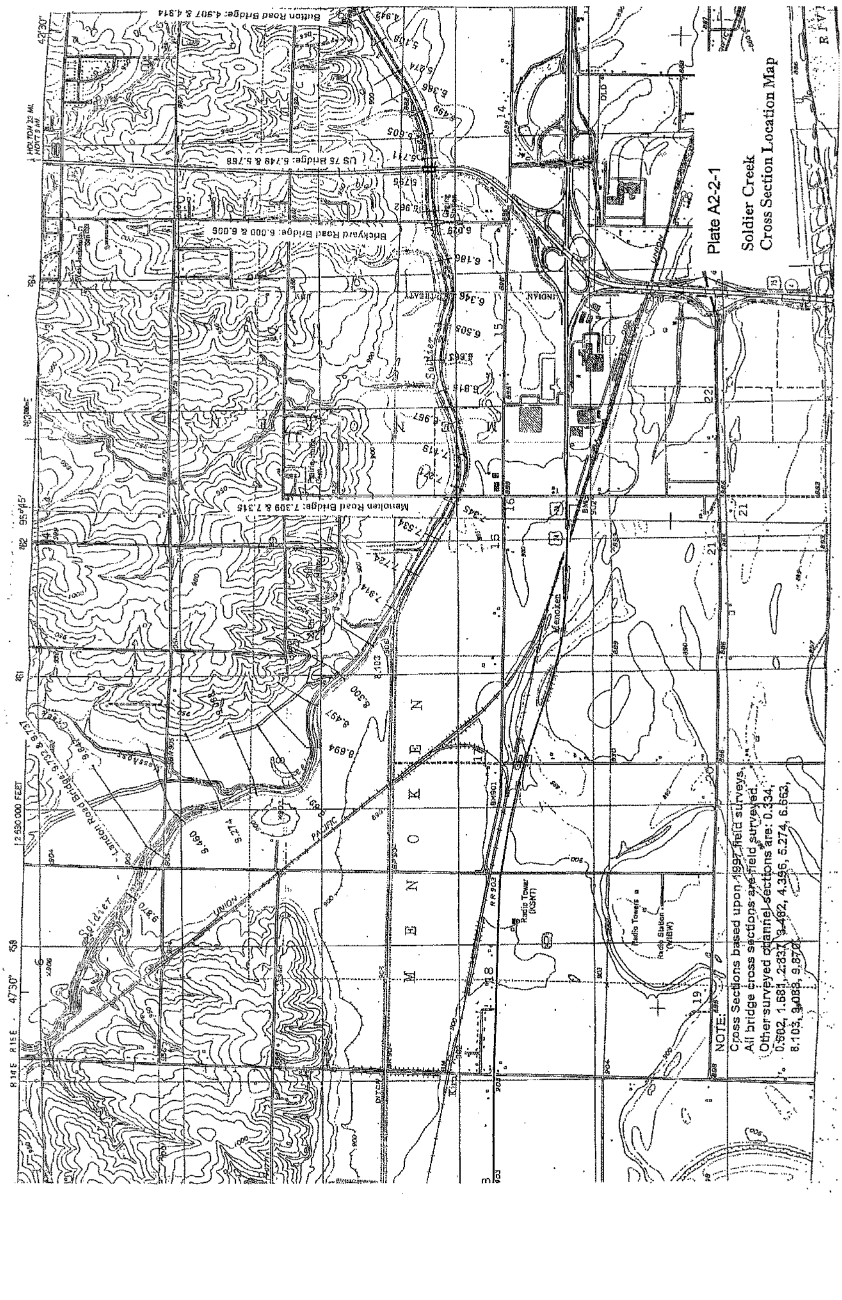


Plate A2-2-1
Soldier Creek
Cross Section Location Map
NOTE:
Cross Sections based upon 1997 field surveys.
All bridge cross sections are field surveyed.
Other surveyed channel sections are: 0.334,
0.602, 1.681, 2.837, 3.482, 4.356, 5.274, 6.663,
8.103, 9.038, 9.870.
Button Road Bridge: 4.907 & 4.914
US 75 Bridge: 5.749 & 5.768
Brickyard Road Bridge: 6.000 & 6.006
Menoken Road Bridge: 7.309 & 7.315
Landon Road Bridge: 9.732 & 9.737
MENOKEN
Menoken
UNION PACIFIC
Soldier
Radio Tower (KSNT)

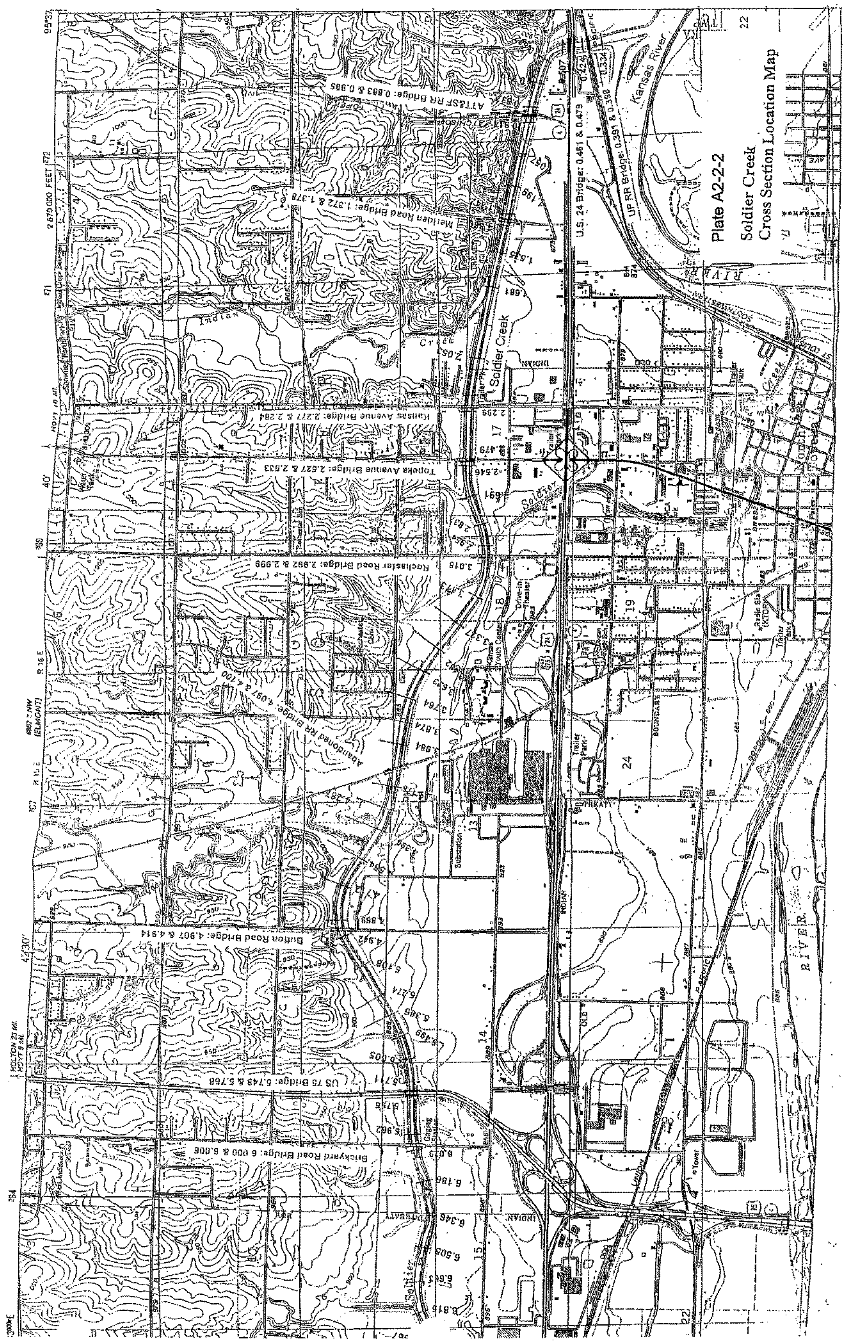
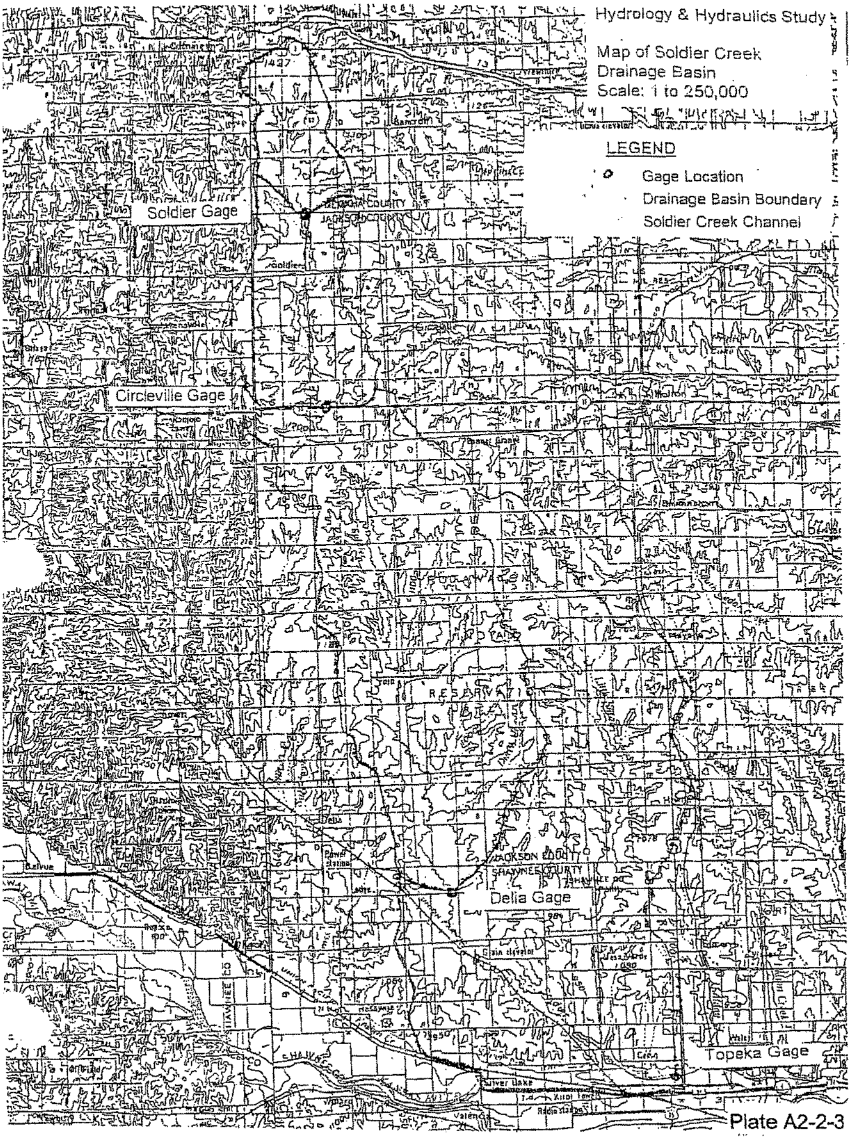


Plate A2-2-2
Soldier Creek
Cross Section Location Map
ATT&SF RR Bridge: 0.883 & 0.885
Meriden Road Bridge: 1.372 & 1.378
Kansas Avenue Bridge: 2.277 & 2.284
Topeka Avenue Bridge: 2.627 & 2.633
Rochester Road Bridge: 2.892 & 2.999
Abandoned RR Bridge: 4.097 & 4.100
Button Road Bridge: 4.907 & 4.914
US 75 Bridge: 5.749 & 5.768
Brickyard Road Bridge: 6.000 & 6.006
U.S. 24 Bridge: 0.461 & 0.479
UP RR Bridge: 0.391 & 0.398
Kansas River
Soldier Creek


Hydrology & Hydraulics Study
Map of Soldier Creek
Drainage Basin
Scale: 1 to 250,000
LEGEND
Gage Location
Drainage Basin Boundary
Soldier Creek Channel
Soldier Gage
Circleville Gage
Delia Gage
Topeka Gage
Plate A2-2-3

Discharge-Frequency Curve for Soldier Creek Gage at Topeka

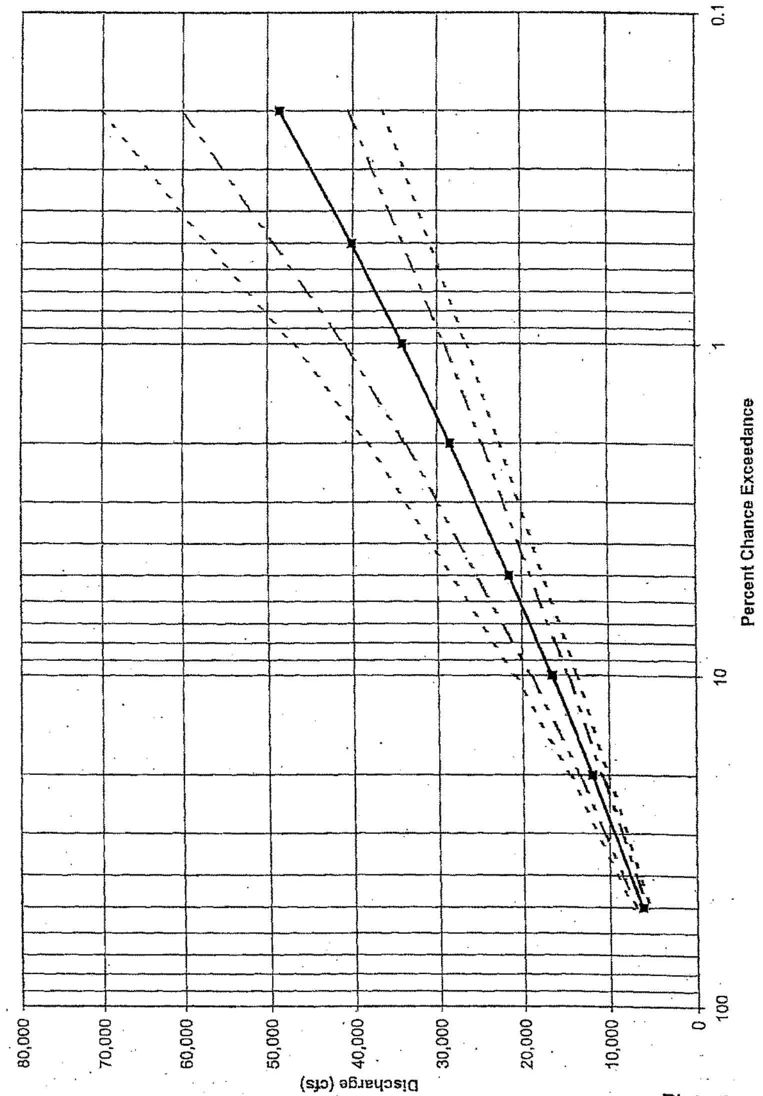
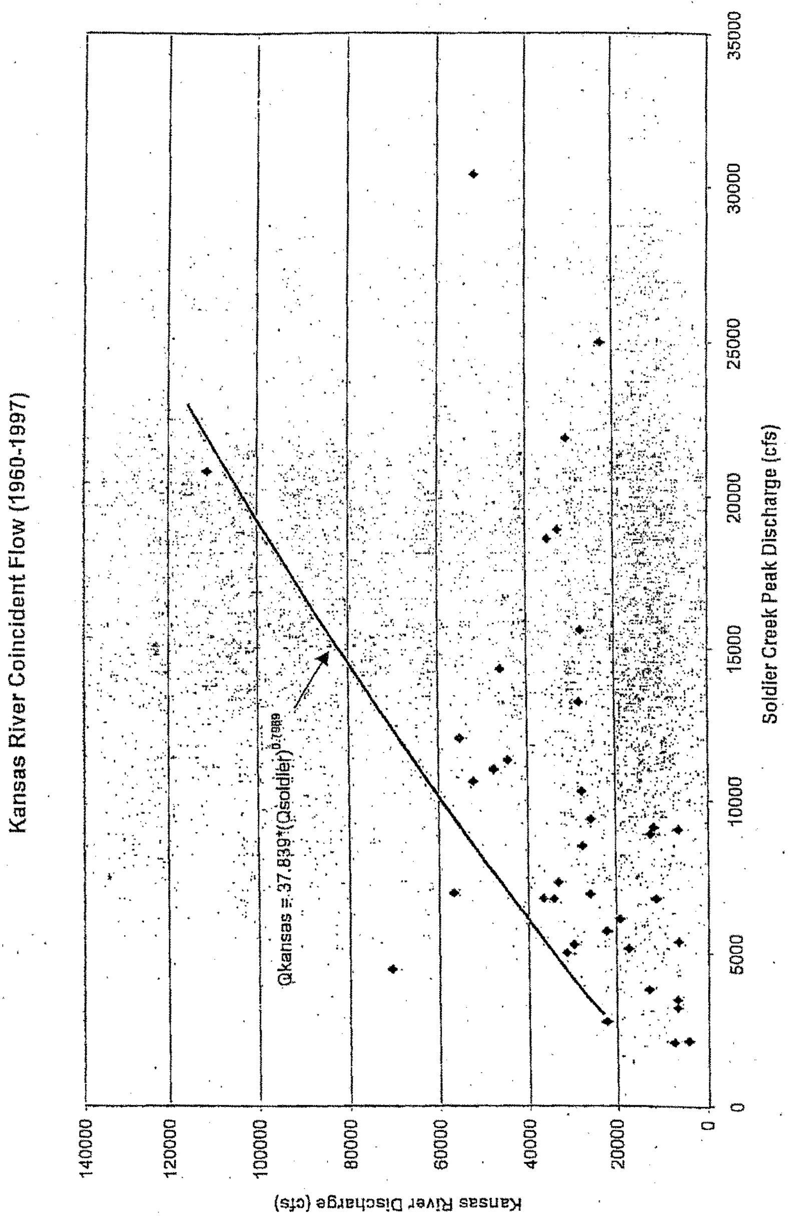


Plate A2-2-4



Kansas River Coincident Flow (1960-1997)
Qkansas = 37.839*(Qsoldier)^0.7989
Kansas River Discharge (cfs)
140000
120000
100000
80000
60000
40000
20000
0
Soldier Creek Peak Discharge (cfs)
0
5000
10000
15000
20000
25000
30000
35000

Plate A2-2-5

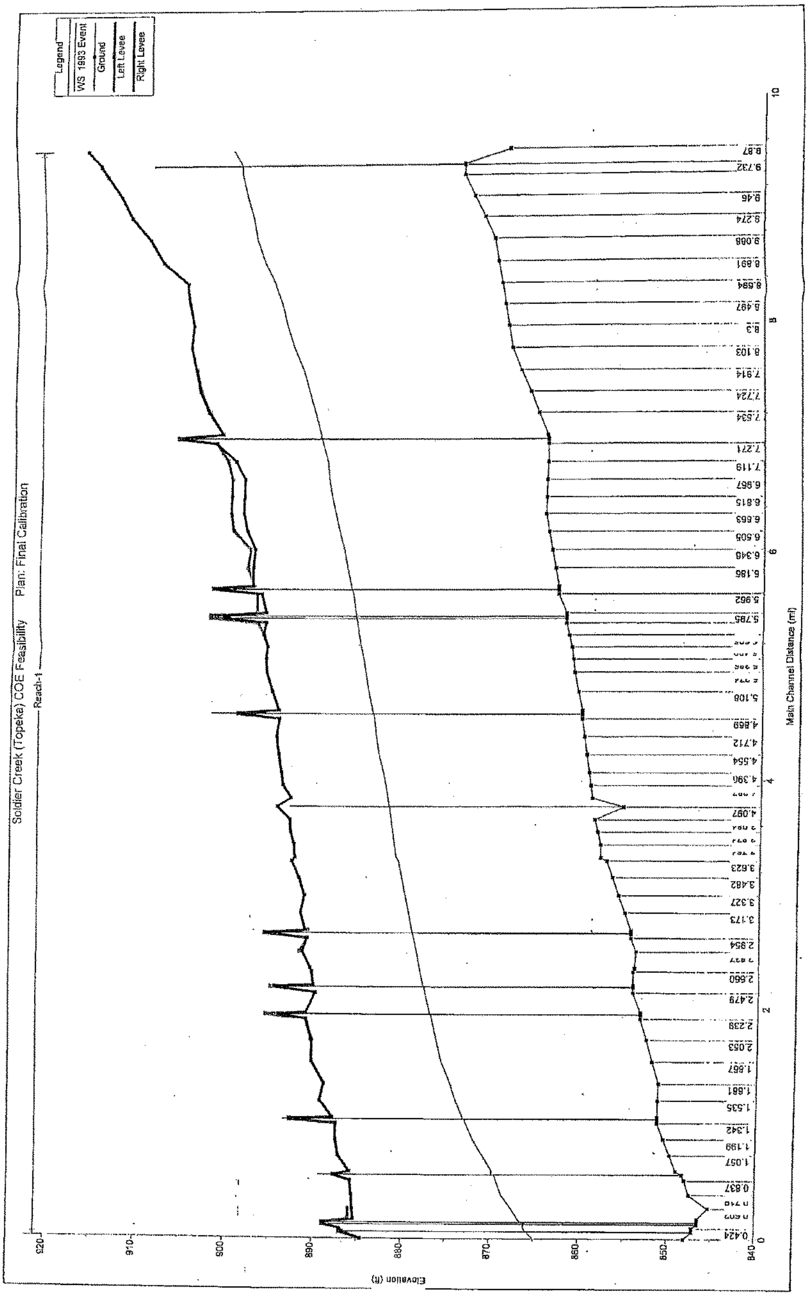
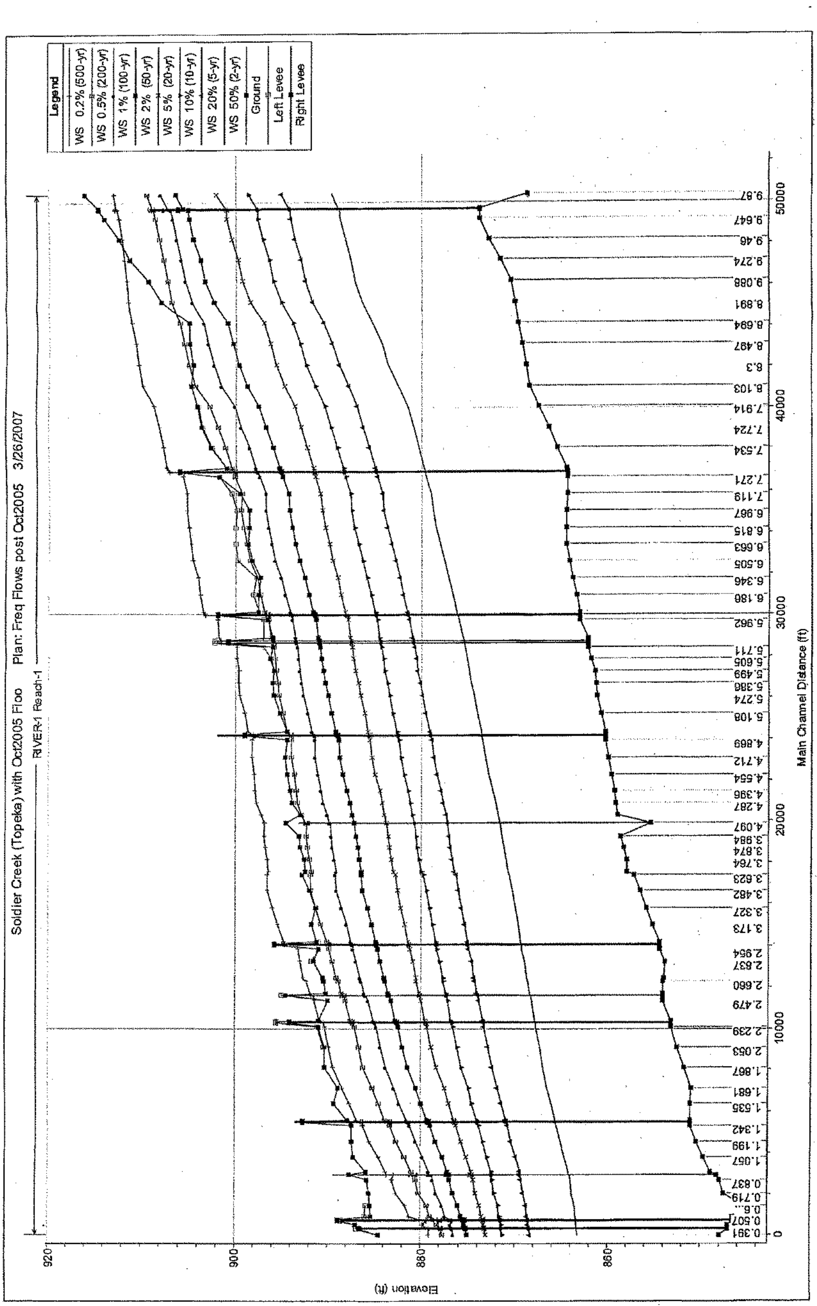

Soldier Creek (Topeka) COE Feasibility Plan: Final Calibration
Reach-1
Legend
WS 1993 Event
Ground
Left Levee
Right Levee
Elevation (ft)
920
910
900
890
880
870
860
850
840
Main Channel Distance (mi)
0
2
4
6
8
10

Plate A2-2-6



Soldier Creek (Topeka) with Oct2005 Floo   Plan: Freq Flows post Oct2005   3/26/2007
RIVER-1 Reach-1
Legend
WS 0.2% (500-yr)
WS 0.5% (200-yr)
WS 1% (100-yr)
WS 2% (50-yr)
WS 5% (20-yr)
WS 10% (10-yr)
WS 20% (5-yr)
WS 50% (2-yr)
Ground
Left Levee
Right Levee
Elevation (ft)
920
900
880
860
Main Channel Distance (ft)
0
10000
20000
30000
40000
50000
0.391
0.507
0.6
0.719
0.837
1.057
1.199
1.342
1.535
1.681
1.867
2.053
2.239
2.479
2.660
2.837
2.954
3.173
3.327
3.482
3.623
3.764
3.874
3.984
4.097
4.287
4.396
4.554
4.712
4.869
5.108
5.274
5.386
5.499
5.606
5.711
5.962
6.186
6.346
6.505
6.663
6.815
6.967
7.119
7.271
7.534
7.724
7.914
8.103
8.3
8.487
8.694
8.891
9.088
9.274
9.46
9.647
9.87

Plate A2-2-7

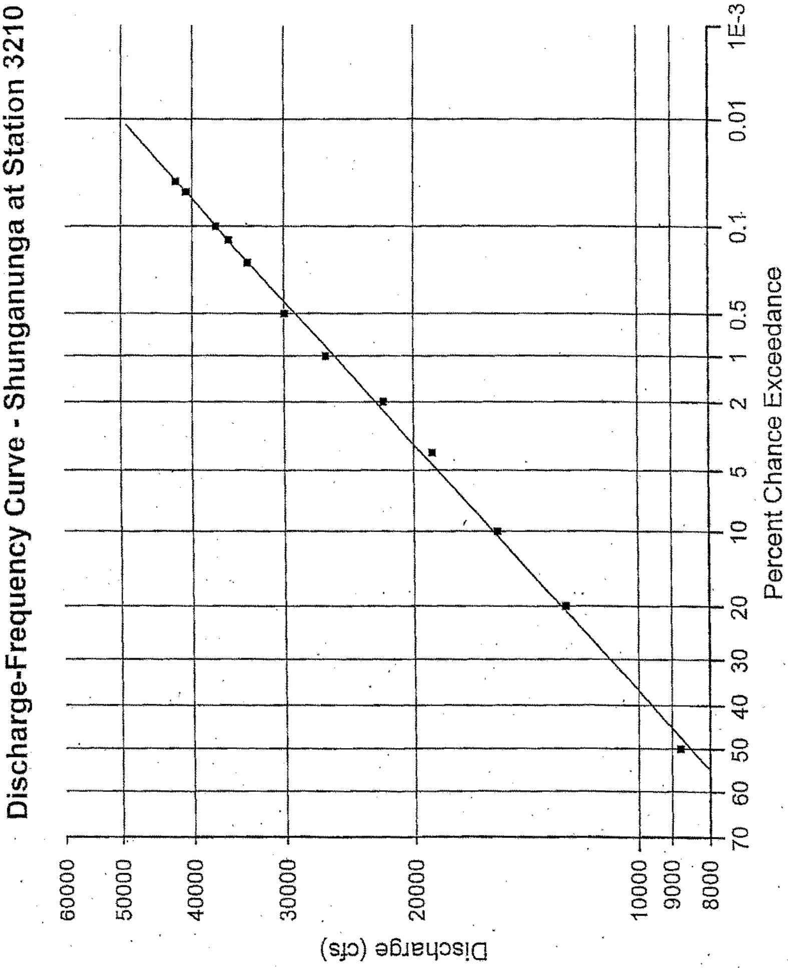

Discharge-Frequency Curve - Shunganunga at Station 3210
Discharge (cfs)
60000
50000
40000
30000
20000
10000
9000
8000
Percent Chance Exceedance
1E-3
0.01
0.1
0.5
1
2
5
10
20
30
40
50
60
70

Plate A2-3-1

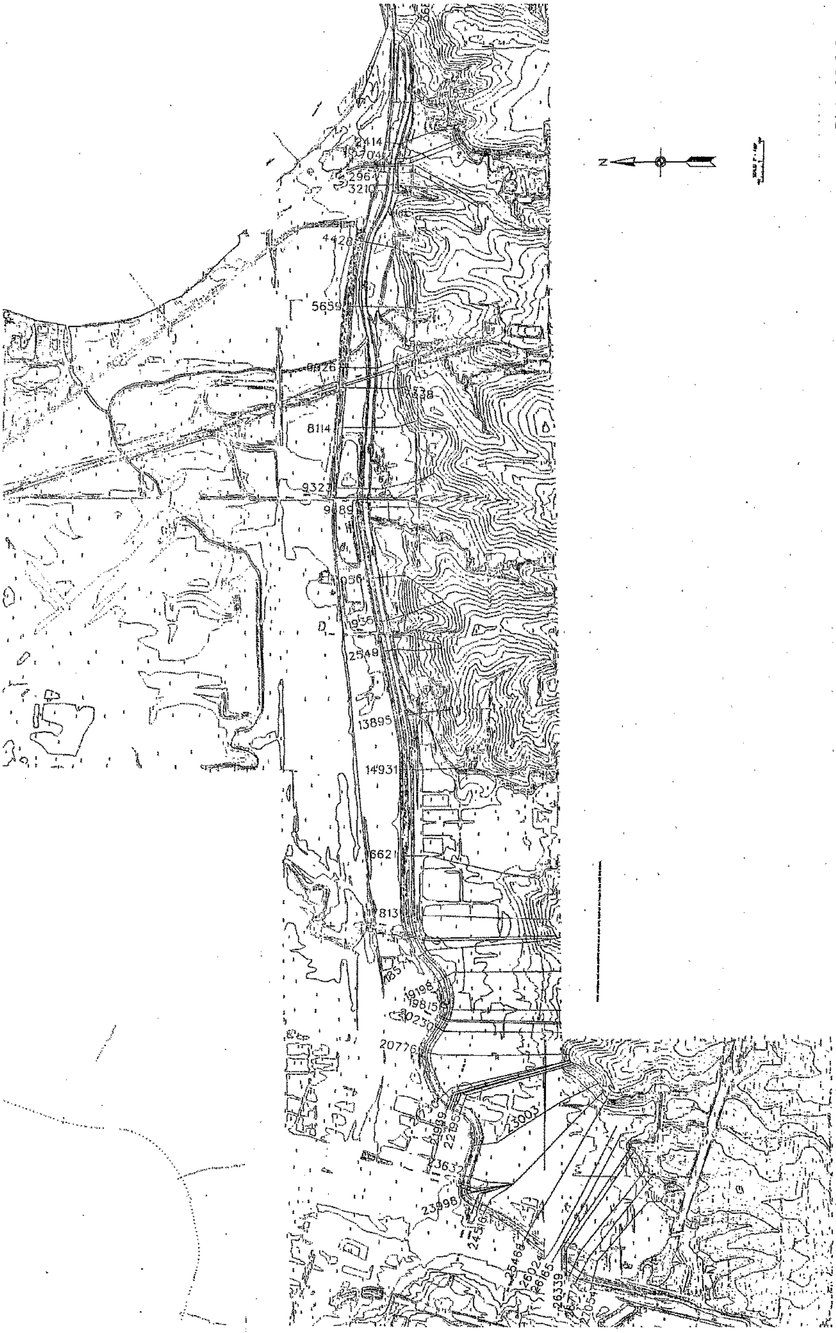


Plate A2-3-2

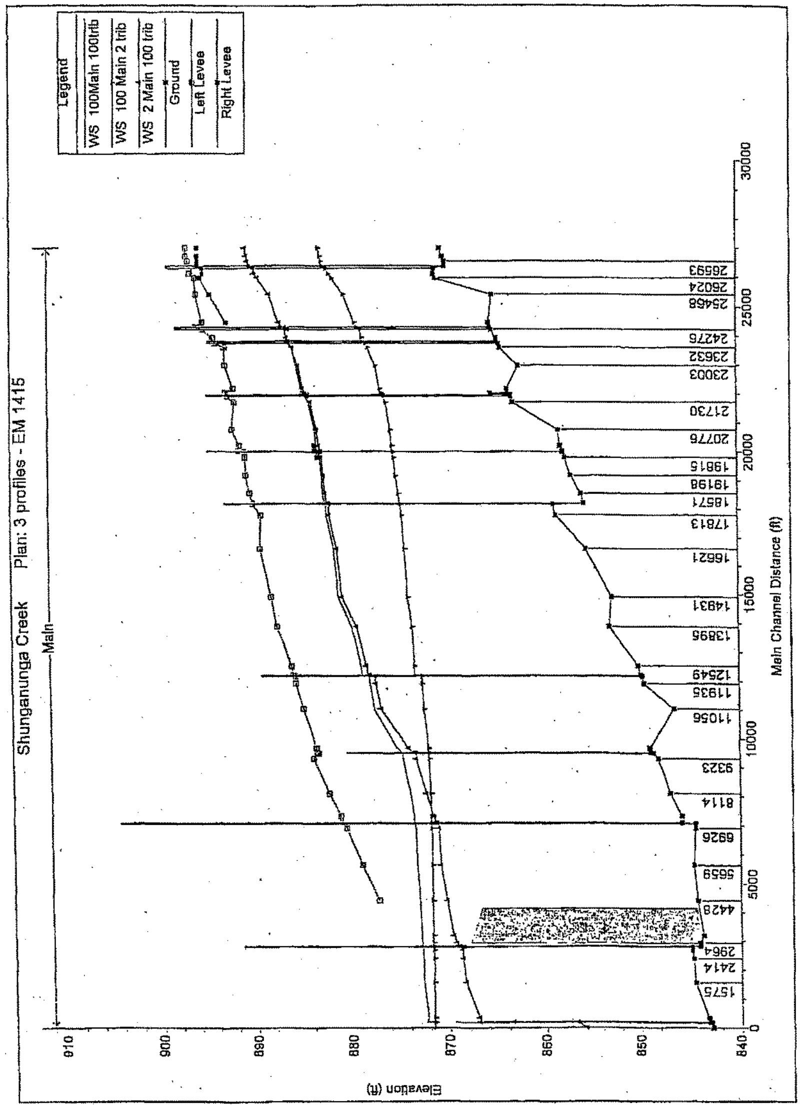

Shunganunga Creek Plan: 3 profiles - EM 1415
Main
Legend
WS 100Main 100trib
WS 100 Main 2 trib
WS 2 Main 100 trib
Ground
Left Levee
Right Levee
Elevation (ft)
910
900
890
880
870
860
850
840
Main Channel Distance (ft)
0
5000
10000
15000
20000
25000
30000
1575
2414
2964
4428
5659
6926
8114
9323
11056
11935
12549
13896
14931
16621
17813
18571
19198
19815
20776
21730
23003
23632
24276
25468
26024
26593

Plate A2-3-3

U.S. Army Corps of Engineers Frequencies for Coincidental Occurrence						
Area Ratio	10 Year Design		50 Year Design		100 Year Design	
	Main Stream	Tributary	Main Stream	Tributary	Main Stream	Tributary
10000 to 1	1	10	1	50	2	100
	10	1	50	1	100	2
1000 to 1	2	10	5	50	10	100
	10	2	50	5	100	10
100 to 1	5	10	10	50	25	100
	10	5	50	10	100	25
10 to 1	10	10	25	50	50	100
	10	10	50	25	100	50
1 to 1	10	10	50	50	100	100
	10	10	50	50	100	100

Plate A2-3-4

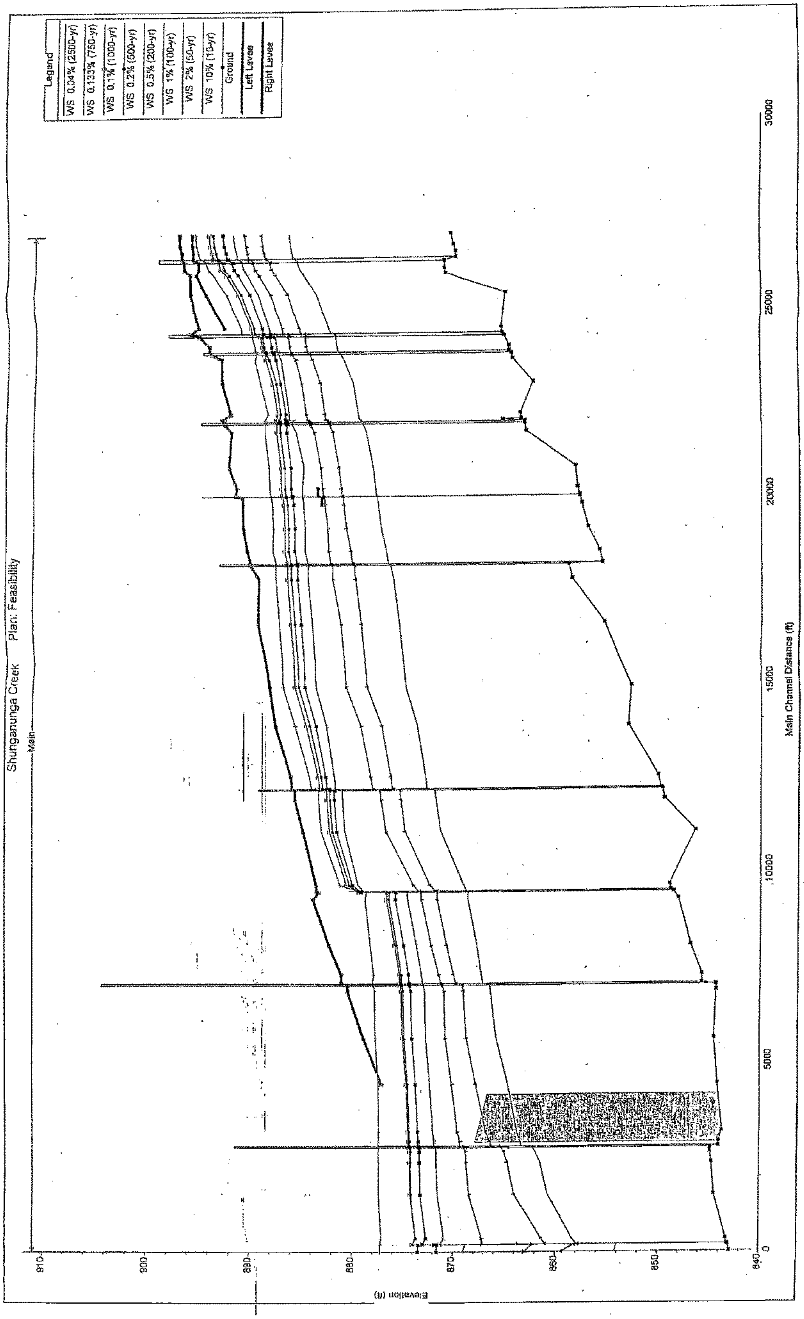

Shunganunga Creek Plan: Feasibility
Main
Legend
WS 0.04% (2500-yr)
WS 0.133% (750-yr)
WS 0.1% (1000-yr)
WS 0.2% (500-yr)
WS 0.5% (200-yr)
WS 1% (100-yr)
WS 2% (50-yr)
WS 10% (10-yr)
Ground
Left Levee
Right Levee
Elevation (ft)
910
900
890
880
870
860
850
840
0
5000
10000
15000
20000
25000
30000
Main Channel Distance (ft)

Plate A2-3-5

Chapter A-3

GEOTECHNICAL DESIGN ANALYSIS

Topeka, Kansas
Flood Risk Management Study
Appendix A – Engineering
Chapter 3 – Geotechnical Analysis

TABLE OF CONTENTS

A-3 GEOTECHNICAL ANALYSIS

A-3.1 Existing Conditions

A-3.1.1 Introduction

This section presents the results of the geotechnical evaluation of the existing conditions performed as part of the feasibility flood study of the Topeka Flood Protection Project at Topeka, Kansas. The flood risk management project within the study area was designed by the Kansas City District U. S. Army Corps of Engineers, and was constructed under its supervision. The unit is operated and maintained by two local sponsors as follows: a) the North Topeka Drainage District operating and maintaining the Soldier Creek and North Topeka units, and b) The City of Topeka maintaining and operating the Waterworks Unit, Auburndale Unit, South Topeka Unit and Oakland Unit.

The primary goal of this phase of the geotechnical evaluation is to gather and review all available data and develop an assessment of the existing conditions of each levee units by identifying the critical reaches for each unit and their probability of failure for different river stages. Additionally, the past performance of the levee system is evaluated. This information is to assist in an assessment of the future performance of the levee during flood events. In particular, the following tasks were performed for this study:

- Review of existing sources of information.
- Description of each existing levee unit including design features and subsurface conditions.
- Reliability analyses of each unit and identification of critical reaches of each unit.

The evaluation of the existing condition was based on the subsurface investigation performed for the design of the project supplemented with the additional investigation performed for this feasibility study, such as cone penetrometer tests and laboratory testing performed on selected samples collected from borings drilled in some areas considered critical.

A-3.1.2 Sources of Information

The primary sources of information include the references listed in Section 12 (References) of this Appendix.

A-3.1.3 Description of the Levee Units

The Topeka Flood Protection Project consists of six (6) flood risk management units along the Kansas River and its tributaries, protecting the city of Topeka, Kansas. The project includes approximately 40 miles of levees along the Kansas River and approximately 3 miles of tie back levees, 0.7 miles of floodwall, 9.2 miles of improved channel on Soldier Creek, 5.5 miles of improved channel on Shunganunga Creek, and 2.6 miles of improved and enlarged channel along the Kansas River. The project also includes pumping plants, gated outlets for drainage structures, sandbag gaps and ponding areas. Flood risk management units forming portions of the Topeka Flood Protection Project are described in the following paragraphs

Soldier Creek Unit

The Soldier Creek Unit is located along Soldier Creek, beginning at Kansas River mile 81.9 and extending northwesterly to the vicinity of the Silver Lake channels and levees. The purpose of this unit is to provide flood risk management for north Topeka against a peak discharge of approximately 50,000 cfs. The Soldier Creek unit includes 17.9 miles of levee, 9.2 miles of channel improvement, approximately 4.3 miles of tributary tie back levees along the left bank of Soldier Creek, and 35 drainage structures. The project was designed in 1958 and constructed between the years 1958 and 1962.

North Topeka Unit

The North Topeka Unit is located along the left bank of the Kansas River beginning on Soldier Creek and extending upstream along the left bank of the Kansas Rive r to approximate river mile 82. The flood risk management unit includes 9.3 miles of earthen levee, 3 relief wells, 3 pumping plants, 15 drainage structures, one sandbag gap, and one stoplog gap. The North Topeka Unit was designed in 1961 and constructed between 1964 and 1967 for the purpose of protecting the North Topeka area.

Waterworks Unit

The Waterworks Unit is located along the right bank of the Kansas River to provide flood risk management for the western side of Topeka. The levee unit includes 1,998 feet of earthen levee and 1,662 feet of floodwall with 9 relief wells for underseepage control, 4 drainage structures for the interior drainage control, and 1 sandbag and 4 stoplog gaps. The project was designed in 1957 and constructed during 1959.

Auburndale Unit

The Auburndale Unit is located east of the Waterworks unit along the right bank of the Kansas River. The unit uses the Interstate I-70 embankment in lieu of a right bank levee between the Waterworks Unit at the upper end and the South Topeka Unit at the lower end. This unit also includes the Waite Street Levee and an 850-foot tie back levee, which serves as the upstream boundary for a ponding area. The entire length of the earthen levee section is 1.3 miles and includes 15 relief wells for underseepage control, 2 pumping plants and 4 drainage structures for interior drainage control and discharge of the relief well system, and one sandbag gap. The unit was designed in 1958 and constructed between the years 1961 and 1962.

South Topeka Unit

The South Topeka Unit is located along the right bank of the Kansas River between the Auburndale Unit at the west upper end (river mile 85.5) and Santa Fe Railroad bridge at mile

83.8 at the lower end. The unit consists of 1.4 miles of earthen levee, 1,944 feet of floodwall and includes 2 stoplog gaps. Underseepage is controlled by 27 relief wells with the water collected from the relief well system and interior drainage discharged into the Kansas River by 5 pumping plants and 15 drainage structures. The unit was designed in 1966 and constructed between the years of 1970 and 1973.

Oakland Unit

The Oakland Unit is located along the Kansas River downstream of South Topeka Unit and continuing along left bank of Shunganunga Creek. The unit consists of 10 miles of earthen levee, one sandbag gap, and 5.5 miles of channel improvement. Underseepage is controlled by underseepage berms and 22 relief wells. The collected interior drainage and relief well water is discharged into the Kansas River by 2 pumping plants and 48 drainage structures. The Oakland Unit was designed in 1960 and constructed during the period between 1965 and 1969.

A-3.1.4 Subsurface Conditions

Assessments of the subsurface conditions along the project are derived from the Design Memoranda (DMs) referenced later in this Appendix and from additional subsurface investigation performed for this feasibility study.

The Topeka area is located within the Eudora-Muir soils association. A review of available geological information indicates that part of the study area is situated in an area of alluvial deposition and erosion at the confluences of Soldier Creek with the Kansas River and Shunganunga Creek with the Kansas River. The efforts to control the flooding are done with a series of upstream flood control dams and levees. Subsurface investigations performed during the design of the subject flood risk management project and the additional subsurface investigation performed for this feasibility study indicate that the composition and thickness of the natural blanket in the Topeka area generally conforms to that found elsewhere in Kansas River Valley. The natural surface impervious blanket consists of sandy silts from 10 to 20 feet thick overlaying a deposit of sands and gravels 40 to 80 feet thick, which become coarser with depth. In a few reaches along the river the impervious blanket is absent requiring a constructed underseepage protection system. A fairly consistent weak layer of organic material has been found along Soldier Creek, near the base of the excavated channel. The consistency and thickness of the impervious blanket shown on the record drawings have been used for the evaluation of the existing underseepage condition for each levee unit.

Local bedrock in the project area is comprised of the Upper Pennsylvanian limestone and shale formation which may be found at approximate depths of 60 to 80 feet below existing natural ground surface.

A-3.1.5 Levee Design Features

Basic Levee Section

The basic levee section was constructed with a 10' crown width, with generally 1V on 3H riverside and landside slopes. Underseepage and stability berms were added when necessary in certain reaches. The following table presents the average and maximum height for each levee unit.

Table 1 - Levee Embankment Characteristics

	Soldier Creek	North Topeka	Waterworks	Auburndale	South Topeka	Oakland
Average Height (ft)	15	16	12	15	13	12
Maximum Height (ft)	17	20	19	26	16	25

The levee embankment consists of compacted earthen material placed in random and impervious zones. Riprap protection is provided on the riverside slopes where needed and around the inlets and outlets of drainage structures. All other sloped surfaces are protected by established grasses. The levee crown, turnouts, and ramps are surfaced with 6 inches of aggregate surfacing.

Seepage Control Measures

Seepage control measures consist of underseepage berms, relief wells and area fill where necessary. Typical locations of existing underseepage controls are located where the natural blanket is thin in a localized area.

Stability Berms

Levee sections were designed to provide a minimum factor of safety of 1.25 for riverward submerged toe case, and 1.5 for the steady seepage case. Typically stability berms were used for levee sections over 10 feet. For the existing soil conditions, this appears to be the limiting height, or spring point.

A-3.1.6 Assessment of Levee Integrity

The current levee system is in good condition with no presently identifiable problem areas. The entire levee system has performed well during past flood events. The seepage and stability berms have performed as designed over the years. A partial top of levee survey was provided to the Corps of Engineers by the City of Topeka. Additional cross sections were surveyed as part of this feasibility study.

A-3.1.7 Uncertainty Analysis

Geotechnical failure in this study is defined as failure of the embankment slope resulting from the river flowing to landside areas of the levee with resulting economic damages or due to a sudden drawdown of the water elevation from the maximum level, considered at the levee crest, to the normal operating level. Further, geotechnical failure may occur when river stages reach an elevation at or below the top of the levee. Within this range, geotechnical failure modes are excessive seepage leading to a piping condition and slope instability.

Uncertainty analyses were performed to define the existing condition of the Topeka Flood Protection system. The probability of failure was evaluated by assessing the foundation and embankment materials and assigning values for the probability moments of the random variables considered in the analyses. The First-Order-Second-Moment (FOSM) method, as recommended in ETL 1110-2-556, "Risk-Based Analysis in Geotechnical Engineering for Support of Planning Studies" dated 28 May 1999, was followed during the evaluation of the existing conditions of each levee unit. In this approach, the uncertainty in performance is taken to be a function of the uncertainty in model parameters. The standard deviations of a performance function were estimated based on the expected values (means) and the standard deviation of the random variable means. The performance functions considered were slope stability and underseepage piping stability. The final result of the FOSM is a reliability index, Beta (β), representing the amount of standard deviation of the performance function by which the expected value exceeds the limit state. The limit state for the slope stability and underseepage piping stability was defined using a factor of safety of 1.0. The standard deviation and variance of the performance function are calculated from the standard deviation and variance of the foundation and embankment parameters using the Taylor's series method based on a Taylor's series expansion of the performance function about the expected values. The partial derivatives were calculated numerically using an increment of plus and minus one standard deviation centered on the expected value. The variance of the performance function was obtained by summing the products of the partial derivatives of the performance function considering the variance of the corresponding parameters. For the existing condition of the levee, the probability of slope or underseepage piping failure (Pr_f) was expressed as a function of the river water elevation and other factors including soil strengths, permeabilities, and subsurface stratification. Reliability (R) is defined as:

$$R = (1 - Pr_f)$$

A set of conditional-probability-of-failure versus floodwater-elevation graphs were developed as related to underseepage piping stability and slope stability for the long-term seepage or sudden drawdown condition.

The probability of geotechnical failure of a levee is conditional on the uncertainties associated with hydrologic and hydraulic aspects of determining the water surface profile during a flood. These uncertainties can be combined with the geotechnical uncertainties and in the @RISK model. This is accomplished, for economic purposes, through estimation of two index elevations for each levee reach within the study area. These index elevations are defined as follows:

The Probable Non-Failure Point (PNP) is the water elevation below which it is highly likely that the levee would not fail.
The Probable Failure Point (PFP) is the water elevation above which it is highly likely that the levee would fail.

The terms "highly likely that the levee would fail" is defined by the ETL as having 85% probability of occurrence. Therefore, the probability of failure at the PNP is 15% and the probability of failure at the PFP is 85%. A linear distribution is assumed in the economic model between the PNP and PFP.

A-3.1.8 Underseepage Reliability

Underseepage analyses were performed for every levee unit. Subsurface conditions were developed based on past investigations conducted for the design of each levee unit and on additional Cone Penetration Tests (CPT) performed at selected locations for this feasibility study. The impervious blanket thickness, soil type (for determination of the permeability ratio), and aquifer thickness were determined for each characteristic reach of every levee system. The standard deviation and the coefficient of variation of the blanket thickness for each reach and for the entire levee unit are provided as enclosure 1: Underseepage Analysis of this appendix. Underseepage analysis was performed using the Kansas City District method as approved by Corps of Engineers Missouri River Division Conference, 27 November 1962. A 50% relief well efficiency is assumed to determine the amount of artesian pressure to be used between relief wells. Critical area was determined based on the blanket thickness and material and levee height. The standard deviation for the blanket thickness and levee height was calculated for typical reaches on each levee unit and was used in underseepage reliability evaluation. Critical reach was determined for each levee unit by calculating the underseepage factor of safety for the existing conditions at the toe of the levee. The underseepage factor of safety is defined as the ratio between the actual gradient at the levee toe obtained by analysis and the computed critical gradient ($FS = i_0/i_{cr}$). If the factor of safety was deemed unsatisfactory, i.e. had a factor of safety of less than 1.0, an uncertainty analysis was performed for that particular reach. In the uncertainty analysis, the maximum exit gradient at the landside toe of the levee was considered as the performance function and the value of the critical gradient, assumed to be 0.84, considered the limit state. The foundation sand gradient obtained during the underseepage analyses was used in the stability analyses to assist in defining the steady state condition of the landside slope or the rapid drawdown condition of the riverside slope if the critical surface passed through the aquifer layer.

Reliability analysis was performed using Taylor's Series Method. In the Taylor method, random variables are quantified by their expected values, standard deviations, and correlation coefficients. These variables were used in the generalized equation for underseepage analysis as follows:

$$i_0 = \frac{H\left(\dfrac{K_f}{K_{bL}} D_f D_{bL}\right)^{1/2}}{D_{bo}\left[C_R \dfrac{e^{2L_R}-1}{e^{2L_R}+1} + 6H + 10 + \left(\dfrac{K_f}{K_{bL}} D_f D_{bL}\right)^{1/2}\right]}$$

$$P(F) = P(c_{critical} < i_o)$$

Thus, an equation is used to calculate seepage gradient for a range of water levels on the riverside of the levee. From previous studies, the Taylor Series method appears to be more conservative and appropriate for a reconnaissance level investigation.

Permeability ratios of the blanket landside (K_L) and riverside (K_R) values were obtained by studying the classification information listed on the available boring logs and CPT. The Kansas City District Corps of Engineers correlations between soil classifications and K_L values for soils in this region were used to determine the K_L values for this study

Details of the underseepage analyses for each unit are shown on Figures 1 through 5 at the end of this section. A summary of underseepage evaluation for each levee unit is provided below.

Soldier Creek

The unit consists of the improved Soldier Creek channel and levees on both banks to contain the designed flood event, and tie back levees on the left bank of the creek. Foundation soils consist of a natural blanket with an average thickness of 23 feet overlaying a deposit of poorly graded sand averaging 20 feet in thickness. The composition of the natural blanket varies from clays (CL, CH) to silty sands, but primarily of lean clays. A weak layer of fat clay was mapped between stations 180+00 and 213+00 as substantiated by slides along the original channel. An extensive cinder fill overlaying the impervious blanket between stations 222+00 and 245+00 required the construction of a riverside seepage cut-off trench. Landside underseepage berms exist between station 397+50 and the levee end, relief wells for an existing Goodyear Plant between stations 205+00 and 206+00, and the existence of the thick impervious blanket indicates that underseepage instability was expected for this unit during initial design.

North Topeka Unit

This unit, constructed along the left bank of the Kansas River, includes 9.3 miles of earthen levee with heights varying between 2 feet and 21 feet. The natural blanket for the entire levee unit, consisting predominantly silt, varies in thickness from 1 to 23 feet, with an average thickness of 12 feet. The coefficient of variation in the thickness of the natural blanket has been calculated to be 39.4% with a standard deviation of 4.8 feet. Underseepage is controlled by landside underseepage berms between stations 83+00 and 220+00. Cut-off trenches are present between stations 205+00 and 462+50 at locations where the blanket is overlain by a sand layer or by existing pervious fill. Three (3) relief wells were placed at station 392+05 where the natural impervious blanket had been excavated for the basement of a warehouse building. Underseepage analyses for the reaches between stations 165+00 and 180+00 and between stations 205+00 to 298+00 evaluating the existing conditions indicate piping safety factors less than 1.0 for a river stage at the existing levee crest and were considered critical for reliability evaluation. The assumed soil material parameters and the details of the uncertainty analyses performed for these two reaches are shown on Figures 1 and 2 at the end of this section.

The critical water stage for 85 percent probability of failure for the reach between stations 165+00 and 180+00 is elevation 891 feet and 892 feet for the reach between stations 205+00 and 298+00.

Waterworks Unit.

The Waterworks Unit, located on the right bank of the Kansas River, consists of 1,998 feet of earthen levee and 1,662 feet of floodwall. The floodwall is constructed on a foundation soil consisting of an impervious blanket varying in thickness from 9 to 13 feet, overlaying a layer of very fine sand, which becomes progressively coarser with depth. The average impervious blanket thickness is 9.6 feet with a coefficient of variation of 28.2% and a standard deviation of 2.7 feet. Nine (9) relief wells provide underseepage control along the floodwall reach. A landside fill controls the underseepage along the levee embankment reach. Underseepage analyses considering the existing conditions indicated factors of safety less than 1.0 for a river stage at the levee crest for the reaches between stations 33+00 and 40+00. The assumed soil material parameters and the details of the uncertainty analyses performed at this reach are shown on Figure 3 at the end of this section.

The critical water stage for an 85 percent probability of failure within this reach is elevation 892.5 feet.

Auburndale Unit.

The Auburndale Unit is located along the right bank of the Kansas River east of the Waterworks Unit. The Interstate I-70 embankment is used as the right bank levee between the Waterworks Unit at the upper end and the South Topeka Unit at the lower end. Foundation soils below the levee embankment consist of an impervious blanket of silt or sandy silts varying in thickness between 8 and 14 feet. Near the bluff line, a clay blanket overlays the poorly graded foundation sand to a depth of up to 45 feet. A layer of impervious fill was placed on the highway landside slope to control through seepage in the embankment. Fifteen (15) relief wells are located between stations 2+00 and 17+50. A riverside impervious cut-off trench was keyed 1 foot into the impervious blanket between stations 80+00 and 137+00. Due to the high level of underseepage control and thickness of blanket, risk and uncertainty analyses were not considered to be required.

South Topeka Unit.

The South Topeka Unit is located along the right bank of the Kansas River and consists of 1.4

miles of earthen levee, and 1,944 feet of floodwall founded on an impervious blanket varying in thickness between 5 and 24 feet, with an average of 15.5 feet. The standard deviation of the blanket thickness is 5 feet and the coefficient of variation 32.4%. The blanket consisting of silty clays and silty sands overlays a sand deposit more than 80 feet thick. Fill placed on the top of the natural blanket between station 50+00 and 74+30 contains debris, rock, rubble, and sand requiring the construction of riverside cut-off trenches to reduce seepage. Between station 74+30 and 93+90, a 6 to 7 foot thick layer of debris required construction of 27 relief wells for underseepage control. The blanket beneath this fill averages only a few feet in thickness and appears to be entirely missing between stations 77+50 and 80+50. A seepage interceptor drain and relief wells were placed between stations 74+05 and 93+25. The interceptor was designed to control underseepage flow along a void detected at the base of the pile cap. The void was measured as 1/16" at the sheet pile cut-off wall and 3/4" at the toe. Underseepage analyses considering the existing conditions and a factor of safety less than 1.0 was computed for a river stage at the levee crest for the reaches between stations 0+00 and 72+20 where no relief wells exist. The assumed soil material parameters and the details of the uncertainty analysis performed for this reach is shown in Figure 4 at the end of this section.

Oakland Unit.

The Oakland Unit is located along the Kansas River downstream of the South Topeka Unit and along left bank of Shunganunga Creek. The Oakland Unit consists of 10 miles of earthen levee and 5.5 miles of channel improvements. Foundation soils of this flood risk management unit contain an impervious blanket that can be divided into three general areas considering blanket material and blanket thickness. The blanket in the upper reach, between stations 0+00 to 60+00, consists of clay-type material varying from silty clay to fat clay. Blanket thickness ranges between 20 and 30 feet. The middle reach, between stations 60+00 and 285+00, is overlain by an impervious silt blanket having a thickness of between 2 and 30 feet. The blanket thickness between stations 200+00 and 245+00 is very thin; having a thickness of between 0 and 4 feet. The reach along Shunganunga creek, from station 285+00 to the end, has a substantial blanket consisting of lean to fat clays with a thickness of between 20 and 35 feet. Underlying foundation sands possess a thickness ranging between 10 and 60 feet. Sands vary in grain size from very fine to medium in the upper half of the aquifer to coarser near the top of bedrock. The entire foreshore area between station 0+00 and approximate station 40+00 contains deposits of fill material consisting of waste material, debris, cinders, and rubble. A riverside cut-off trench exists between stations 0+00 and 523+20, constructed to reduce the seepage through the levee foundation. Relief wells between stations 205+00 and 237+50 control the underseepage. Underseepage analyses indicate factors of safety less than 1.0 for the reaches between stations 60+00 and 85+55 with a river stage at the levee crest. A relief well between stations 200+00 and 245+00, considering 50 percent efficiency, increases the underseepage stability to an acceptable level of greater than 1.0. The assumed soil material parameters and the results of the uncertainty analyses performed for the reach between stations 60+00 and 85+55 is shown on Figure 5 at the end of this section.

The critical water stage for an 85 percent probability of failure for the reach between stations 64+00 and 80+00 is elevation 880.5 feet.

FIGURE 1 - UNDERSEEPAGE ANALYSIS
NORTH TOPEKA Section I
Station 172+00

Crest width (feet) 10.00
Horizontal to vertical slope ratio 3.00

K-r	riverside permeability ratio
K-L	landside permeability ratio
Dbr	riverside blanket thickness
DbL	landside blanket thickness
Dbo	blanket thickness under levee footprint
Df	pervious foundation thickness
Lr	length of riverside blanket
Ll	length of landside blanket
H	design water head
Hwt	head above tailwater at levee toe without berm
H'wt	head above tailwater at 1/2 berm
H'o	head above tailwater at levee toe (w/ berm)
i-c	critical seepage gradient
Wt	berm width
i-o	seepage gradient
Wt	landside berm width
Cr	riverside effective length coefficient
Cl	landside effective length coefficient
L1	riverside effective length
L2	levee base width
Le	landside effective length
Lt	total effective length
t'	underseepage berm thickness at toe

Station	K-r	K-L	DbL	Dbo	Dbr	Df	H	i-c	Lr	Wt	Safety Factor	L't	Hwt	H'wt	i-o	Cr	Cl	L1	L2	Le	Lt	H'o	t'
70+00	300	300	12.3	12.3	12.3	85.0	12.0	0.840	1500	0	1.84	1197	5.6	5.6	0.46	560	560	555	82	560	1197	NA	NA
105+00	300	300	4.0	4.0	4.0	20.0	15.9	0.840	500	250	1.65	540	4.6	2.0	0.51	155	155	154	105	155	415	7.17	3.16
150+00	400	400	12.0	12.0	12.0	30.0	15.3	0.840	350	25	1.38	769	7.5	7.3	0.61	379	379	276	102	379	757	6.76	0.03
172+00	300	300	4.8	4.8	4.8	40.0	17.6	0.840	250	190	0.90	637	6.63	4.5	0.93	240	240	187	116	240	542	8.05	3.44
190+00	300	300	6.5	6.5	6.5	40.0	14.5	0.840	200	150	1.10	623	6.5	5.0	0.76	279	279	172	97	279	548	7.17	2.27
248+00	300	300	6.7	6.7	6.7	70.0	13.7	0.840	50	10	0.58	522	9.8	9.7	1.45	375	375	50	92	375	517	8.68	3.16

Station 172+00

Head = 17.60
X2 = 116

	Kf/Kb	z	d	X3	s	ho	I	Variance Component	Percent of Variance
Mean	300	6.70	70.0	375	334.56	9.3	1.388468		
	180	6.70	70.0	291	318.36	8.4	1.253442	0.0131303	8.1367
	420	6.70	70.0	444	342.53	9.9	1.482617		
	300	4.60	70.0	311	323.14	8.6	1.875816	0.1446893	89.662
	300	8.80	70.0	430	341.17	9.8	1.115055		
	300	6.70	55.0	332	327.56	8.9	1.323249	0.0035521	2.2012
	300	6.70	85.0	413	339.40	9.7	1.442447		
							Total	0.1613717	100

E[I] = 1.3885
Var[I]= 0.16137
sigma[I]= 0.40171
V(I) = 0.2893

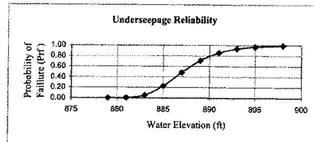
E[ln I] = 0.28801
sigma [ln I] = 0.283525

I crit = 0.840
ln(I crit) = -0.17435

F(z) = 0.05147
Pr(f) = 94.85295

Table 1 : Random Variables for North Topeka

Parameter	Expected Value	Standard Deviation	Coefficient of Variation, %
Blanket z	6.7	2.08	31.22
Perm Ratio	300	120	40.00
Fdn Sand	70	15	20.00



Head	Elev.	Prf
3	879	0.00000
5	881	0.00240
7	883	0.05118
9	885	0.22750
11	887	0.48432
13	889	0.70880
15	891	0.85420
17	893	0.93268
19	895	0.97051
22	898	0.99192

FIGURE 2 - UNDERSEEPAGE ANALYSIS

NORTH TOPEKA
Station 248+00

Crest width (feet)	10.00	H	design water head	L2	levee base width
Horizontal to vertical slope ratio	3.00	Hwt	head above tailwater at levee toe without berm	Le	landside effective length
		H'wt	head above tailwater at 1/2 berm	Lt	total effective length
K-r riverside permeability ratio		H'o	head above tailwater at levee toe (w/ berm)	t'	underseepage berm thickness at toe
K-L landside permeability ratio		i-c	critical seepage gradient		
Dbr riverside blanket thickness		Wt	berm width		
DbL landside blanket thickness		i-o	seepage gradient		
Dbo blanket thickness under levee footprint		Wt	landside berm width		
Df pervious foundation thickness		Cr	riverside effective length coefficient		
Lr length of riverside blanket		Cl	landside effective length coefficient		
Ll length of landside blanket		L1	riverside effective length		

Station	K-r	K-L	DbL	Dbo	Dbr	Df	H	i-c	Lr	Wt	Safety Factor	L't	Hwt	H'wt	i-o	Cr	Cl	L1	L2	Le	Lt	H'o	t'
70+00	300	300	12.3	12.3	12.3	85.0	12.0	0.840	1500	0	1.84	1197	5.6	5.6	0.46	560	560	555	82	560	1197	NA	NA
105+00	300	300	4.0	4.0	4.0	20.0	15.9	0.840	500	250	1.65	540	4.6	2.0	0.51	155	155	154	105	155	415	7.17	3.16
150+00	400	400	12.0	12.0	12.0	30.0	15.3	0.840	350	25	1.38	769	7.5	7.3	0.61	379	379	276	102	379	757	6.76	0.03
172+00	300	300	4.8	4.8	4.8	40.0	17.6	0.840	250	190	0.90	637	6.63	4.5	0.93	240	240	187	116	240	542	8.05	3.44
190+00	300	300	6.5	6.5	6.5	40.0	14.5	0.840	200	150	1.10	623	6.5	5.0	0.76	279	279	172	97	279	548	7.17	2.27
248+00	300	300	6.7	6.7	6.7	70.0	16.0	0.840	50	10	0.51	536	11.2	11.1	1.65	375	375	50	106	375	531	9.87	3.92

Station 248+00

z = Dbl
d = Df
X3 = Cr

ho = Hwt

Head = 16.00
X2 = 106

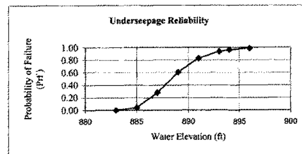
	Kf/Kb	z	d	X3	s	ho	l	Variance Component	Percent of Variance
Mean	300	6.70	70.0	375	155.71	11.3	1.687549		
	180	6.70	70.0	291	155.51	10.4	1.555504	0.0112464	4.3943
	420	6.70	70.0	444	155.79	11.8	1.767602		
	300	4.60	70.0	311	155.57	10.7	2.317993	0.2417777	94.471
	300	8.80	70.0	430	155.78	11.7	1.334575		
	300	6.70	55.0	332	155.63	10.9	1.626674	0.0029048	1.1350
	300	6.70	85.0	413	155.76	11.6	1.734467		
							Total	0.2559289	100

E[l] =	1.6875	E[ln l] =	0.48025
Var[l]=	0.25593		
sigma[l]=	0.50589	sigma [ln l] =	0.293354
V(l) =	0.2998		
l crit =	0.840	ln(l crit) =	-0.17435

F(z) =	0.01283
Pr(f) =	98.71739

Table 1 : Random Variables for North Topeka

Parameter	Expected Value	Standard Deviation	Coefficient of Variation, %
Blanket z	6.7	2.08	31.22
Perm Ratio	300	120	40.00
Fdn Sand depth	70	15	21.40



Head	Elev.	Prf
3	883	0.00026
5	885	0.04140
7	887	0.27874
9	889	0.60646
11	891	0.83000
13	893	0.93620
14	894	0.96215
16	896	0.98717

FIGURE 3 - UNDERSEEPAGE ANALYSIS

WATERWORKS
Station 172+00

Crest width (feet)	10.00	H	design water head		
Horizontal to vertical slope ratio	3.00	Hwt	head above tailwater at levee toe without berm	L2	levee base width
		H'wt	head above tailwater at 1/2 berm	Le	landside effective length
K-r riverside permeability ratio		H'o	head above tailwater at levee toe (w/ berm)	Lt	total effective length
K-L landside permeability ratio		i-c	critical seepage gradient	t'	underseepage berm thickness at toe
Dbr riverside blanket thickness		Wt	berm width		
DbL landside blanket thickness		i-o	seepage gradient		
Dbo blanket thickness under levee footprint		Wt	landside berm width		
Df pervious foundation thickness		Cr	riverside effective length coefficient		
Lr length of riverside blanket		Cl	landside effective length coefficient		
Ll length of landside blanket		L1	riverside effective length		

Station	K-r	K-L	DbL	Dbo	Dbr	Df	H	i-c	Lr	Wt	Safety Factor	L't	Hwt	H'wt	i-o	Cr	Cl	L1	L2	Le	Lt	H'o	t'
10+00	600	600	8.0	8.0	8.0	40.0	10.0	0.840	200	0	0.98	640	6.8	6.8	0.86	438	438	187	15	438	640	NA	NA
16+20	500	500	7.6	7.6	7.6	50.0	9.5	0.840	150	0	0.92	595	7.0	7.0	0.92	436	436	144	15	436	595	NA	NA
19+00	500	500	7.2	7.2	7.2	40.0	10.5	0.840	250	0	1.02	672	5.9	5.9	0.82	379	379	219	73	379	672	NA	NA
33+50	500	500	7.3	7.3	7.3	40.0	12.0	0.840	70	0	0.71	533	8.60	8.6	1.18	382	382	69	82	382	533	NA	NA

Station 33+50

Head = 14.00
X2 = 82

	Kf/Kb	z	d	X3	s	ho	I	Variance Component	Percent of Variance
Mean	500	7.30	40.0	382	151.23	10.0	1.374005		
	300	7.30	40.0	296	150.72	9.3	1.270705	0.0068789	8.8793
	700	7.30	40.0	452	151.45	10.5	1.436583		
	500	5.80	40.0	341	151.03	9.7	1.672249	0.0632867	81.690
	500	8.80	40.0	420	151.36	10.3	1.169112		
	500	7.60	30.0	342	151.04	9.7	1.245085	0.0073057	9.4302
	500	7.30	50.0	427	151.38	10.3	1.416032		
							Total	0.0774713	100

E[I] = 1.3740
Var[I]= 0.07747
sigma[I]= 0.27834
V(I) = 0.2026

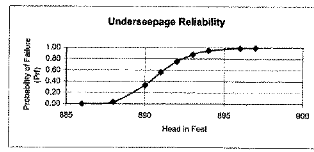
E[ln I] = 0.29762
sigma [ln I] = 0.200540

I crit = 0.840
ln(I crit) = -0.17435

F(z) = 0.00930
Pr(f) = 99.07017

Table 1 : Random Variables for Waterworks

Parameter	Expected Value	Standard Deviation	Coefficient of Variation, %
Blanket z	7.3	1.5	20.80
Perm Ratio	600	240	40.00
Fdn Sand d	40	10	25.00



Head	Elev.	Prf
4	886	0.00005
6	888	0.03063
8	890	0.33105
9	891	0.55974
10	892	0.75038
11	893	0.87512
12	894	0.94350
14	896	0.99070
15	897	0.99651

FIGURE 4 - UNDERSEEPAGE ANALYSIS

SOUTH TOPEKA
Station 58+70

Crest width (feet)	10.00	H	design water head
Horizontal to vertical slope ratio	3.00	Hwt	head above tailwater at levee toe without berm
		H'wt	head above tailwater at 1/2 berm
K-r riverside permeability ratio		H'o	head above tailwater at levee toe (w/ berm)
K-L landside permeability ratio		i-c	critical seepage gradient
Dbr riverside blanket thickness		Wt	berm width
DbL landside blanket thickness		i-o	seepage gradient
Dbo blanket thickness under levee footprint		Wt	landside berm width
Df pervious foundation thickness		Cr	riverside effective length coefficient
Lr length of riverside blanket		Cl	landside effective length coefficient
Ll length of landside blanket		L1	riverside effective length

L2 levee base width
Le landside effective length
Lt total effective length
t' underseepage berm thickness at toe

											Factor									Le	Lt	H'o	t'
58+70	400	400	11.3	11.3	11.3	80.0	11.7	0.840	10	0	0.93	692	10.2	10.2	0.90	601	601	10	80	601	692	NA	NA
75+84	300	300	15.5	15.5	15.5	80.0	12.0	0.840	20	0	1.15	647	11.3	11.3	0.73	610	610	20	17	610	647	NA	NA
78+40	300	300	16.0	16.0	16.0	80.0	12.0	0.840	20	0	1.19	657	11.3	11.3	0.71	620	620	20	17	620	657	NA	NA
87+50	300	300	14.0	14.0	14.0	80.0	12.0	0.840	20	0	1.04	617	11.3	11.3	0.81	580	580	20	17	580	617	NA	NA

Station 58+70

Head = 16.00
X2 = 80

	Kf/Kb	z	d	X3	s	ho	I	Variance Component	Percent of Variance
Mean	400	11.30	80.0	601	89.9991	13.9	1.231600		
	560	11.30	80.0	712	89.9993	14.2	1.256937	0.0012351	0.4020
	240	11.30	80.0	466	89.9985	13.4	1.186649		
	400	6.70	80.0	463	89.9984	13.4	1.999435	0.3057468	99.511
	400	15.90	80.0	713	89.9993	14.2	0.893548		
	400	11.30	64.0	538	89.9988	13.7	1.212962	0.0002684	0.0874
	400	11.30	96.0	659	89.9992	14.1	1.245730		
							Total	0.3072504	100

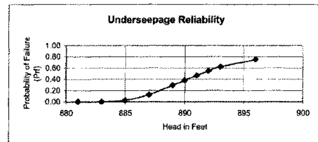
E[I] = 1.2316 E[ln I] = 0.11609
Var[I]= 0.30725
sigma[I]= 0.55430 sigma [ln I] = 0.429479
V(I) = 0.4501

I crit = 0.840 ln(I crit) = -0.17435

F(z) =	0.24944
Pr(f) =	75.05637

Table 1 : Random Variables for South Topeka Sta. 58+70

Parameter	Expected Value	Standard Deviation	Coefficient of Variation, %
Blanket z	11.3	4.6	40.80
Perm Ratio	400	160	40.00
Fdn Sand	80	16	20.00



Head	Elev.	Prf
1	881	0.00000
3	883	0.00094
5	885	0.02753
7	887	0.12819
9	889	0.29122
10	890	0.38038
11	891	0.46710
12	892	0.54777
13	893	0.62035
16	896	0.75056

FIGURE 5 - UNDERSEEPAGE ANALYSIS

OAKLAND
Station 78+00

Crest width (feet) 10.00
Horizontal to vertical slope ratio 3.00

K-r	riverside permeability ratio
K-L	landside permeability ratio
Dbr	riverside blanket thickness
DbL	landside blanket thickness
Df	pervious foundation thickness
Lr	length of riverside blanket
Ll	length of landside blanket
H	design water head
Hwt	head above tailwater at berm end
H'wt	head above tailwater at 1/2 berm
H'o	head above tailwater at levee toe (w/ berm)
i-c	critical seepage gradient
Wt	berm width
i-o	seepage gradient
Cr	riverside effective length coefficient
Cl	landside effective length coefficient
L1	riverside effective length
L2	levee base width
Le	landside effective length
Lt	total effective length
t'	underseepage berm thickness at toe
Sc	= calculated slope of underseepage berm
tu	= used thickness of underseepage berm

Station	K-r	K-L	DbL	Dbc	Dbr	Df	H	i-c	Lr	Wt	Safety Factor	L't	Hwt	H'wt	i-o	Cr	Cl	L1	L2	Le	Lt	H'o	t'
78+00	600	600	7.0	7.0	7.0	40.0	16.0	0.850	10	0	0.48	526	12.5	12.5	1.78	410	410	10	106	410	526	NA	NA
78+00	600	600	7.0	7.0	7.0	40.0	15.0	0.850	10	0	0.51	526	11.7	11.7	1.67	410	410	10	106	410	526	NA	NA
78+00	600	600	7.0	7.0	7.0	40.0	14.0	0.850	10	0	0.55	526	10.9	10.9	1.56	410	410	10	106	410	526	NA	NA
78+00	600	600	7.0	7.0	7.0	40.0	13.0	0.850	10	0	0.59	526	10.1	10.1	1.45	410	410	10	106	410	526	NA	NA
78+00	600	600	7.0	7.0	7.0	40.0	12.0	0.850	10	0	0.64	526	9.4	9.4	1.34	410	410	10	106	410	526	NA	NA
78+00	600	600	7.0	7.0	7.0	40.0	11.0	0.850	10	0	0.69	526	8.6	8.6	1.22	410	410	10	106	410	526	NA	NA
78+00	600	600	7.0	7.0	7.0	40.0	10.0	0.850	10	0	0.76	526	7.8	7.8	1.11	410	410	10	106	410	526	NA	NA
78+00	600	600	7.0	7.0	7.0	40.0	8.0	0.850	10	0	0.95	526	6.2	6.2	0.89	410	410	10	106	410	526	NA	NA
78+00	600	600	7.0	7.0	7.0	40.0	6.0	0.850	10	0	1.27	526	4.7	4.7	0.67	410	410	10	106	410	526	NA	NA
78+00	600	600	7.0	7.0	7.0	40.0	3.0	0.850	10	0	2.54	526	2.3	2.3	0.33	410	410	10	106	410	526	NA	NA
78+00	600	600	7.0	7.0	7.0	40.0	1.0	0.850	10	0	7.63	526	0.8	0.8	0.11	410	410	10	106	410	526	NA	NA

Head = 10.00
X2 = 100

Station 220+00

ho= 4.9 (no relief wells)
ho=2.4 (100% relief wells efficiency)
ho=3.6 (50% relief wells effiency)
9

	Kf/Kb	z	d	X3	s	ho	I	Variance Component	Percent of Variance
Mean	50	3.00	60.0	95	109.96	4.6	1.543844		
	30	3.00	60.0	73	109.94	4.0	1.335429	0.0045853	1.1399
	70	3.00	60.0	112	109.97	3.6	1.200000		
	50	1.60	60.0	69	109.93	3.9	2.416188	0.3937432	97.888
	50	4.40	60.0	115	109.97	5.1	1.161209		
	50	3.00	51.0	87	109.96	4.4	1.476782	0.0039106	0.9722
	50	3.00	69.0	102	109.97	4.8	1.601851		
							Total	0.4022391	100

E[I] = 1.5438
Var[I]= 0.40224
sigma[I]= 0.63422
V(I) = 0.4108

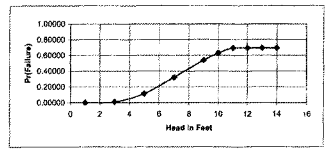
E[ln I] = 0.35630
sigma [ln I] = 0.394800

I crit = 0.850
ln(I crit) = -0.16252

F(z) = 0.09446
Pr(f) = 90.55439

Table 1 : Random Variables for Oakland Levee Sta. 71+25

Parameter	Expected Value	Standard Deviation	Coefficient of Variation, %
Blanket z	3	1.4	47.14
Perm Ratio	50	20	40.00
Fdn Sand	60	9	15.00



Head	Prf
1	0.00000
3	0.00958
5	0.11369
7	0.32296
9	0.53945
10	0.62851
11	0.69512
12	0.69512
13	0.69512
14	0.69512

A-3.1.9 Slope Stability Reliability

A risk analysis was performed on a basic typical section of the levee embankment for each unit, at reaches considered critical due to the levee height or foundation conditions. A sensitivity study was done to determine which three parameters in the slope stability calculations were most influential. For this study, those variables are soil strength in the embankment, soil strength in the foundation material such as cohesive soils and cohesionless soils. Statistical descriptors for these three variables were determined using available site-specific information and published statistical data as in the underseepage study. Details and results of the slope stability analysis are shown in Figures 6 through 10 at the end of this section.

Cases of Stability Analyses

Conditions analyzed for stability analyses considered long-term conditions having a steady state seepage condition along the landside slope for levees located on the Kansas River or rapid drawdown of the channel water for the riverside slope of projects located along Soldier Creek and Shunganunga Creek. When steady state conditions were analyzed, the water pressure in the sand layer underlying the natural impervious blanket was computed by underseepage analysis for every flood stage considered in calculations.

Soil Strength Parameters

Soil Strength Parameters used in the stability analyses were the drained soil parameters used for the original flood control project design. The only new subsurface investigation performed to refine the understanding of existing conditions involved cone penetration testing (CPT) at selected locations. The coefficient of variation for soil strength parameters were obtained using methodologies outlined in ETL 1110-2-556. The coefficient of variation of the blanket thickness was determined using all existing subsurface data.

Method of Stability Analysis

The limit equilibrium computer program "UTEXAS3" was used to perform the stability analyses. Circular failure surfaces were assumed and the embankment was modeled as homogeneous. All analyses consisted of running a search routine to identify the critical failure surface using the Spencer's Method. Three random variables were defined for each unit. Stability analyses were performed for different assumed river stages. Results of the stability analyses are summarized in the following paragraphs.

Probability Analysis

The Probability of Failure of a slope ($P_{rf(Failure)}$) is defined as the probability that the critical failure surface could be loaded to the limit equilibrium state. This infers the slope is loaded to its maximum capacity. For this study, the variables for slope stability were not assumed to be correlated to the parameters for underseepage analyses.

Results of Stability Analyses by Unit

Soldier Creek Unit. The Soldier Creek Unit was analyzed for a rapid drawdown condition in the channel. The critical section on Soldier Creek was considered to be the channel excavation between stations 13+00 and 113+00 where the channel slope is approximately 39 feet in height. The sand layer within this reach extends 56 feet below the top of the levee. The levee is located adjacent to the riverbank. Original design soil properties and those determined from the uncertainty analyses are shown on Figure 6. The probability that the factor of safety for slope stability could be less than 1.0 for increasing river levels for a reach between stations 13+00 and 133+00 is also shown on Figure 6. The 85% probability of failure corresponds to water elevation of 886 feet.

North Topeka Unit. The North Topeka Unit was analyzed assuming steady state seepage conditions and that the aquifer layer under the impervious blanket is being pressurized by the hydraulic gradient determined during underseepage analyses for different river stage elevations and different blanket thicknesses. The critical reach was considered to be located between levee stations 246+00 and 250+00. Impervious blanket thickness is 5 feet or less in thickness. Original design soil properties and those determined from the uncertainty analyses are provided in Figure 7. The probability that the factor of safety for slope stability is less than 1.0 for increasing river stages is shown by the curve presented in Figure 7.

Waterworks Unit. The Waterworks Unit was analyzed for the steady state condition considering the aquifer layer underneath the impervious blanket as being pressurized by the hydraulic gradient developed during underseepage analyses for different river stage elevations and different blanket thicknesses. The critical section for stability was considered to be between stations 7+00 and 73+00 where the impervious layer thickness is less than 7 feet thick. The original design soil properties and those determined from the uncertainty analyses are also provided in Figure 8. The probability that the factor of safety for slope stability is be less than 1.0 for increasing river stages is indicated by the curve presented in Figure 8. The elevation corresponding to 85 % probability of failure is 893 feet.

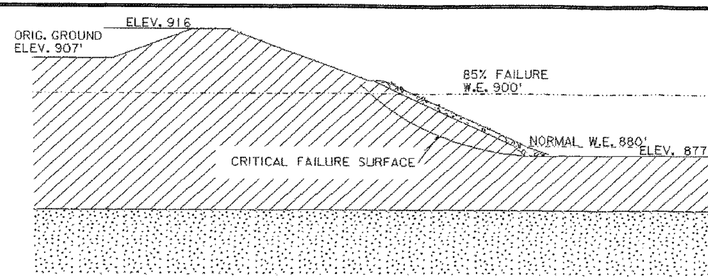
Auburndale Unit. The Auburndale Unit is located along the right bank of the Kansas River east of the Waterworks Unit. No stability analyses were performed for this levee unit since the foundation conditions and the height of the levee did not give any indication of any weak reaches. The impervious blanket is thicker than 8 feet throughout and consists of silt or sandy silts having an internal friction angle of 26.5 degrees, as recommended for the original design. The levee height does not exceed 15 feet, with the crest elevation varying between 897.23 feet at the upper end and 895.75 at the lower end. Critical failure surfaces for steady state seepage conditions will not penetrate the impervious blanket. Considering all these conditions, no instabilities were deemed to exist within this unit.

South Topeka Unit. The South Topeka Levee Unit was analyzed for steady state seepage conditions considering the aquifer layer underneath the impervious blanket as being pressurized by the hydraulic gradient determined during underseepage analyses for different river stage elevations. The critical section for stability was identified as the reach between stations 50+00 and 73+00 where the impervious blanket layer thickness is less than seven feet. Original design soil properties and the variations used in the uncertainty analysis are also provided in Figure 9.The probability that the factor of safety for slope stability is be less than 1.0 for increasing river stages is indicated by the curve presented in Figure 9.

Oakland Unit. The Oakland Levee Unit was analyzed for the steady state seepage condition considering the aquifer layer underneath the impervious blanket as being pressurized by the hydraulic gradient determined during underseepage analyses for different river stage elevations. The critical section for stability was identified as being between stations 64+00 and 80+00 where the impervious blanket layer thickness is less than 8 feet. Original design soil properties and those determined from the uncertainty analyses are provided in Figure 10. The probability that the factor of safety for slope stability is be less than 1.0 for increasing river stages is indicated by the curve presented in Figure 10.

FIGURE 6 - STABILITY ANALYSIS **Reliability Analysis**

Soldier Creek	Sta.	Rapid
Unit	13+00	Drawdown



Head = 23.00
Water Elev. 900
Levee Crest 916

	Phi Clay Mat.	Phi Sand	Gamma Clay	FS
Mean	26.50	32.0	Clay Mat	0.609
	23.80	32.00	107.00	0.569
	29.20	32.00	107.00	0.682
	26.50	28.20	107.00	0.609
	26.50	35.80	107.00	0.609
	26.50	32.00	98.00	0.572
	26.50	32.00	116.00	0.617

100

26.5	2.70
32	3.80
107	9.00

	Required
	1.0
	Pr(f)
877	0.00590
880	0.22558
883	0.59073
886	0.85000
890	0.96361
900	1.00000

E[FS] = 0.60900
Var[FS]= 0.00370
sigma[FS]= 0.06082

E[ln FS] = -0.50090
sigma [ln FS] = 0.099613

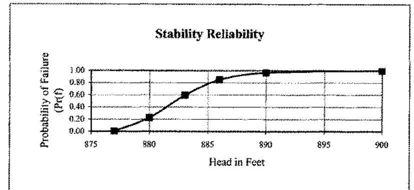
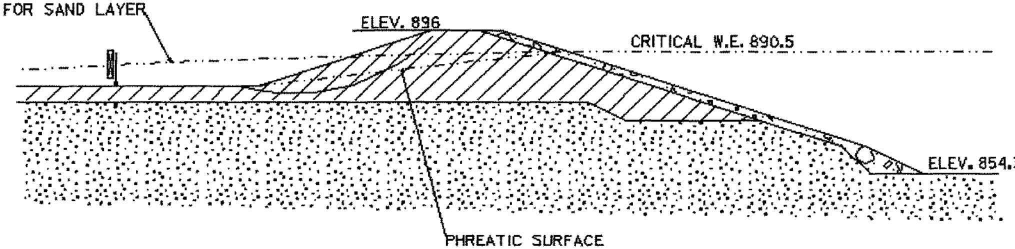


FIGURE 7 - STABILITY ANALYSIS Reliability Analysis

North Topeka — Sta. 248+00 — Steady State



Head = 16.00
W.E. 896.0

	Reliability Analysis of Critical Slide					
	Ph Clay	Phi Sand	Clay Depth Elev.	FS	Variance Component	Percent of Variance
Mean	26.50	32.0	873.30	0.950		
	23.80	32.00	873.30	0.840	0.0126563	10.5258
	29.20	32.00	873.30	1.065		
	26.50	28.00	873.30	0.950	0.0000000	0.000
	26.50	36.00	873.30	0.950		
	26.50	32.00	875.30	0.294	0.1075840	89.4742
	26.50	32.00	871.20	0.950		
				Total	0.1202403	100

E[FS] = 0.9500 E[ln FS] = -0.11383
Var[FS]= 0.12024
sigma[FS]= 0.34676 sigma [ln FS] = 0.353655
V(FS) = 0.3650

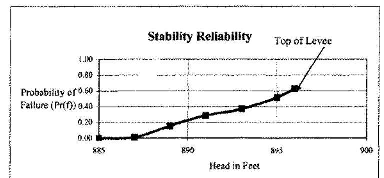
FS req'd = 1.000 ln(FS req'd) = 0.00000

Beta =	-0.321865
F(z) =	0.62622
Pr(f) =	62.622259

Pr(f) = Probability of a stability factor of safety less than one

Table 1 : Random Variables for North Topeka

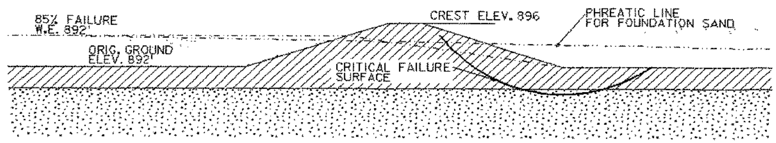
Parameter	Expected Value	Standard Deviation	Coefficient of Variation, %
Impervious Phi	26.5	1.700	10.00
Foundation Sand Phi	32	3.200	12.00
Clay Blanket Thickness	6.7	2.000	21.60



Head	Required 1.0 Pr(f)
885	0.0005
887	0.01217
889	0.15412
891	0.28620
893	0.36752
895	0.51674
896	0.62622

FIGURE 8 - STABILITY ANALYSIS **Reliability Analysis**

Waterworks Sta. Steady
Unit 33+00 State



Head = 12.00
Water Elev. 894
Levee Crest 896

	Reliability Analysis of Critical Slide					
	Phi Clay Mat.	Phi Sand	Blanket Thickness	FS	Variance Component	Percent of Variance
Mean	26.50	32.0	7.00	0.759		
	23.80	32.00	7.00	0.626	0.0163840	41.2560
	29.20	32.00	7.00	0.882		
	26.50	28.20	7.00	0.793	0.0023040	5.802
	26.50	35.80	7.00	0.697		
	26.50	32.00	5.50	0.708	0.0210250	52.9424
	26.50	32.00	8.50	0.998		
				1	0.0397130	100

E[FS] = 0.7590
Var[FS]= 0.03971
sigma[FS]= 0.19928
V(FS) = 0.2626

FS req'd = 1.000

E[ln FS] = -0.30909

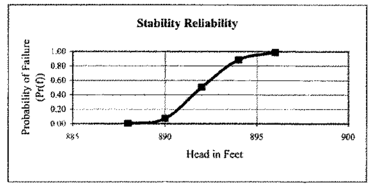
sigma [ln FS] = 0.258194

ln(FS req'd) = 0.00000

Beta =	-1.197105
F(z) =	0.88437
Pr(f) =	88.436727

Table 1 : Random Variables for Waterworks

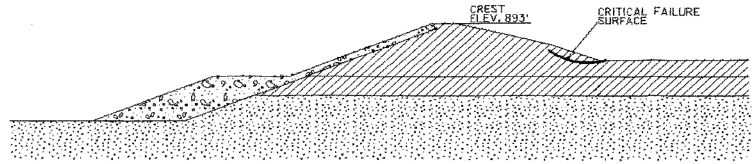
Parameter	Expected Value	Standard Deviation	Coefficient of Variation, %
Phi Clay Material	26.5	2.70	10.00
Phi Foundation Sand	32	3.80	12.00
Blanket Thickness	7	1.50	21.40



Head	Required 1.0 Pr(f)
888	0.00178
890	0.06908
892	0.50438
894	0.88437
896	0.98845

FIGURE 9 - STABILITY ANALYSIS **Reliability Analysis**

South Topeka Unit — Sta. 56+00 — Steady State



Head = 13.00
W.E. 893
Crest 893

	Reliability Analysis of Critical Slide					
	Phi Exist. Fill	Phi New Fill	Phi Found. Clay	FS	Variance Component	Percent of Variance
Mean	24.00	26.50	Clay Mat.	0.963		
	21.60	26.50	22.00	0.857	0.0219040	88.6299
	26.40	26.50	22.00	1.153		
	24.00	28.20	22.00	0.961	0.0000010	0.004
	24.00	35.80	22.00	0.963		
	24.00	26.50	19.80	0.963	0.0028090	11.3660
	24.00	26.50	24.20	1.069		
				1		
				Total	0.0247140	100

E[FS] = 0.9630
Var[FS]= 0.02471
sigma[FS]= 0.15721
V(FS) = 0.1632

FS req'd = 1.000

E[ln FS] = -0.05085

sigma [ln FS] = 0.162175

ln(FS req'd) = 0.00000

Beta =	-0.313564
F(z) =	0.62307
Pr(s) =	62.307394

Table 1 : Random Variables for South Topeka Levee

Parameter	Expected Value	Standard Deviation	Coefficient of Variation, %
Phi Existing Fill	24	2.40	10.00
Phi Embakment Fill	26.5	2.70	10.00
Phi Foundation Clay	22	2.20	10.00

Head	Required 1.0 Pr(s)
887	0.00000
890	0.06228
891	0.19843
892	0.38931
893	0.62307

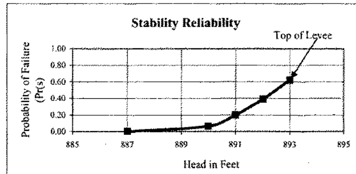
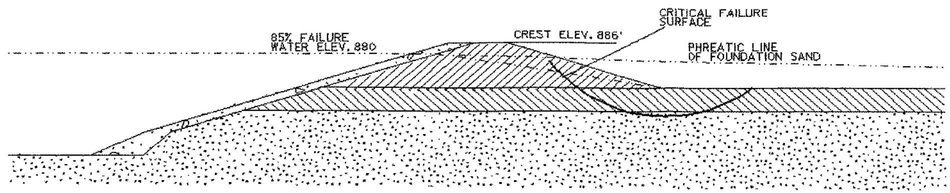


FIGURE 10 - STABILITY ANALYSIS Reliability Analysis

Oakland Unit — Sta. 78+00 — Steady State



Head = 14.00
W.E. 884

	Reliability Analysis of Critical Slide					
	Phi Embank.	Phi Found.	Pfhi Sand	FS	Variance Component	Percent of Variance
Mean	26.50	19.0	32.00	0.460		
	24.00	19.00	32.00	0.455	0.0000250	0.1129
	29.00	19.00	32.00	0.465		
	26.50	17.00	32.00	0.342	0.0129960	58.696
	26.50	21.00	32.00	0.570		
	26.50	19.00	28.00	0.347	0.0091203	41.1912
	26.50	19.00	36.00	0.538		
				Total	0.0221413	100

E[FS] = 0.4600
Var[FS]= 0.02214
sigma[FS]= 0.14880
V(FS) = 0.3235

FS req'd = 1.000

E[ln FS] = -0.82629

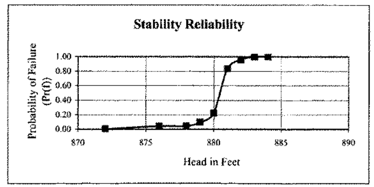
sigma [ln FS] = 0.315463

ln(FS req'd) = 0.00000

Beta =	-2.619283
F(z) =	0.99559
Pr(u) =	99.559425

Table 1 : Random Variables for Oakland Levee

Parameter	Expected Value	Standard Deviation	Coefficient of Variation, %
Embankment Phi	26.5	2.500	10.00
FoundationClay Phi	19	2.000	10.00
Foundation Sand Phi	32	4.000	12.00



Head	Required 1.0 Prf
872	0.00648
876	0.04207
878	0.04425
879	0.09584
880	0.22161
881	0.83448
882	0.95774
883	0.99854
884	0.99945

A-3.1.10 Conclusions of the Uncertainty Analysis

The total conditional probability of failure as a function of floodwater elevation has been developed by combining the probability of failure functions for two failure modes; underseepage piping and slope instability. The reliability is the probability of no failure due to each mode considered in the calculations. The total probabilities of failure function computed for each critical levee unit are indicated in the following figures. The combined probability curves are shown on Figures 11 through 15 at the end of this section.

Soldier Creek Levee Unit.

The combined probability of failure along the Soldier Creek Channel between stations 13+00 and 130+00 is as shown in Figure 11. The 85 percent probability of having a localized channel slope failure for the Soldier Creek Unit between stations 13+00 and 130+00 occurs for a flood stage of 886 feet, a water level of between 6 and 13 feet above the bottom of the existing channel. This channel reach does have an established history of bank slides. In 1967, near station 40+00, an emergency rehabilitation contract was required to repair a major bank failure into the extended toe of the levee. Without emergency repair, the levee embankment could have been lost. No other bank slides have directly threatened the levee integrity in this area. No underseepage piping has been considered critical for these analyses. The levee crest elevation along Soldier Creek varies between 919 and 886 feet and the Soldier Creek Channel bottom varies between elevations 880 and 873 feet. As determined during stability analyses, channel side slopes fail in this area due to sudden drawdown conditions. This creates the possibility of a progressive failure of the channel and failure of the levee if repair of the channel banks are not accomplished shortly after the initial signs of distress are observed. However, since the failures are due to sudden drawdown of the water elevation in the Soldier Creek, after the water reaches a very low elevation, the risk of flood damages of the protected area are not existent if the riverside slope is repaired before the next flood occurs. Consequently, the probability of failure of the riverside slope due to sudden drawdown should not be included in the risk analysis since the repairs can be done between two consequent floods and the damages are limited to the riverbank slope. The damages described in Table 12 are limited to the riverbank and can be repaired if they occurred after a flood event.

North Topeka Levee Unit.

The combined probability of failure for the critical sections between stations 246+00 and 250+00 is illustrated in Figure 12. The 85 percent probability of failure for this reach occurs for a flood stage of elevation 890.5 feet. The levee crest elevation varies within this reach between elevations 895.6 and 896.0 feet.

Waterworks Levee Unit.

The combined probability of failure for the critical section between stations 16+62 and 33+50 is illustrated by the curve shown in Figure 13. The 85 percent probability of failure for this reach occurs for a flood stage of elevation 892 feet. The levee crest elevation varies between 897.0 and 897.6 feet.

South Topeka Levee Unit.

The combined probability of failure for the critical section between stations 0+00 and 73+00 is illustrated in Figure 14. The 85 percent probability of failure for this reach occurs for a flood stage of elevation 893 feet corresponding to the elevation of the levee crest.

Oakland Levee Unit.

The combined probability of failure for the critical section between stations 64+00 and 80+00 is illustrated by the curve shown in Figure 15. The 85 percent probability of failure for this reach occurs at a flood stage of elevation 880 feet. The levee crest elevation varies within this reach between 886 and 887 feet.

Figure 11
Topeka - Soldier Creek Station 13+00 to 113+00
Top Elev. 916

Flood Water Elevation	Pr(f)	R	Pr(f)	R	Pr(f)	R
	Underseepage		Slope Stability		Combined	
877	0.00000	1.00000	0.00590	0.994100	0.00590	0.99410
880	0.00000	1.00000	0.22558	0.774420	0.22558	0.77442
883	0.00000	1.00000	0.59073	0.409270	0.59073	0.40927
886	0.00000	1.00000	0.85000	0.150000	0.85000	0.15000
890	0.00000	1.00000	0.96361	0.036390	0.96361	0.03639
900	0.00000	1.00000	1.00000	0.000000	1.00000	0.00000

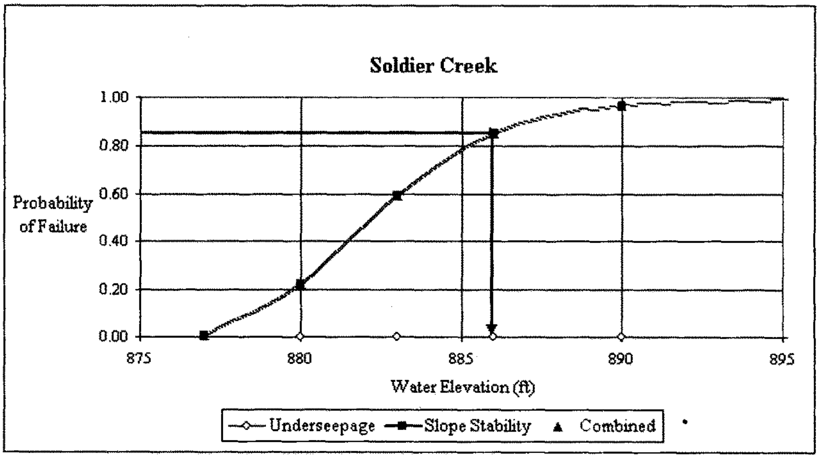


Figure 12
Topeka - North Topeka Unit
Station 246+00 to 260+00
Levee Crest Elev. 896.5

Flood Water Elevation	Underseepage		Slope Stability		Combined	
	Pr(f)	R	Pr(f)	R	Pr(f)	R
	Underseepage		Slope Stability		Combined	
883	0.00026	0.99974	0.00000	1.00000	0.00026	0.99974
885	0.04140	0.95860	0.00050	0.99950	0.04188	0.95812
887	0.27874	0.72126	0.01217	0.98783	0.28752	0.71248
889	0.60646	0.39354	0.15412	0.84588	0.66711	0.33289
891	0.83000	0.17000	0.28620	0.71380	0.87865	0.12135
893	0.93620	0.06380	0.36752	0.63248	0.95965	0.04035
896	0.98717	0.01283	0.62622	0.37378	0.99520	0.00480

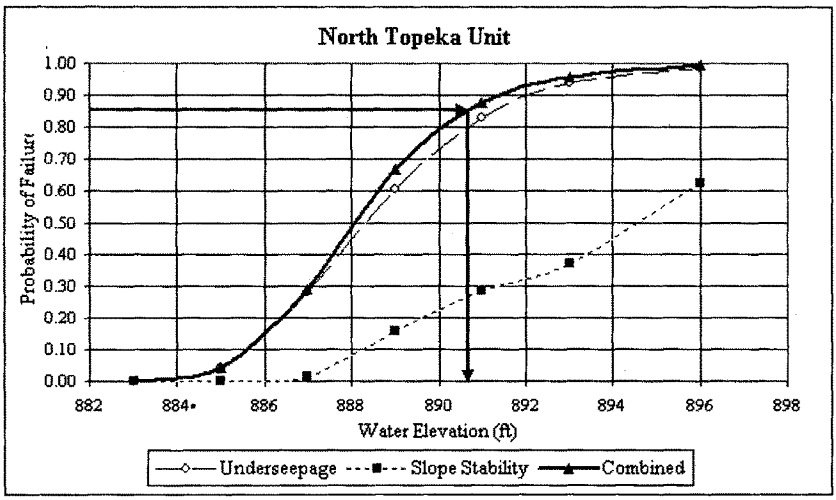


Figure 13

Waterworks Levee Unit **Station 16+62 and 33+50**

Top of Levee 896'

Flood Water Elevation	Underseepage		Slope Stability		Combined	
	Pr(f)	R	Pr(f)	R	Pr(f)	R
	Underseepage		Slope Stability		Combined	
888	0 03063	0.96937	0.00178	0.998220	0.032355	0.967645
890	0.33105	0.66895	0.06908	0.930920	0.377261	0.622739
892	0.75038	0.24962	0.50438	0.495620	0.876283	0.123717
894	0.94350	0.0565	0.88437	0.115630	0.993467	0.006533
896	0.99070	0.00930	0.98845	0.011550	0.999893	0.000107

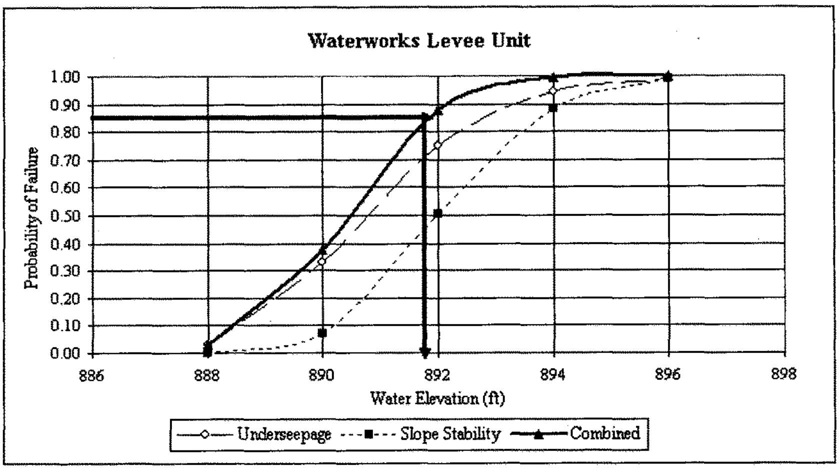


Figure 14
Topeka - South Topeka Unit **Station 0+00 to 73+00**

Levee Crest Elev. 893'

Flood Water Elevation	Underseepage		Slope Stability		Combined	
	Pr(f)	R	Pr(f)	R	Pr(f)	R
	Underseepage		Slope Stability		Combined	
881	0.00000	1.00000	0.00000	1.000000	0.00000	1.00000
883	0.00094	0.99906	0.00000	1.000000	0.00094	0.99906
885	0.02753	0.97247	0.00000	1.000000	0.02753	0.97247
887	0.12819	0.87181	0.00000	1.000000	0.12819	0.87181
890	0.38038	0.61962	0.06228	0.937720	0.41897	0.58103
891	0.46710	0.5329	0.20843	0.791570	0.57817	0.42183
892	0.54777	0.45223	0.38931	0.610690	0.72383	0.27617
893	0.62035	0.37965	0.62307	0.376930	0.85690	0.14310

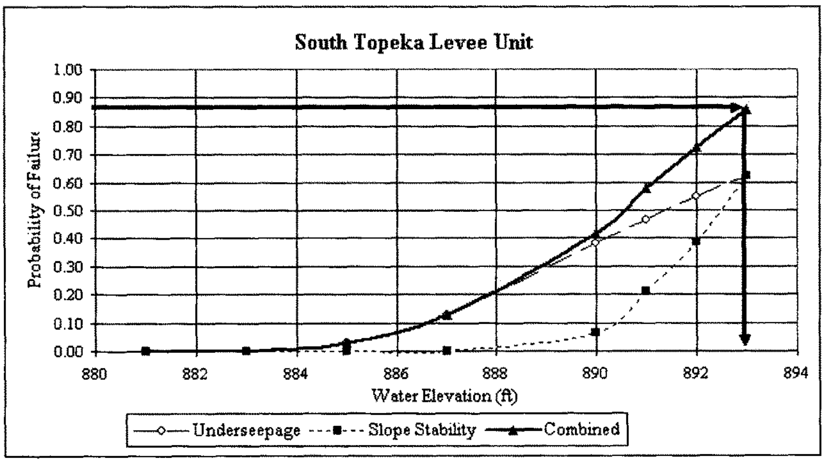
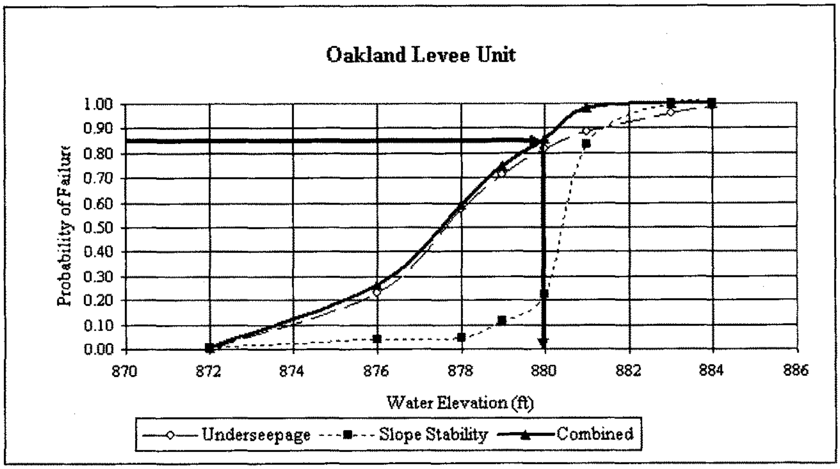


Figure 15
Topeka - Oakland Unit Station 64+00 to 80+00
Levee Crest 886'

Flood Water Elevation	Underseepage		Slope Stability		Combined	
	Pr(f)	R	Pr(f)	R	Pr(f)	R
	Underseepage		Slope Stability		Combined	
872	0.00000	1.00000	0.00648	0.99352	0.00648	0.99352
876	0.23152	0.76848	0.04207	0.95793	0.26385	0.73615
878	0.57522	0.42478	0.04425	0.95575	0.59402	0.40598
879	0.71492	0.28508	0.11584	0.88416	0.74794	0.25206
880	0.81754	0.18246	0.22161	0.77839	0.85797	0.14203
881	0.88725	0.11275	0.83448	0.16552	0.98134	0.01866
883	0.95954	0.04046	0.99854	0.00146	0.99994	0.00006
884	0.98990	0.01010	0.99945	0.00055	0.99999	0.00001



A-3.1.11 Levee System Reliability Summary

Based on the uncertainty analyses of the individual units of the Topeka Flood Protection System, critical reaches of the Topeka levee system have been identified and are summarized in Table 2. The geotechnical order of risk based on the combined risk and uncertainty analysis is shown in Table 3.

Table 2 - Critical Reaches for Topeka Levee System

Levee Unit	Critical Station Range	Average Levee Crest Elevation	Flood Stage for 85% Probability of Failure	Freeboard Distance to Levee Crest @ 85% Failure Probability Stage
North Topeka	246+00 to 250+00	896.0	890.5	5.5
Waterworks	16+62 to 33+50	897.0	892.0	5.0
Auburndale	N/A	N/A	N/A	N/A
South Topeka	0+00 to 73+00	893.0	893.0	0.0
Oakland	64+00 to 80+00	886.50	880.0	6.5

Table 3 - Combined Geotechnical Risk and Uncertainty Analysis

Order of Risk (high to low)	Levee Unit Reach	Nature of Risk	**Damages**	Nature of Cost
1. North Topeka	246+00 to 260+00	• Slope Failure • Loss of Levee	• Property • Loss of Lives	• Dollars • Loss of Lives
2. Waterworks	16+62 to 33+50	• Slope Failure • Loss of Levee	• Loss of water plant • Loss of Lives	• Utility Loss • River Contamination • Loss of Lives
3. Oakland	64+00 to 80+00	• Potential loss of full levee	• Property • Loss of Lives	• Flooding of Oakland area • Flood Fighting Costs •Levee Repair Costs
4. South Topeka	0+00 to 73+00	• Levee Toe Slide • Complete loss of Levee Toe	• Property • Loss of Life	• Levee Repair Costs • Loss of Life
5. Soldier Creek	13+00 to 130+00	• Bank slides	• Uncontrolled Revision of Channel • Channel Flow Impacts • Opposite Bank Scour	• Repair of Flood Damages on the Riverbank

A-3.2 Future Conditions

A-3.2.1 Introduction

Future conditions were modeled and recommendations are made to improve underseepage conditions during flood conditions. This section presents the geotechnical evaluation and results for five of the six units of Topeka levee system.

A-3.2.2 Future Flooding Concerns

Observations after the completion of the Existing Conditions analysis has resulted in refinements to proposed areas of concern. The areas of concern outlined in Table 4 reflect a reduced scope based on observations by the Geotechnical Design Section of Engineering and Construction Division of the Kansas City District.

Table 4. Levee Unit Areas of Concern

Levee Unit	Area of Concern
North Topeka	165+00 to 189+00
	245+75 to 249+50
Oakland	64+00 to 80+00
South Topeka	22+00 to 48+00
Waterworks	64+00 to 80+00

Area Site Characterization

Boring logs located in the as-built drawings serve as the basis for the characterization of the foundation for each berm analyzed.

Underseepage Analysis

The underseepage analysis is modeled after consideration of the types of soils landward of the levee, the consistency of the thickness of the soil blanket clays or silts, the thickness and type of sand deposit below the levee blanket materials, the lateral extent of the blanket landside and riverward of the levee, the effects of the location of the Kansas river, and the height of the existing levee. All of these variables were considered during the development of the model to characterize the representative reaches along the alignment of the levee.

Underseepage can lead to piping. Piping of the blanket materials could lead to subsequent piping of sand grains toward the river entrance, leading to ultimate collapse of the levee section due to the foundation voids caused by piping. Piping occurs when soil begins moving in the blanket. Soil can become mobilized when the pressure in a vertical column of material changes and exceeds the weight of the material bearing on the location where the pressure change occurs. Because pressure typically decreases from depth to the surface, a diagram of the change in pressure typically produces a sloping line or "gradient". The underseepage design aims to assure that the weight of the soil column at any depth exceeds the upward gradient by a factor of safety.

Levee Loading Conditions

An analysis was performed to evaluate existing seepage conditions. Analysis is based on rationale and formulas presented in the Kansas City District's Guidance link on the Geotechnical Section Home Page:

http://www.nwk.usace.army.mil/local_protection/guidance.html.

Deficient conditions are determined by checking the factor of safety (FS) for piping to occur under different river elevations. One condition exists when the river is at the top of the levee, known as full head (FH). Deficiency under these conditions is defined when the FSFH is less than 1.1. The other condition exists when the river is three feet below the top of levee. Deficiency under this condition is defined at any FSFH-3 less than 1.5. The threshold value for FSFH-3 is higher than FSFH because the likelihood of the water reaching three feet below the top of levee, and maintaining that level, is greater than the likelihood of water reaching the top of levee and maintaining that level for a period of time.

The Kansas City District method of estimating the underseepage gradient and the required FS deviates somewhat from the method presented in the EM-1110-2-1913. The Kansas City District's traditional empirical approach has been extensively used and has proven effective in providing adequate underseepage control for most reaches within the Topeka Levee System. This method is based on conclusions of a Corps of Engineers conference, held in Omaha in November, 1962.

Underseepage results will be verified at PED based on ETL 1110-2-569 (1 May 2005).

Input

Permeability parameters were assigned to the blanket materials based on the content of silt, clay, or sand. Only areas that contained a blanket thickness of least 1/4 the height of the levee were considered meaningful in the underseepage model. The traditionally assumed permeability ratios for blanket materials are shown in Table 5. Table 6 shows design assumptions for each unit analyzed.

Table 5. Permeability Ratios for Blanket Materials

Blanket Material	Assigned Permeability Ratio
SM: Silty Sand	100
ML: Silt	200-400
ML-CL: Silt and Clay	400
CL: Low Plasticity Clay	400-600
CH: High Plasticity Clay	800-1000

Table 6. Assumptions for Design

Unit	Max. Water Head at Top of Levee, ft	Ave. Blanket Thickness, ft	Material Type
Oakland	10.75	7	Silt and Clay
North Topeka, sta. 165+00	16.7	6.7	Silt
North Topeka, sta. 246+00	16	6.7	Silt
South Topeka	17	10.6	Silt and Clay

Mitigation Strategies

Berm design was considered only when the area landside of the levee was available for construction. If area for a berm was not available, a buried collector system was considered. In areas that exhibited a blanket thickness of less than 5 feet, relief wells were considered appropriate to provide the underseepage control.

Calculations

The calculations of the underseepage factors of safety used in the underseepage analysis are shown below:

The gradient piping factor of safety is defined as:

$$FSi = \frac{i_c}{i_o}$$

where: ic = critical (or maximum) gradient through blanket = (γs – γw) / γw
io = actual gradient = ho / DbL

The actual gradient, io, is the change in head from the base of the blanket to the top of the blanket. The reference datum is set at the top of the blanket because the movement of the soil grain will begin at the top of the blanket. Actual gradient, io, is defined as the head above the tailwater at the landside levee toe, ho, divided by the depth of the blanket on the landside, DbL. The head above tailwater on the landside, ho, is defined by the following equation:

$$h_0 = \frac{H * L_e}{L_1 + L_2 + L_e}$$

where: H = total head on levee
Le = distance from the landside toe of the assumed impervious section to the effective

seepage exit.
L1= effective length of the riverside blanket
L2= base width of the assumed impervious fill and natural blanket beneath it

The effective length of riverside blanket, L1, is defined by the following equation:

$$L_1 = C_r * \frac{e^{\left(\frac{2L_r}{C_r}\right)} - 1}{e^{\left(\frac{2L_r}{C_r}\right)} + 1}$$

where: Lr= actual length of the riverside natural blanket
Cr= effective length of the pervious foundation of infinite length covered by a natural impervious blanket

$$= \sqrt{D_{fr} * D_{br} * \left(\frac{k_{fr}}{k_{br}}\right)}$$

where: Dfr =depth of pervious riverside foundation
Dbr= depth of impervious riverside natural blanket
kfr= permeability of pervious riverside foundation
kbr= permeability of impervious riverside natural blanket

A-3.2.3 Recommendations

The original designers considered underseepage berms, buried collector, and relief wells for the area being considered. No underseepage control measures were adopted due to marginal safety concerns. The constructed levee section did include a riverside cutoff trench through any unknown upper sand lens layers and a landside sand blanket above the existing ground surface to control any underseepage infiltrating beyond the riverside cutoff trench. The area was to be monitored closely during high water, and future consideration for underseepage control measures were to be based on the monitoring of these reaches.

Geotechnical concerns are related to underseepage beneath the levee which may occur during high flow events. If uncontrolled underseepage is allowed to surface on the landside during a flood, it can create a failure of the levee foundation by piping. Underseepage pressures can be countered using either landside underseepage berms (additional soil placed on the ground surface) to prevent flow to the surface, or by pressure relief wells that provide a controlled path for the underseepage. Berms are the preferred method based on lower installation cost and maintenance needs, but require more real estate for installation and borrow areas. In locations where real estate is not available, relief wells can be installed.

Table 7 shows conclusions from the Existing Conditions Analysis and this Future Conditions

Analysis. The first row is shaded to highlight that it is taken from Table 3.

Table 7. Existing Analysis Summarized with Future Conditions Analysis

	Order of Risk					
	(1) North Topeka		(2) Waterworks	(3) Oakland	(4) South Topeka	(5) Soldier Creek
Existing Conditions Analysis (Table 3) Geotechnical Risk Extents		246+00 to 260+00	16+62 to 33+50	64+00 to 80+00	0+00 to 73+00	13+00 to 130+00
Levee Reaches Analyzed in Future Conditions Analysis	165+00 to 189+00	245+75 to 249+50	No improvements recommended	64+00 to 80+00	22+00 to 48+00	None.
Remedy	Landside underseepage berm	New pressure relief wells	No geotechnical action.	Landside underseepage berm	Land side underseepage berm	No geotechnical action.
Changes from Existing Conditions Analysis	Updated design parameters resulted in adding the proposed length of improvement	Updated design parameters resulted in adjusting the proposed length of improvement.	An existing berm placed by others after construction of unit is not identified on as-built drawings. Need for further action to be identified during PED phase.	No change	Updated design parameters resulted in adjusting the proposed length of improvement.	Low risk. No loss of life or property impacts due to bank slides during falling river phases.

The following is list of the specific modifications proposed for the Topeka Levee system by unit and location:

Oakland Unit

From stations 64+00 to 80+00, install new land side underseepage berm. Dimensions would be

6.5 feet thickness of fill at levee toe sloping to three feet thick at end of berm, and 240 ft. wide. Total borrow required would be 84,500 cy, which includes an additional 25% to account for volume change during excavation and compaction.

Oakland Berm
Station 64+00 to 80+00 = 1600 ft of levee
Berm width: 240 ft landward
Thickness at levee toe: 6.5 ft.
Thickness at end of berm: 3.0 ft.
Average berm thickness: 4.75 ft.

(1600' x 240' x 4.75')/27 = 67,600 cy + 25% = 84,500 cy

North Topeka Unit

Approximately from stations 165+00 to 189+00, install new land side underseepage berm. Dimensions would be seven feet thickness of fill at the levee toe sloping to three feet thick at end of berm, and 220 feet wide. Total borrow required would be 122,250 cy, including an additional 25% required due to volume change during excavation and compaction.

North Topeka Berm
Station 165+00 to 189+00 = 2400 ft of levee
Berm width: 220 ft. landward
Thickness at levee toe: 7 ft
Thickness at end of berm: 3 ft
Average berm thickness: 5 ft

(2400' x 220' x 5')/27 = 97,800 cy + 25% = 122,250 cy

From station 245+75 to 249+50, install new pressure relief wells. Install six wells spaced at 75 feet, each to a depth of 75 feet. The wells are to drain to a central manhole using a buried header system; the total discharge of the system is to be one cfs per well or six cfs total (2700 GPM). The drainage district will be required to pump the water down one foot below existing ground when the river is near the top of levee. A pad should be constructed on the slope for access. The railroad has a series of tracks just outside of the toe of the levee. Work may need to be done inside of the footprint (temporary excavation for drilling access, header pipe system and manhole installation). Civil and mechanical engineers should be consulted to determine the number of manholes required.

Soldier Creek Unit

Most damage to the Soldier Creek Unit is estimated to be from bank slides that would occur after the river rapidly drops then rises again. No loss of life or property impacts are projected to occur. Therefore, no mitigation is considered for this unit.

South Topeka Unit

Approximately from stations 22+00 to 48+00, install new land side underseepage berm. Dimensions would be five feet thickness of fill at levee toe sloping to three feet thick at end of berm, and 100 feet wide. Total borrow would be 48,150 cy, including an additional 25% required due to volume change during excavation and compaction. The calculations are shown below:

South Topeka Berm
Station 22+00 to 48+00 = 2600 ft of levee
Berm width: 100 ft landward
Thickness at levee toe: 5 ft.
Thickness at end of berm: 3 ft
Average berm thickness: 4 ft.

(2600' x 100' x 4')/27 = 38,520 cy + 25% = 48,150 cy

Waterworks Unit

Seepage at this unit was determined not to be a concern after it was discovered fill has been placed where an underseepage berm would have been recommended. The preconstruction, engineering, and design (PED) phase should include analysis of existing conditions to verify assumptions.

A-3.2.4 Borrow Sources

Local sources on the riverside of the levee are probable candidates for borrow material. The PED phase will further evaluate borrow sources with borings, testing, and characterization to determine if the borrow material is suitable. Requirements for underseepage berm material dictate the berm material have a permeability equal to or greater than the underlying soil. It is anticipated all borrow material will be the same and is expected to meet the permeability requirements. Borrow material will be stripped below existing grade before construction of the underseepage berm. Strippage will be replaced as a cap for the completed underseepage berm and serve as topsoil.

A-3.3 References

The following documents prepared by the Kansas City District, U. S. Army Corps of Engineers were used in this study:

Topeka, Kansas, Design Memorandum No. 13, South Topeka Unit, dated May, 1966.

Topeka, Kansas, Design Memorandum No. 3, Waterworks Unit, dated July, 1957.

Topeka, Kansas, Design Memorandum No. 11, Oakland Unit, dated September, 1960.

Topeka, Kansas, Design Memorandum No. 15, North Topeka Unit, dated June, 1961.

Topeka, Kansas, Design Memorandum No. 7, Auburndale Unit, dated September, 1958.

Topeka, Kansas, Design Memorandum No. 2, Soldier Creek Diversion Unit, dated July 1956.

Operation and Maintenance Manual, Flood Protection Project, Topeka, Kansas, Volume Three, Auburndale Unit, Appendix I

Operation and Maintenance Manual, Flood Protection Project, Topeka, Kansas, Volume Two, Soldier Creek Diversion Unit, Appendix I, dated January, 1963.

Topeka, Kansas, Waterworks Unit, Flood Control Project Construction Plans for Relief Well System, Levee, and Appurtenances, dated April 1958.

Operation and Maintenance Manual, Flood Protection Project, Topeka, Kansas, Oakland Unit, Volume Four, Appendix I, dated January 1965.

Operation and Maintenance Manual, Flood Protection Project, Topeka, Kansas, North Topeka Unit, Volume Five, Appendix I

Operation and Maintenance Manual, Flood Protection Project, Topeka, Kansas, Volume Three, Auburndale Unit, Appendix I

Master Operations and Maintenance Manual, Flood Protection Project, Kansas River Basin, Volume 8, Topeka Kansas", dated April 1978.

In addition, the following documents were used in this study:

Design and Construction of Levees, EM 1110-2-1913, prepared by the Department of the Army, Office of the Chief of Engineers, dated April 2000.

Duncan, J. M., Buchignani, A. L., "Geotechnical Engineering: An Engineering Manual for

Slope Stability Studies" Department of Civil Engineering, University of California, Berkeley. March 1975.

Reliability Assessment of Existing Levees for Benefit Determination, ETL 1110-2-328, prepared by the U. S. Army Corps of Engineers, dated March 22, 1993.

Shackelford, C. D., Nelson, P. P., Roth, M. J. S., Uncertainty in the Geologic Environment: From Theory to Practice, Geotechnical Special Publication No. 58 (1996), ASCE, New York, New York.

Risk Based Analysis for Evaluation of the Hydrology/Hydraulics, Geotechnical Stability, and Economics in Flood Damage Reduction Studies, ER 1105-2-101, prepared by the U. S. Army Corps of Engineers, dated March 1996

Risk-Based Analysis in Geotechnical Engineering for Support of Planning Studies. EC 1110-2-554, prepared by the U. S. Army Corps of Engineers, dated February 1998.

HEC-FDA, Flood Damage Reduction Analysis, Users Manual, prepared by the U. S. Army Corps of Engineers, dated March 1998

J. Michael Duncan, Michael Navin, and Katherine Patterson, "Manual for Geotechnical Engineering Reliability Calculations", Department of Civil Engineering, Virginia Polytechnic Institute and State University, December 1999.

J. Michael Duncan, Hon M., "Factors of Safety and Reliability in Geotechnical Engineering" Department of Civil Engineering, Virginia Polytechnic Institute and State University, paper submitted for publication in ASCE Geotechnical Journal, May 1999

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Chapter A-4

CIVIL DESIGN ANALYSIS

A-4 TOPEKA CIVIL DESIGN ANALYSIS

A-4.1 INTRODUCTION

This chapter presents the results of the civil design evaluation performed as part of the existing conditions analysis for the Topeka Local Flood Protection Project. The area of civil design encompasses utility relocations, bridges, and other infrastructure items affected by proposed work. Sanitary, Gas, and water lines were analyzed for Auburndale, N. Topeka, S. Topeka, Oakland, Soldier Creek, and Waterworks.

A-4.2 BRIDGE CLEARANCES

S. Topeka floodwall from sta.74+41 to 93+86 will be replaced due to structural risks detailed in the structural portion of this report. Kansas Avenue Bridge is directly above floodwall. This feasibility doesn't modify the access road or the wall elevations.

A-4.3 REAL ESTATE

A Preliminary Attorney's Opinion of Compensability has been prepared and used for the purpose of completing the study. Final opinions and final relocation determinations will later occur as required by paragraph 12-22 of Engineering Regulation 405-1-12. Any conclusion or categorization contained in this appendix that an item is a utility or facility relocation would result in work to be performed at the cost of the nonfederal sponsor as part of LERRD responsibilities and is preliminary only. The Government will make a final determination of the relocations necessary for the construction, operation or maintenances of the project after further analysis and completion and approval of Final Attorney's Opinions of Compensability for each of the impacted utilities and facilities. For further details on all real estate issues, see the Real Estate Appendix included as part of the main Engineering Feasibility Report.

A-4.4 UTILITY RELOCATIONS

A review of the Kansas City District's criteria for utility lines was performed and a criteria document was developed. See attached document Exhibit A-4.3 Topeka Utility Crossing Guidance. This document was used in determining the disposition of existing utility lines crossing the levee.

A-4.4.1 UTILITY CROSSINGS

N. Topeka Unit

UL 2: Sta 9+35, 24 in Corrugated metal Pipe (CMP). Approximately 6' below top of levee. **Replace with Reinforced Concrete Pipe (RCP).**

UL 3: Sta 275+50, 21 in gravity CMP, Approximately 20 ft below top of levee. **Replace with Reinforced Concrete Pipe (RCP).**

UL 4: Sta 303+60, 18 in waterline CIP, Approximately 16 ft below top of levee. **No action**

Oakland Unit

UL 5: Sta 300+81, 6 in classification unknown , unknown depth. **Investigate during PED.**

UL 7: Sta 516+85, 6 in water, Approximately 12 ft below top of levee. **Relocate up and over levee or provide positive closure.**

Soldier Creek Unit

UL 8: Sta 114+60, 4 in steel gas , Approximately 4 ft below top of levee. **Relocate up and over levee.**

Waterworks Unit

UL 10: Sta 14+90, 2300 Volt powerline in , Approximately 12 ft below top of levee. **Relocate or provide positive closure.**

UL 11: Sta 33+75, 18 in water CIP, Approximately 24 ft below top of levee. **Relocate or provide positive closure.**

UL 12: Sta 35+90, 18 in water CIP, Approximately 24 ft below top of levee. **Relocate or provide positive closure.**

A-4.4.2 Power Lines

No levee raises are anticipated as a result of this feasibility study. As such, modifying powerlines for clearances aren't required.

A-4.4.3 Utility Uplift

The study of uplift on existing utilities was conducted to estimate costs for relocation or removal of functioning or abandoned utilities. Regions were identified for utility uplift concern, based on geotechnical and structural criteria. The region is 500 feet landward of the levee centerline and corresponds with the "critical zone" of the levee.

The attached spreadsheets are titled "Pipe Uplift" (Exhibit A-4.3) and are labeled for the various pipe locations. The civil designer provided the expected types of piping and depths that may be anticipated for the existing piping.

HDR Inc provided a review of the existing project dated January 2000. The HDR report was assumed to have most current data. The references used to determine pipe uplift were taken from 1) HDR reports or 2) Topeka operational and maintenance manual 1978 or 3) Topeka various supplemental designs. Pipe types and sizes, and related comments were taken from the HDR reports. Top of levee and supporting information were taken from the operational manual. Necessary information not found in these two data sets were obtained from the supplemental designs.

In some cases, depths of utilities were not available. Assumptions of 2 ft of cover for gravity lines and 3 ft for water lines were made. In cases where geotechnical data wasn't available, the pressure head (H'O) was assumed. These assumption need to be verified during PED.

Acceptable uplift conditions are calculated under extreme conditions as provided for in ETL 1110-2-307. The uplift factor of safety under this condition is 1.1. Utilities that don't meet this condition fail and require corrective course of actions. A general characterization has also been used for utilities, i.e., if a 10 in pipe failed uplift with 4 ft of cover, then a 6 in pipe with similar cover and soil properties would also fail with no uplift calculations needed.

Acceptable uplift conditions:

These utilities are considered acceptable for uplift and are shown as 'OK" in the action column below.
2, 5, 14, 15, 16,17, 26

Unacceptable uplift conditions:

These utilities are considered unacceptable for uplift and are shown as 'NG" in the action column below. Uplift calculations were not performed on each utility but were grouped by similar grouping characteristics.
4, 6,7,8,22,24,25,27,28

Investigate during PED:

These utilities don't have enough information to be analyzed properly. In some cases, the utilities are shown on The HDR inventory list but not on operational drawings. The ground survey work, which will be done at PED, will provide the information necessary to determine their uplift condition.

In the cases where H'O has been assumed, utilities 18,19,20,21 have failed uplift considerations. H'O needs to be verified once proper geotechnical data is available. For cost purposes, an average utility relocation will be applied to 50% of the total amount of utilities that need to be investigated during PED. These utilities will need further investigation.
1,3, 9,10,11,12,13,18,19,20,21, 23,29

A-4.4.3.1 Auburndale

a. Six utilities were reviewed on this system. Two uplift calculations were performed. The row heading Pipe Line Item No. refers to the 2nd column of spreadsheet exhibit A-4.5 UPLIFT SUMMARY. The results are as follows:

Pipe Line Item No.	Action
1	unknown. Dia. investigate PED
2	Assume OK for grouted pipe
3	unknown. Dia. investigate PED
4	Uplift calc #1 NG
5	Uplift calc #2 OK
6	Uplift NG based on calc #1

Missing information for Pipes 1 and 3 require further investigation during PED. Uplift calculations show failure for uplift on pipe 4 and 6.

A-4.4.3.2 N. Topeka

a. Four utilities were reviewed on this system. Two uplift calculations were performed. The results are as follows:

Pipe Line Item No.	Action
7	Uplift NG
8	Uplift NG
9	Investigate PED
10	Investigate PED

Uplift Calculations for No. 7 and No. 8 show failing uplift conditions. These pipes require investigation during PED.

A-4.4.3.3 Oakland

Not enough information was available to determine uplift.

Pipe Line Item No.	Action
11	Investigate PED
12	Investigate PED
13	Investigate PED

A-4.4.3.4 Soldier Creek

a. Eight utilities were reviewed on this system. Four uplift calculations were performed. The results are as follows:

Pipe Line Item No.	Action
14	Uplift OK based on calc #9
15	Uplift OK, based on calc no. 10
16	Uplift OK, Calc no. 9
17	Uplift OK based on calc #9
18	Uplift NG, Calc No. 11
19	Uplift NG, based on calc #11
20	Uplift NG, Calc No. 12
21	Uplift NG based on calc #12

Reliable geotechnical data wasn't available for the Soldier creek analysis for the above soil types. As such, pressure heads (H'O) were assumed to be at levee top elevations (worst case conditions).

A-4.4.3.5 S. Topeka

a. Four utilities were reviewed on this system. Three uplift calculations were performed. The results are as follows:

Pipe Line Item No.	Action
22	Uplift NG, Calc No. 5
23	Investigate PED
24	Uplift NG, Calc No. 7
25	Uplift NG , Calc No. 8

Pipe Line item 22 is in the floodwall section that will be replaced.

A-4.4.3.6 Waterworks

a. Four utilities were reviewed on this system. Two uplift calculations were performed on the worst cases. The results are as follows:

Pipe Line Item No.	Action
26	Uplift OK, Calc No. 6
27	Uplift NG, Calc No. 13
28	Uplift NG, based on Calc No. 13
29	Investigate PED

A-4.4.3.7 REFFERENCE

The following documents were used in this study:

Topeka, Kansas, HDR reconnaissance study, Topeka Units, dated Sep, 1997.

Topeka, Kansas, Operation and Maintenance Manual Volume III, dated August, 1978.

Topeka, Kansas, Operation and Maintenance Manual Volume III, Auburndale Unit, dated July 1963.

Topeka, Kansas, Operation and Maintenance Manual, Volume VI, South Topeka Unit, dated April 1974

Topeka Kansas, Operation and Maintenance Manual, Section I, Oakland Unit, dated Dec 1961

Topeka, Kansas, Operations and Maintenance Manual, Volume 5, N. Topeka Unit, dated Dec 1968

Topeka, Kansas, Design Memorandum No. 3, Waterworks Unit, dated July, 1957.

Engineering Technical Letter (ETL) 1110-2-307, Flotation Stability Criteria for Concrete Hydraulic Structures, Department of the Army, dated August 1987

CHAPTER A-4

EXHIBITS

Exhibit A-4.1
Topeka Uplift

Assumptions:
Utilities are on landside of levee
units
All lines shall be lowered 2 feet to alleviate uplift
concern
Manholes shall be replaced with
new
Blanket thicknesses are assumed to be 2 ft.
gravity lines assumed to have 2 ft of cover unless stated otherwise
Pressure lines assumed to have 3 ft of cover unless stated otherwise
Pipes not found on drawings are assumed to be 300 ft in length

Auburndale

Utility No.	line size	Material	Type	Length (ft)	Headwalls	depth of cover (ft)
4	18	cmp	gravity	300		2
6	18	cmp	gravity	300		2
N. Topeka						
7	24	cmp	gravity	300		4
8	12	steel	pressure	300		2
S. Topeka						
22	15x24	rcb	pressure	40	2	3
24	27x43	rcb	gravity	200	2	2
25	8	pvc	gravity	300		2
Waterworks						
27	10	cmp	gravity	300		2
28	8	cmp	gravity	300		2

Exhibit A-4.2
Topeka Utility Levee Crossings

Station	line size	Material	Type	Length (ft)	Headwalls	depth of cover (ft)
N. Topeka Unit						
UL 2, 9+35	24	cmp	gravity	100	2	6
UL 3, 275+50	21	cmp	gravity	50	2	20
Oakland Unit						
UL 7, 516+85	6	ci	pressure	86		12
Soldier Creek						
UL 8, 114+60	4	steel	pressure	400		4
Water Works						
UL 10, 14+90	2300 V		Power	86		12
UL 11, 33+75	18	CIP	Water	400		24
UL 12, 35+90	18	CIP	Water	350		24

Exhibit A-4.3
Topeka Utility Crossing Guidance

LEVEE AND FLOODWALL GRAVITY AND UTILITY PIPELINE GUIDANCE

PURPOSE

The purpose of this document is to provide specific guidance as to the disposition of existing utilities and drainage structures within the sections of levee and floodwall to be raised. This guidance will be used for the feasibility level of effort in order to develop reasonable costs associated with the modification of drainage structures and the relocation of utilities.

Uplift of utilities within the critical zone of the levee or floodwall will be addressed in accordance with COE criteria. Uplift is not addressed in this KCL guidance.

REFERENCES

	Local Protection – Web page guidance
	Local Protection - Guidebook on web page
EM 1110-2-1913	Design and Construction of Levees
EM 1110-2-2902	Conduits, Culverts, and Pipes
EM 1110-2-3102	General Principles of Pumping Station Design and Layout
EM 1110-2-3104	Structural and Architectural Design of Pumping Stations
EM 1110-2-3105	Mechanical and Electrical Design of Pumping Stations (Changes 1 of 2)

GRAVITY PIPELINES

Existing pipelines crossing the levee that do not meet current COE criteria shall be replaced with pipelines that are compliant. Existing pipelines that meet current COE criteria shall remain with the following exceptions:

> Any Corrugated Metal Pipe (CMP) with a diameter greater than 36" shall be replaced with a minimum diameter 48" Reinforced Concrete Pipe (RCP).
>
> Any pipe inadequate to handle the drainage shall be replaced with a minimum diameter 48" RCP.
>
> Any pipe known to have joints that are not watertight shall be replaced with a minimum diameter 48" RCP.

For new pipe installations, CMP will not be allowed.

Pipe strengths, unless otherwise known, will be assumed to be that required by Corps criteria at the time of their installation. Pipe condition shall be determined by field assessment.

GATEWELLS AND POSITIVE CLOSURES

In areas where levee raises are performed, positive closure will be provided for all drainage and utility lines crossing the levee. EM 1110-2-1913 states that gravity lines that penetrate the embankment or foundation of a levee must be provided with devices to assure positive closure. This criteria also states that gravity lines should be provided with flap-type or slide-type service gates on the riverside of the levee. Because the KS River and MO River are not fast rising rivers, a flap gate will not be recommended on existing outfalls where sluice gates are present but no flap gate. For new outfall structures, however, flap gates will generally we installed.

Emergency means of closure is suggested for gravity lines in addition to the positive closure device. Historically, a flap gate on the end of the pipe has acted as this second closure device. However, it is possible to use sandbags or concrete to fill a gatewell as a means of emergency closure during a flood situation, although this is not the recommended alternative.

All gatewells within the Kansas City Levee study area are considered confined spaces. OSHA regulations and Corp EM 385-1-1 require anyone entering a confined space to comply with specific confined space entry requirements. New or modified gatewells will be designed so that these confined space entry requirements can be met. For example, space will be provided above the gatewell opening so that a tripod can be set to facilitate non-entry rescue.

NON-GRAVITY PIPELINES CROSSING THROUGH OR UNDER LEVEES

It is preferable for all non-gravity pipes or conduits to cross over the levee rather than penetrate the embankment or foundation materials. This includes pipes carrying fiber optic, pressurized gas or pressurized liquid. Where raises are made to the levee, non-gravity pipelines should be relocated over the crest of the new levee raise. See detail "Typical Utility Crossing Levee Raise".

Pressure pipe

All pipes allowed to penetrate the embankment or foundation of a levee must be provided with devices to assure positive closure. These valves shall be placed at various locations that can be closed rapidly to prevent gas or fluid from escaping within or beneath a levee should the pipe rupture within these areas. Provisions for closure of pressure pipes on the water side must also be provided to prevent backflow of floodwater into the protected area should the pipe rupture.

Casing Pipes and Conduits Crossing Through or Under Levees (Telecommunications)

It is preferred that conduits or casing pipes cross up and over the levee. However, where it is not possible to go over the levee, casing pipes or conduits must be installed in accordance with COE criteria. This criteria states that the conduit crossing through or under a levee must end in an encasement to prevent a preferred seepage path (both external and internal to the conduit). EM 1110-2-1913.

ABANDONED PIPELINES

Pipelines which are currently abandoned and grouted in accordance with COE criteria under or through the levee will not be disturbed. Pipes that have been abandoned and do not meet criteria or it is unknown if they meet criteria shall be removed or filled with grout. Pipelines that are currently active but are to be abandoned as part of this project will be removed or grouted full.

Removal

For feasibility purposes only, the following guidance is used in determining if an abandoned pipeline will be removed or abandoned in-place in accordance with Corps criteria.

Where levee heights are less than 10 feet and when an abandoned utility is buried less than 5 feet below the base of the levee, the abandoned utility crossing under the levee should be removed unless special circumstances warrant a different approach.

Exploration Trench

For cost estimating purposes during feasibility, all known pipes are assumed to be located as shown on maps and plans or as located in the field during feasibility site visits.

No exploration trenches will be specified during feasibility. However, it is noted that during PED phase, it may be determined that exploration trenches will be needed during construction in order to find some utilities or to verify that some utilities do not exist as shown on the drawings.

Grouting Abandoned Pipelines

In accordance with Local Protection guidance, if removal of piping system is not feasible, (i.e. line is too deep for removal) the pipes should be filled with a grout based substance, cement-bentonite, or flowable fill. The grout or flowable fill mix should be approved by the Corps of Engineers. The grout shall be fluid enough, and pumped in the up-slope direction so that the pipe will be completely filled leaving no voids. Points of access need to be made into the pipe at sufficient intervals to accomplish the grouting. See detail "Typical Utility Abandonment – Left in Place" for additional details regarding abandoning a utility in place.

OTHER CONSIDERATIONS

Other considerations will be given to whether a pipe crosses over or under levee on a case by case basis when HTRW concerns or real estate issues exist. HTRW concerns exist in various locations along the Kansas City Seven Levee system. When it is desirable to not disturb the existing ground due to HTRW concerns, the final recommendation for relocating an existing utility will weigh the risks involved with disturbing the ground against leaving an existing utility in place. When real estate issues exist, the final recommendation will consider how real estate is affected.

SUMMARY OF RECOMMENDATIONS

For sections of levee or floodwall to be raised or modified, current Corps requirements will be extended to all components of that levee section, including any pipes and closure structures therein. When it is not practical to meet Corps requirement, each utility will be evaluated on a case-by-case basis.

EXHIBIT A-4.4

UPLIFT SUMMARY

EXHIBIT A-4.4 UPLIFT SUMMARY

	Item No.	uplift calc #	Sta (from hdr)	flow type	conduit type	conduit size (in)	function	depth below flood protection	source	note	findings
Auburndale											
	1		1 - 10						hdr spreadsheet misc structures.xls	possible exp for water treatment, not enough information to asses	need to investigate during design
	2		15.96	force		6	water		hdr spreadsheet misc structures.xls		Abandoned/grouted in place
	3		23 - 36				water		hdr spreadsheet misc structures.xls		need to investigate during design
	4	1	27.70		cmp	18	storm		hdr spreadsheet misc structures.xls	No depth provided assumed 2.5' cover for drainage	uplift ng
	5	2	28.30			3 - 42"			hdr spreadsheet misc structures.xls	discharge pipes for ward martin	uplift ok
	6		31.00	gravity	cmp	18			hdr spreadsheet misc structures.xls		uplift ng based on calc #1
N Topeka	7	3	277.00	gravity	cmp	24	sand	4	hdr spreadsheet floodprotection.xls	field located, not on drawings, geot info 50' away	uplift ng
	8	4	295.00	pressure	steel	12	sand plant suction	2	hdr spreadsheet floodprotection.xls	field located, not on drawings	uplift ng
	9		sta 12+50	pressure		16	water		hdr spreadsheet misc structures.xls	not on drawings, hdr notes	need to investigate during design
	10		sta 82+50	pressure	dip	18	water		hdr spreadsheet misc structures.xls	not on drawings, hdr notes	need to investigate during design
Oakland											
	11		sta 168		steel pipe	6	magnolia steel pipe		hdr spreadsheet oakfloodprotection.xls		need to investigate during design
	12		sta 185+65	pressure		6			hdr spreadsheet oakfloodprotection.xls		need to investigate during design
	13		sta 300+08	pressure		6	magnolia steel pipe		hdr spreadsheet oakfloodprotection.xls		need to investigate during design
Soldier Creek											
	14		sta 294	pressure	dip	12	water	6.5	hdr spreadsheet soldier floodprotection.xls	no geotechnical parameters provided for uplift	uplift ok based on calc #9
	15	10	sta 317+33	gravity	cip	6	sanitary	2.2	hdr spreadsheet soldier floodprotection.xls	no geotechnical parameters provided, assumed Ho at top of levee, blanket, bedrock assumed	uplift ok
	16	9	sta 356	pressure	dip	12	water	5.3	hdr spreadsheet soldier floodprotection.xls	no geotechnical parameters provided, assumed Ho at top of levee, blanket, bedrock assumed	uplift ok
	17		sta 410	gravity	cmp	12	storm	7	hdr spreadsheet soldier floodprotection.xls	no geotechnical parameters provided for uplift	uplift ok based on calc #9
	18	11	sta 8+85	gravity	cmp	30	storm	8.9	hdr spreadsheet soldier floodprotection.xls	Ho assumed at levee top	need to investigate during design
	19		sta 10+33	gravity	cmp	24	storm	7.8	hdr spreadsheet soldier floodprotection.xls	no geotechnical parameters provided for uplift	need to investigate based on uplift #11
	20	12	sta 6+50	gravity	cmp	12	storm	9	hdr spreadsheet soldier floodprotection.xls	no geotechnical parameters provided, assumed Ho at top of levee, blanket, bedrock assumed	need to investigate
	21		sta 14	gravity	cmp	18	storm	9	hdr spreadsheet soldier floodprotection.xls	no geotechnical parameters provided for uplift	need to investigate based on #12
S Topeka											
	22	5	sta 75+74	pressure	cip	15, 24	discharge piping	3	hdr spreadsheet south topeka floodprotection.xls		uplift ng
	23		sta 2+40	gravity	rcb	15x7			hdr spreadsheet south topeka floodprotection.xls	not found on drawings,	need to investigate
	24	7	sta 39+50	gravity	rcb	27 x 43"	storm		hdr spreadsheet south topeka misc structures.xls	300' ls	uplift ng
	25	8	sta 61+50	gravity	pvc	8"	sanitary		hdr spreadsheet south topeka misc structures.xls	250' ls, 2 ft cover assumed	uplift ng <.95
Waterworks											
	26	6	sta 17+49	gravity	steel pipe	20	storm	6.8	hdr spreadsheet waterworks floodprotection.xls		uplift ok
	27	13	sta 0+60		cmp	10	storm		hdr spreadsheet waterworks floodprotection.xls	not found on drawings assumed 2' of cover	uplift ng
	28		sta 1+20			8	storm		hdr spreadsheet waterworks floodprotection.xls	not found on drawings assumed 2' of cover	uplift ng based on calc # 13
	29		sta 11+20 to 13+00			36	interceptor		hdr spreadsheet waterworks floodprotection.xls	not found on drawings, assumed 2' of cover	uplift ng based on calc # 13

Assumptions:

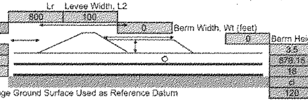
EXHIBIT A-4.5

UPLIFT CALCULATION TABLES

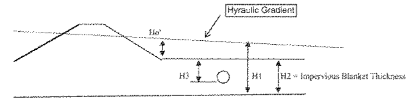
EXHIBIT A - 12.5 UPLIFT CALCULATIONS

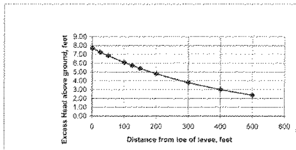
Auburndale	K-r	K-L	DbL	Dbo	Dbr	Df	H	i-c	Lr	Wt	Safety	L1	L2	Le	Lt	L't	Ho'	Hwt/2	Hwt	i-o	Cr	Cl	t	s
uplift #1																							feet	
	500	500	9	9	9	40	16.85	0.84	800	0	0.99	405	100	424	929	929	7.69	7.69	7.69	0.85	424	424	0	0.000

Geotechnical data (above) presented in this spreadsheet was provided by Geotechnical Engineer, Scott Loehr, and is used to develop the Hydraulic Gradient at various distances from the toe. Verification of these numbers is done separately.



Ground Elev = Landside Average Ground Surface Used as Reference Datum





d=Landside Distance from Toe Feet	No Berm Calcs Excess Head Feet, Ho'	Invert Elev of pipe	Design Base Blanket Feet, MSL	Ground Elev Feet, MSL	H3 Feet	H2 Feet	H1 Feet	P3 Psf	Ws lb	Wc lb	S lb	U lb	Wg lb	SFf (Full)	SFf (Empty)
0	7.69	878.15	872.65	881.65	3.5	9	16.7	405.1	20	110	360	608	0	0.81	0.62
25	7.25	878.15	872.65	881.65	3.5	9	16.3	394.4	20	110	360	592	0	0.83	0.64
50	6.84	878.15	872.65	881.65	3.5	9	15.8	384.3	20	110	360	578	0	0.85	0.66
100	6.08	878.15	872.65	881.65	3.5	9	15.1	365.9	20	110	360	549	0	0.89	0.69
125	5.73	878.15	872.65	881.65	3.5	9	14.7	357.4	20	110	360	536	0	0.91	0.71
150	5.40	878.15	872.65	881.65	3.5	9	14.4	349.5	20	110	360	524	0	0.93	0.72
200	4.80	878.15	872.65	881.65	3.5	9	13.8	334.9	20	110	360	502	0	0.97	0.76
300	3.79	878.15	872.65	881.65	3.5	9	12.8	310.4	20	110	360	466	0	1.05	0.81
400	3.00	878.15	872.65	881.65	3.5	9	12.0	291.1	20	110	360	437	0	[illegible]	0.87
500	2.37	878.15	872.65	881.65	3.5	9	11.4	275.8	20	110	360	414	0	[illegible]	0.92

Ws Calc
19.5
Wc Calc
110

See Sample Calculations for list of abbreviations and sample calculations

S = surcharge loads = weight of satuarted soils above = (H3-Pipe Diameter/12)*(Pipe Diameter/12)*1γsoil

P3 = H3*(H1/H2)*γwater

U = Uplift force on the project area of structure = Area of pipe * P3 = (Pipe Diameter/12)*1*P3

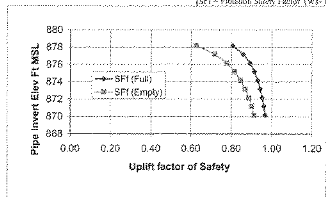
Wg = weight of surcharge water above top surface of structure control by gravity flow

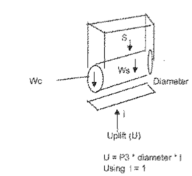
SFf = Flotation Safety Factor (Ws+Wc+S)/(U-Wg)

Use this table to determine the distance from toe at which the Safety Factor is me

Enter the Distance from toe and change the value until the SFf is equal to that required

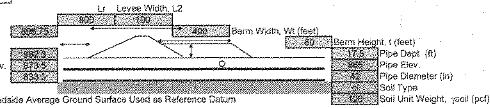
	Ground Elev 881.65		Distance from toe (ft)	0			
		Ws = 20		Wc = 110 Full		Uplift Safety Extreme Case (1.1 REQ'D)	
Depth Below Ground	Pipe Inv Elev, Ft	Surcharge Load, S, lbs/ft	Uplift (U) Force, lbs/ft	Pipe Weight, Lbs/ft	Full water Wt, Lbs / ft	SFf Full	SFf Empty
	881.65	0		20	110		
3.5	878.15	360	608	20	110	0.81	0.62
4.5	877.15	540	781	20	110	0.86	0.72
5.5	876.15	720	955	20	110	0.89	0.77
6.5	875.15	900	1128	20	110	0.91	0.81
7.5	874.15	1080	1302	20	110	0.93	0.84
8.5	873.15	1260	1476	20	110	0.94	0.87
9.5	872.15	1440	1649	20	110	0.95	0.89
10.5	871.15	1620	1823	20	110	0.96	0.90
11.5	870.15	1800	1996	20	110	0.97	0.91



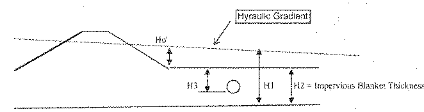


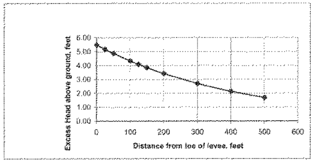
Auburndale	K-r	K-L	DbL	Dbo	Dbr	Df	H	i-c	Lr	Wt	Safety	L1	L2	Le	Lt	L't	Ho'	Hwt/2	Hwt	i-o	Cr	Cl	t	s
uplift #2																							feet	
	500	500	9	9	9	40	12	0.84	800	0	1.38	405	100	424	929	929	5.48	5.48	5.48	0.61	424	424	0	0.000

Geotechnical data (above) presented in this spreadsheet was provided by Geotechnical Engineer, Scott Loehr, and is used to develop the Hydraulic Gradient at various distances from the toe. Verification of these numbers is done separately.



Ground Elev = Landside Average Ground Surface Used as Reference Datum





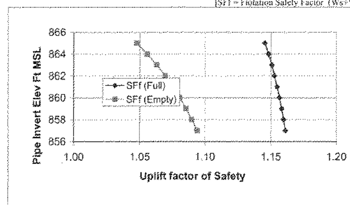
d=Landside Distance from Toe Feet	No Berm Calcs Excess Head Feet, Ho'	Invert Elev of pipe 42 -in steel	Design Base Blanket Feet, MSL	Ground Elev Feet, MSL	H3 Feet	H2 Feet	H1 Feet	P3 Psf	Ws lb	Wc lb	S lb	U lb	Wg lb	SFf (Full)	SFf (Empty)
0	5.48	865	873.5	882.5	17.5	9	14.5	1756.6	561	600	5880	6148	0	[illegible]	1.05
25	5.16	865	873.5	882.5	17.5	9	14.2	1718.6	561	600	5880	6015	0	[illegible]	1.07
50	4.87	865	873.5	882.5	17.5	9	13.9	1682.7	561	600	5880	5890	0	[illegible]	1.09
100	4.33	865	873.5	882.5	17.5	9	13.3	1617.1	561	600	5880	5660	0	[illegible]	[illegible]
125	4.08	865	873.5	882.5	17.5	9	13.1	1587.0	561	600	5880	5555	0	[illegible]	[illegible]
150	3.85	865	873.5	882.5	17.5	9	12.8	1558.7	561	600	5880	5455	0	[illegible]	[illegible]
200	3.42	865	873.5	882.5	17.5	9	12.4	1506.8	561	600	5880	5274	0	[illegible]	[illegible]
300	2.70	865	873.5	882.5	17.5	9	11.7	1419.7	561	600	5880	4969	0	[illegible]	[illegible]
400	2.13	865	873.5	882.5	17.5	9	11.1	1350.9	561	600	5880	4728	0	[illegible]	[illegible]
500	1.69	865	873.5	882.5	17.5	9	10.7	1296.5	561	600	5880	4538	0	[illegible]	[illegible]

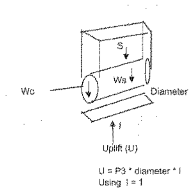
Ws Calc
561
Wc Calc
600

See Sample Calculations for list of abbreviations and sample calculations
Ws = weight of structure per foot of length = 500 lb per ft 42-inch Diameter ...
Wc = weight of water contained in the structure ...
S = surcharge loads = weight of satuarted soils above = (H3-Pipe Diameter/12)*(Pipe Diameter/12)*1*γsoil
P3 = H3*(H1/H2)*γwater
U = Uplift force on the project area of structure = Area of pipe * P3 = (Pipe Diameter/12)*1*P3
Wg = weight of surcharge water above top surface of structure control by gravity flow
SFf = Flotation Safety Factor (Ws+Wc+S)/(U-Wg)

Use this table to determine the distance from toe at which the Safety Factor is me
Enter the Distance from toe and change the value until the SFf is equal to that required

	Ground Elev 882.5	Distance from toe (ft)	0			Uplift Safety Extreme Case (1.1 REQ'D)	
		Ws = 561		Wc = 600 Full			
Depth Below Ground	Pipe Inv Elev, Ft	Surcharge Load, S, lbs/ft	Uplift (U) Force, lbs/ft	Pipe Weight, Lbs/ft	Full water Wt, Lbs / ft	SFf Full	SFf Empty
	882.5	0		561	600		
17.5	865	5880	6148	561	600	[illegible]	1.05
18.5	864	6300	6500	561	600	[illegible]	1.06
19.5	863	6720	6851	561	600	[illegible]	1.06
20.5	862	7140	7202	561	600	[illegible]	1.07
21.5	861	7560	7554	561	600	[illegible]	1.08
22.5	860	7980	7905	561	600	[illegible]	1.08
23.5	859	8400	8256	561	600	[illegible]	1.09
24.5	858	8820	8607	561	600	[illegible]	1.09
25.5	857	9240	8959	561	600	[illegible]	1.09





n. topeka	K-r	K-L	DbL	Dbo	Dbr	Df	H	i-c	Lr	Wt	Safety	L1	L2	Le	Lt	L't	Ho'	Hwt/2	Hwt	i-o	Cr	Cl	t	s
uplift #3																							feet	
	300	300	14	14	14	56	11.6	0.84	350	0	1.77	300	58	485	843	843	6.68	6.68	6.68	0.48	485	485	0	0.000

Geotechnical data (above) presented in this spreadsheet was provided by Geotechnical Engineer, Scott Loehr, and is used to develop the Hydraulic Gradient at various distances from the toe. Verification of these numbers is done separately.

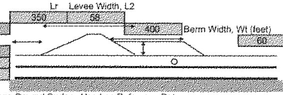
Levee Elev. 895.6

Lr 350 | Levee Width, L2 58

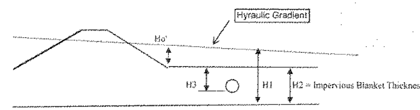
Berm Width, Wt (feet) 400

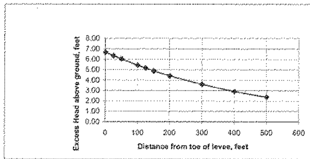
Berm Height, t (feet) 60

Ground Elev.	884	4	Pipe Dept (ft)
Blanket Base Elev.	870	880	Pipe Elev.
Bedrock Elev.	814	24	Pipe Diameter (in)
		ml	Soil Type
		120	Soil Unit Weight, γsoil (pcf)



Ground Elev = Landside Average Ground Surface Used as Reference Datum





d=Landside Distance from Toe Feet	No Berm Calcs Excess Head Feet, Ho'	Invert Elev of pipe 24 -in steel	Design Base Blanket Feet, MSL	Ground Elev Feet, MSL	H3 Feet	H2 Feet	H1 Feet	P3 Psf	Ws lb	Wc lb	S lb	U lb	Wg lb	SFf (Full)	SFf (Empty)
0	6.68	880	870	884	4	14	20.7	368.6	26	195	480	737	0	0.95	0.69
25	6.34	880	870	884	4	14	20.3	362.6	26	195	480	725	0	0.97	0.70
50	6.02	880	870	884	4	14	20.0	357.0	26	195	480	714	0	0.98	0.71
100	5.43	880	870	884	4	14	19.4	346.4	26	195	480	693	0	1.01	0.73
125	5.16	880	870	884	4	14	19.2	341.6	26	195	480	683	0	1.03	0.74
150	4.90	880	870	884	4	14	18.9	337.0	26	195	480	674	0	1.04	0.75
200	4.42	880	870	884	4	14	18.4	328.4	26	195	480	657	0	1.07	0.77
300	3.60	880	870	884	4	14	17.6	313.7	26	195	480	627	0	[illegible]	0.81
400	2.93	880	870	884	4	14	16.9	301.8	26	195	480	604	0	[illegible]	0.84
500	2.38	880	870	884	4	14	16.4	292.1	26	195	480	584	0	[illegible]	0.87

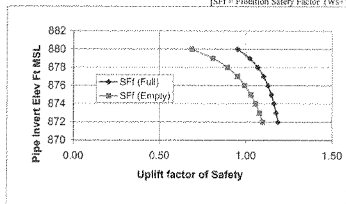
Ws Calc 25.5

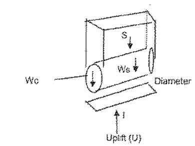
Wc Calc 195

See Sample Calculations for list of abbreviations and sample calculations
[illegible]
[illegible]
S = surcharge loads = weight of satuarted soils above = (H3-Pipe Diameter/12)*(Pipe Diameter/12)*1*γsoil
P3 = H3*(H1/H2)*γwater
U = Uplift force on the project area of structure = Area of pipe * P3 = (Pipe Diameter/12)*1*P3
Wg = weight of surcharge water above top surface of structure control by gravity flow
SFf = Flotation Safety Factor (Ws+Wc+S)/(U-Wg)

Use this table to determine the distance from toe at which the Safety Factor is me
Enter the Distance from toe and change the value until the SFf is equal to that required

	Ground Elev 884		Distance from toe (ft)	0			
		Ws = 26		Wc = 195 Full		Uplift Safety Extreme Case (1.1 REQ'D)	
Depth Below Ground	Pipe Inv Elev. Ft	Surcharge Load, S, lbs/ft	Uplift (U) Force, lbs/ft	Pipe Weight, Lbs/ft	Full water Wt, Lbs / ft	SFf Full	SFf Empty
	884	0		26	195		
4	880	480	737	26	195	0.95	0.69
5	879	720	922	26	195	1.02	0.81
6	878	960	1106	26	195	1.07	0.89
7	877	1200	1290	26	195	[illegible]	0.95
8	876	1440	1474	26	195	[illegible]	0.99
9	875	1680	1659	26	195	[illegible]	1.03
10	874	1920	1843	26	195	[illegible]	1.06
11	873	2160	2027	26	195	[illegible]	1.08
12	872	2400	2212	26	195	[illegible]	1.10





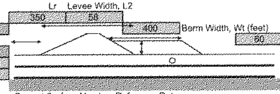
U = P3 * diameter * l
Using l = 1

n. topeka
uplift #4

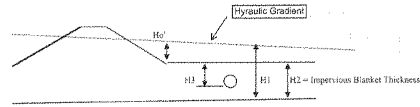
K-r	K-L	DbL	Dbo	Dbr	Df	H	i-c	Lr	Wt	Safety	L1	L2	Le	Lt	L't	Ho'	Hwt/2	Hwt	i-o	Cr	Cl	t	s
																						feet	
300	300	14	14	14	56	4	0.84	350	0	5.13	300	58	485	843	843	2.30	2.30	2.30	0.16	485	485	0	0.000

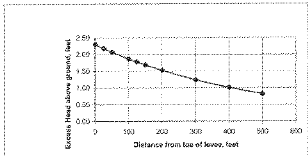
Geotechnical data (above) presented in this spreadsheet was provided by Geotechnical Engineer, Scott Loehr, and is used to develop the Hydraulic Gradient at various distances from the toe. Verification of these numbers is done separately.

Lr	350
Levee Width, L2	58
Berm Width, Wt (feet)	400
Berm Height, t (feet)	60
Levee Elev.	894
Ground Elev.	890
Blanket Base Elev.	876
Bedrock Elev.	820
Pipe Dept (ft)	2
Pipe Elev.	888
Pipe Diameter (in)	12
Soil Type	ml
Soil Unit Weight, γsoil (pcf)	120



Ground Elev = Landside Average Ground Surface Used as Reference Datum





d=Landside Distance from Toe Feet	No Berm Calcs Excess Head Feet, Ho'	Invert Elev of pipe 12 -in steel	Design Base Blanket Feet, MSL	Ground Elev Feet, MSL	H3 Feet	H2 Feet	H1 Feet	P3 Psf	Ws lb	Wc lb	S lb	U lb	Wg lb	SFf (Full)	SFf (Empty)
0	2.30	888	876	890	2	14	16.3	145.3	50	49	120	145	0	[illegible]	[illegible]
25	2.19	888	876	890	2	14	16.2	144.3	50	49	120	144	0	[illegible]	[illegible]
50	2.08	888	876	890	2	14	16.1	143.3	50	49	120	143	0	[illegible]	[illegible]
100	1.87	888	876	890	2	14	15.9	141.5	50	49	120	141	0	[illegible]	[illegible]
125	1.78	888	876	890	2	14	15.8	140.7	50	49	120	141	0	[illegible]	[illegible]
150	1.69	888	876	890	2	14	15.7	139.9	50	49	120	140	0	[illegible]	[illegible]
200	1.52	888	876	890	2	14	15.5	138.4	50	49	120	138	0	[illegible]	[illegible]
300	1.24	888	876	890	2	14	15.2	135.9	50	49	120	136	0	[illegible]	[illegible]
400	1.01	888	876	890	2	14	15.0	133.8	50	49	120	134	0	[illegible]	[illegible]
500	0.82	888	876	890	2	14	14.8	132.1	50	49	120	132	0	[illegible]	[illegible]

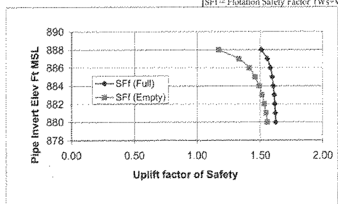
Ws Calc
50

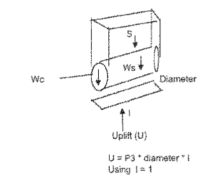
Wc Calc
49

See Sample Calculations for list of abbreviations and sample calculations
S = surcharge loads = weight of satuarted soils above = (H3-Pipe Diameter/12)*(Pipe Diameter/12)*1*γsoil
P3 = H3*(H1/H2)*γwater
U = Uplift force on the project area of structure = Area of pipe * P3 = (Pipe Diameter/12)*1*P3
Wg = weight of surcharge water above top surface of structure control by gravity flow
SFf = Flotation Safety Factor (Ws+Wc+S)/(U-Wg)

Use this table to determine the distance from toe at which the Safety Factor is me
Enter the Distance from toe and change the value until the SFf is equal to that required

Depth Below Ground	Pipe Inv Elev, Ft	Surcharge Load, S, lbs/ft	Uplift (U) Force, lbs/ft	Pipe Weight, Lbs/ft	Full water Wt, Lbs / ft	Uplift Safety Extreme Case (1.1 REQ'D) SFf Full	SFf Empty
Ground Elev 890	Distance from toe (ft) 0						
		Ws = 50		Wc = 49 Full			
	890	0		50	49		
2	888	120	145	50	49	[illegible]	[illegible]
3	887	240	218	50	49	[illegible]	[illegible]
4	886	360	291	50	49	[illegible]	[illegible]
5	885	480	363	50	49	[illegible]	[illegible]
6	884	600	436	50	49	[illegible]	[illegible]
7	883	720	509	50	49	[illegible]	[illegible]
8	882	840	581	50	49	[illegible]	[illegible]
9	881	960	654	50	49	[illegible]	[illegible]
10	880	1080	727	50	49	[illegible]	[illegible]





U = P3 * diameter * l
Using l = 1

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Page 1 of 1

s. topeka
uplift #5

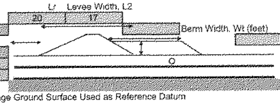
K-r	K-L	DbL	Dbo	Dbr	Df	H	i-c	Lr	Wt	Safety	L1	L2	Le	Lt	L't	Ho'	Hwt/2	Hwt	i-o	Cr	Cl	t	s
																						feet	
300	300	15.5	15.5	15.5	80	12	0.84	20	0	1.50	20	17	610	647	843	8.68	8.68	8.68	0.56	610	610	0	0.000

Geotechnical data (above) presented in this spreadsheet was provided by Geotechnical Engineer, Scott Loehr, and is used to develop the Hydraulic Gradient at various distances from the toe. Verification of these numbers is done separately.

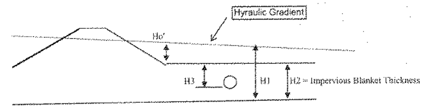
Lr Levee Width, L2
20 17

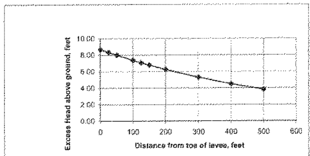
Levee Elev. 892
Ground Elev. 890
Blanket Base Elev. 874.5
Bedrock Elev. 794.5

Berm Width, Wt (feet)
Berm Height, t (feet)
7 Pipe Dept (ft)
883 Pipe Elev.
24 Pipe Diameter (in)
ml Soil Type
120 Soil Unit Weight, γsoil (pcf)



Ground Elev = Landside Average Ground Surface Used as Reference Datum





d=Landside Distance from Toe Feet	No Berm Calcs Excess Head Feet, Ho'	Invert Elev of pipe 24 -in steel	Design Base Blanket Feet, MSL	Ground Elev Feet, MSL	H3 Feet	H2 Feet	H1 Feet	P3 Psf	Ws lb	Wc lb	S lb	U lb	Wg lb	SFf (Full)	SFf (Empty)
0	8.68	883	874.5	890	7	15.5	24.2	681.5	8	195	1200	1363	0	1.03	0.89
25	8.33	883	874.5	890	7	15.5	23.8	671.6	8	195	1200	1343	0	1.04	0.90
50	8.00	883	874.5	890	7	15.5	23.5	662.2	8	195	1200	1324	0	1.06	0.91
100	7.37	883	874.5	890	7	15.5	22.9	644.5	8	195	1200	1289	0	1.09	0.94
125	7.07	883	874.5	890	7	15.5	22.6	636.1	8	195	1200	1272	0	[illegible]	0.95
150	6.79	883	874.5	890	7	15.5	22.3	628.1	8	195	1200	1256	0	[illegible]	0.96
200	6.25	883	874.5	890	7	15.5	21.8	613.1	8	195	1200	1226	0	[illegible]	0.98
300	5.31	883	874.5	890	7	15.5	20.8	586.4	8	195	1200	1173	0	[illegible]	1.03
400	4.51	883	874.5	890	7	15.5	20.0	563.8	8	195	1200	1128	0	[illegible]	1.07
500	3.82	883	874.5	890	7	15.5	19.3	544.6	8	195	1200	1089	0	[illegible]	[illegible]

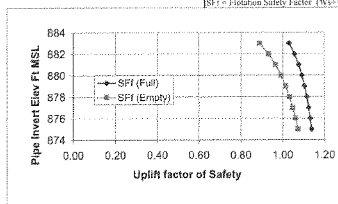
Ws Calc
7.66

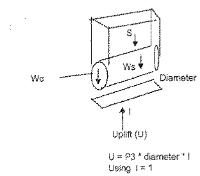
Wc Calc
195

See Sample Calculations for list of abbreviations and sample calculations
Ws = weight of structure per foot of length = 7.7 lb per ft 15 inch Diameter dip
Wc = weight of water contained in the structure = [illegible]
S = surcharge loads = weight of satuarted soils above = (H3-Pipe Diameter/12)*(Pipe Diameter/12)*1*γsoil
P3 = H3*(H1/H2)*γwater
U = Uplift force on the project area of structure = Area of pipe * P3 = (Pipe Diameter/12)*1*P3
Wg = weight of surcharge water above top surface of structure control by gravity flow
SFf = Flotation Safety Factor (Ws+Wc+S)/(U-Wg)

Use this table to determine the distance from toe at which the Safety Factor is me
Enter the Distance from toe and change the value until the SFf is equal to that required

	Ground Elev 890		Distance from toe (ft)	0			
		Ws = 8		Wc = 195 Full		Uplift Safety Extreme Case (1.1 REQ'D)	
Depth Below Ground	Pipe inv Elev, Ft	Surcharge Load, S, lbs/ft	Uplift (U) Force, lbs/ft	Pipe Weight, Lbs/ft	Full water Wt, Lbs / ft	SFf Full	SFf Empty
	890	0		8	195		
7	883	1200	1363	8	195	1.03	0.89
8	882	1440	1558	8	195	1.05	0.93
9	881	1680	1752	8	195	1.07	0.96
10	880	1920	1947	8	195	1.09	0.99
11	879	2160	2142	8	195	[illegible]	1.01
12	878	2400	2336	8	195	[illegible]	1.03
13	877	2640	2531	8	195	[illegible]	1.05
14	876	2880	2726	8	195	[illegible]	1.06
15	875	3120	2921	8	195	[illegible]	1.07





Waterworks uplift #6	K-r	K-L	DbL	Dbo	Dbr	Df	H	i-c	Lr	Wt	Safety	L1	L2	Le	Lt	L't	Ho'	Hwt/2	Hwt	i-o	Cr	Cl	t feet	s
	500	500	7.6	7.6	7.6	50	9.5	0.84	150	0	0.92	144	15	436	595	595	6.96	6.96	7.00	0.92	436	436	0	0.000

Geotechnical data (above) presented in this spreadsheet was provided by Geotechnical Engineer, Scott Loehr, and is used to develop the Hydraulic Gradient at various distances from the toe. Verification of these numbers is done separately.

Lr 150 | Levee Width, L2 15

Levee Elev. 896.5 | Berm Width, W1 (feet) 400

Berm Height, t (feet) 60

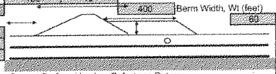
Ground Elev. 879 | Pipe Dept (ft) 6.8

Blanket Base Elev. 871.4 | Pipe Elev. 872.2

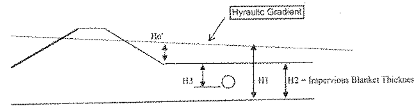
Bedrock Elev. 821.4 | Pipe Diameter (in) 20

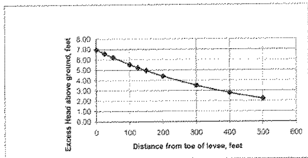
Soil Type cl

Soil Unit Weight, γsoil (pcf) 120



Ground Elev = Landside Average Ground Surface Used as Reference Datum





d=Landside Distance from Toe Feet	No Berm Calcs Excess Head Feet, Ho'	Invert Elev of pipe 20 -in steel	Design Base Blanket Feet, MSL	Ground Elev Feet, MSL	H3 Feet	H2 Feet	H1 Feet	P3 Psf	Ws lb	Wc lb	S lb	U lb	Wg lb	SFf (Full)	SFf (Empty)
0	6.96	872.2	871.4	879	6.8	7.6	14.6	813.0	78	136	1027	1355	0	0.92	0.82
25	6.57	872.2	871.4	879	6.8	7.6	14.2	791.3	78	136	1027	1319	0	0.94	0.84
50	6.21	872.2	871.4	879	6.8	7.6	13.8	770.9	78	136	1027	1285	0	0.97	0.86
100	5.53	872.2	871.4	879	6.8	7.6	13.1	733.3	78	136	1027	1222	0	1.02	0.90
125	5.23	872.2	871.4	879	6.8	7.6	12.8	716.1	78	136	1027	1194	0	1.04	0.93
150	4.93	872.2	871.4	879	6.8	7.6	12.5	699.8	78	136	1027	1166	0	1.06	0.95
200	4.40	872.2	871.4	879	6.8	7.6	12.0	670.0	78	136	1027	1117	0	[redacted]	0.99
300	3.50	872.2	871.4	879	6.8	7.6	11.1	619.6	78	136	1027	1033	0	[redacted]	1.07
400	2.78	872.2	871.4	879	6.8	7.6	10.4	579.6	78	136	1027	966	0	[redacted]	[redacted]
500	2.21	872.2	871.4	879	6.8	7.6	9.8	547.8	78	136	1027	913	0	[redacted]	[redacted]

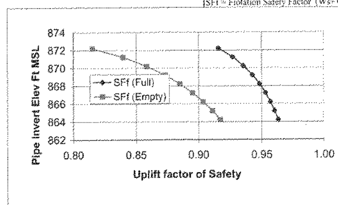
Ws Calc
78

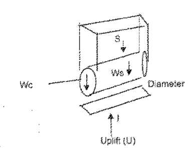
Wc Calc
136

See Sample Calculations for list of abbreviations and sample calculations
Ws = weight of structure per foot of length = 78 lb per ft 20 inch D structure at
Wc = weight of water contained in the structure = ...
S = surcharge loads = weight of satuarted soils above = (H3-Pipe Diameter/12)*(Pipe Diameter/12)*1*γsoil
P3 = H3*(H1/H2)*γwater
U = Uplift force on the project area of structure = Area of pipe * P3 = (Pipe Diameter/12)*1*P3
Wg = weight of surcharge water above top surface of structure control by gravity flow
SFf = Flotation Safety Factor (Ws+Wc+S)/(U-Wg)

Use this table to determine the distance from toe at which the Safety Factor is me
Enter the Distance from toe and change the value until the SFf is equal to that required

	Ground Elev 879	Distance from toe (ft)		0			
		Ws = 78		Wc = 136 Full		Uplift Safety Extreme Case (1.1 REQ'D)	
Depth Below Ground	Pipe Inv Elev, Ft	Surcharge Load, S, lbs/ft	Uplift (U) Force, lbs/ft	Pipe Weight, Lbs/ft	Full water Wt, Lbs / ft	SFf Full	SFf Empty
	879	0		78	136		
6.8	872.2	1027	1355	78	136	0.92	0.82
7.8	871.2	1227	1554	78	136	0.93	0.84
8.8	870.2	1427	1753	78	136	0.94	0.86
9.8	869.2	1627	1953	78	136	0.94	0.87
10.8	868.2	1827	2152	78	136	0.95	0.89
11.8	867.2	2027	2351	78	136	0.95	0.90
12.8	866.2	2227	2551	78	136	0.96	0.90
13.8	865.2	2427	2750	78	136	0.96	0.91
14.8	864.2	2627	2949	78	136	0.96	0.92





U = P3 * diameter * l
Using l = 1

s. Topeka uplift #7	K-r	K-L	DbL	Dbo	Dbr	Df	H	i-c	Lr	Wt	Safety	L1	L2	Le	Lt	L't	Ho'	Hwt/2	Hwt	i-o	Cr	Cl	t	s
																							feet	
	400	400	11.3	11.3	11.3	80	11.7	0.84	10	0	0.94	10	80	601	691	692	10.17	10.17	10.17	0.90	601	601	0	0.000

Geotechnical data (above) presented in this spreadsheet was provided by Geotechnical Engineer, Scott Loehr, and is used to develop the Hydraulic Gradient at various distances from the toe. Verification of these numbers is done separately.

Lr: 10 — Levee Width, L2: 80

Levee Elev.: 893.8 — Berm Width, Wt (feet): 400 — Berm Height, t (feet): 60

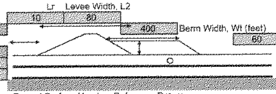
Ground Elev.: 890 — Pipe Dept (ft): 12.5

Blanket Base Elev.: 878.7 — Pipe Elev.: 877.5

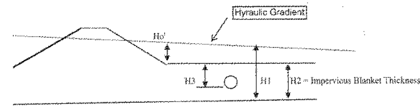
Bedrock Elev.: 796.7 — Pipe Diameter (in): 38

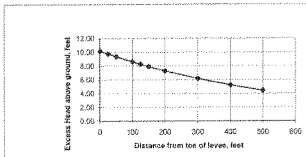
Soil Type: ml-cl

Soil Unit Weight, γsoil (pcf): 120



Ground Elev = Landside Average Ground Surface Used as Reference Datum





d=Landside — No Berm Calcs

Distance from Toe Feet	Excess Head Feet, Ho'	Invert Elev of pipe 38 -in steel	Design Base Blanket Feet, MSL	Ground Elev Feet, MSL	H3 Feet	H2 Feet	H1 Feet	P3 Psf	Ws lb	Wc lb	S lb	U lb	Wg lb	SFf (Full)	SFf (Empty)
0	10.17	877.5	878.7	890	12.5	11.3	21.5	1481.8	435	491	3547	4692	0	0.95	0.85
25	9.75	877.5	878.7	890	12.5	11.3	21.1	1453.2	435	491	3547	4602	0	0.97	0.87
50	9.36	877.5	878.7	890	12.5	11.3	20.7	1425.8	435	491	3547	4515	0	0.99	0.88
100	8.61	877.5	878.7	890	12.5	11.3	19.9	1374.3	435	491	3547	4352	0	1.03	0.91
125	8.26	877.5	878.7	890	12.5	11.3	19.6	1350.1	435	491	3547	4275	0	1.05	0.93
150	7.92	877.5	878.7	890	12.5	11.3	19.2	1326.9	435	491	3547	4202	0	1.06	0.95
200	7.29	877.5	878.7	890	12.5	11.3	18.6	1283.2	435	491	3547	4064	0	[illegible]	0.98
300	6.17	877.5	878.7	890	12.5	11.3	17.5	1206.1	435	491	3547	3819	0	[illegible]	1.04
400	5.23	877.5	878.7	890	12.5	11.3	16.5	1140.8	435	491	3547	3613	0	[illegible]	[illegible]
500	4.43	877.5	878.7	890	12.5	11.3	15.7	1085.6	435	491	3547	3438	0	[illegible]	[illegible]

Ws Calc
435

Wc Calc
491

See Sample Calculations for list of abbreviations and sample calculations

S = surcharge loads = weight of satuarted soils above = (H3-Pipe Diameter/12)*(Pipe Diameter/12)*1*γsoil

P3 = H3*(H1/H2)*γwater

U = Uplift force on the project area of structure = Area of pipe * P3 = (Pipe Diameter/12)*1*P3

Wg = weight of surcharge water above top surface of structure control by gravity flow

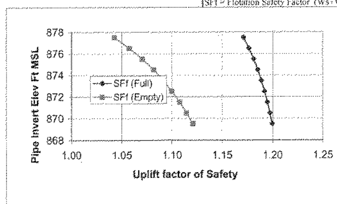
SFf = Flotation Safety Factor (Ws+Wc+S)/(U-Wg)

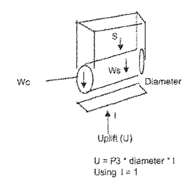
Use this table to determine the distance from toe at which the Safety Factor is me

Enter the Distance from toe and change the value until the SFf is equal to that required

Ground Elev 890 — Distance from toe (ft): 300

Depth Below Ground	Pipe Inv Elev, Ft	Surcharge Load, S, lbs/ft (Ws = 435)	Uplift (U) Force, lbs/ft	Pipe Weight, Lbs/ft (Wc = 491 Full)	Full water Wt, Lbs / ft	Uplift Safety Extreme Case (1.1 REQ'D) SFf Full	SFf Empty
	890	0		435	491		
12.5	877.5	3547	3819	435	491	[illegible]	1.04
13.5	876.5	3927	4125	435	491	[illegible]	1.06
14.5	875.5	4307	4431	435	491	[illegible]	1.07
15.5	874.5	4687	4736	435	491	[illegible]	1.08
16.5	873.5	5067	5042	435	491	[illegible]	1.09
17.5	872.5	5447	5347	435	491	[illegible]	1.10
18.5	871.5	5827	5653	435	491	[illegible]	[illegible]
19.5	870.5	6207	5958	435	491	[illegible]	[illegible]
20.5	869.5	6587	6264	435	491	[illegible]	[illegible]





n. topeka uplift #8	K-r	K-L	DbL	Dbo	Dbr	Df	H	i-c	Lr	Wt	Safety	L1	L2	Le	Lt	L't	Ho'	Hwt/2	Hwt	i-o	Cr	Cl	t	s
																							feet	
	400	400	11.3	11.3	11.3	80	11.7	0.84	10	0	0.94	10	80	601	691	691	10.18	10.18	10.18	0.90	601	601	0	0.000

Geotechnical data (above) presented in this spreadsheet was provided by Geotechnical Engineer, Scott Loehr, and is used to develop the Hydraulic Gradient at various distances from the toe. Verification of these numbers is done separately.

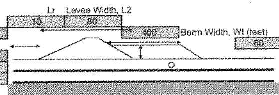
Lr Levee Width, L2

10 | 80

Levee Elev. 893.8

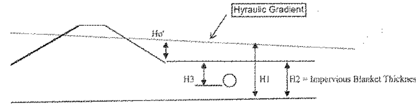
400 Berm Width, Wt (feet)

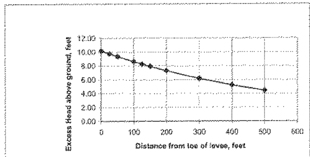
60 Berm Height, t (feet)



Ground Elev.	892	3	Pipe Dept (ft)
Blanket Base Elev.	880.7	889	Pipe Elev.
Bedrock Elev.	800.7	8	Pipe Diameter (in)
		ml-cl	Soil Type
		120	Soil Unit Weight, γsoil (pcf)

Ground Elev = Landside Average Ground Surface Used as Reference Datum





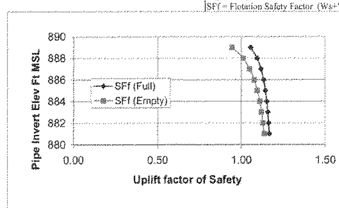
d=Landside Distance from Toe Feet	No Berm Calcs Excess Head Feet, Ho'	Invert Elev of pipe 8 -in steel	Design Base Blanket Feet, MSL	Ground Elev Feet, MSL	H3 Feet	H2 Feet	H1 Feet	P3 Psf	Ws lb	Wc lb	S lb	U lb	Wg lb	SFf (Full)	SFf (Empty)
0	10.18	889	880.7	892	3	11.3	21.5	355.8	1	22	187	237	0	0.88	0.79
25	9.76	889	880.7	892	3	11.3	21.1	348.9	1	22	187	233	0	0.90	0.81
50	9.36	889	880.7	892	3	11.3	20.7	342.3	1	22	187	228	0	0.92	0.82
100	8.62	889	880.7	892	3	11.3	19.9	330.0	1	22	187	220	0	0.95	0.85
125	8.27	889	880.7	892	3	11.3	19.6	324.2	1	22	187	216	0	0.97	0.87
150	7.93	889	880.7	892	3	11.3	19.2	318.6	1	22	187	212	0	0.99	0.88
200	7.30	889	880.7	892	3	11.3	18.6	308.1	1	22	187	205	0	1.02	0.91
300	6.18	889	880.7	892	3	11.3	17.5	289.8	1	22	187	193	0	1.09	0.97
400	5.23	889	880.7	892	3	11.3	16.5	273.9	1	22	187	183	0	[illegible]	1.03
500	4.43	889	880.7	892	3	11.3	15.7	260.6	1	22	187	174	0	[illegible]	1.08

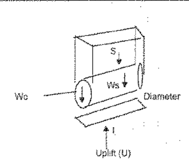
Use this table to determine the distance from toe at which the Safety Factor is me
Enter the Distance from toe and change the value until the SFf is equal to that required

	Ground Elev 892	Distance from toe (ft)	250			Uplift Safety Extreme Case (1.1 REQ'D)	
		Ws = 1		Wc = 22 Full			
Depth Below Ground	Pipe Inv Elev, Ft	Surcharge Load, S, lbs/ft	Uplift (U) Force, lbs/ft	Pipe Weight, Lbs/ft	Full water Wt, Lbs / ft	SFf Full	SFf Empty
	892	0		1	22		
3	889	187	199	1	22	1.05	0.94
4	888	267	265	1	22	1.09	1.01
5	887	347	332	1	22	[illegible]	1.05
6	886	427	398	1	22	[illegible]	1.07
7	885	507	464	1	22	[illegible]	1.09
8	884	587	531	1	22	[illegible]	[illegible]
9	883	667	597	1	22	[illegible]	[illegible]
10	882	747	663	1	22	[illegible]	[illegible]
11	881	827	730	1	22	[illegible]	[illegible]

Ws Calc
1
Wc Calc
22

See Sample Calculations for list of abbreviations and sample calculations
S = surcharge loads = weight of satuarted soils above = (H3-Pipe Diameter/12)*(Pipe Diameter/12)*1*γsoil
P3 = H3*(H1/H2)*γwater
U = Uplift force on the project area of structure = Area of pipe * P3 = (Pipe Diameter/12)*1*P3
Wg = weight of surcharge water above top surface of structure control by gravity flow
SFf = Flotation Safety Factor (Ws+Wc+S)/(U-Wg)

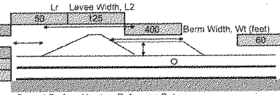




U = P3 * diameter * l
Using l = 1

Soldier Crk uplift #9	K-r	K-L	DbL	Dbo	Dbr	Df	H	i-c	Lr	Wt	Safety	L1	L2	Le	Lt	L't	Ho'	Hwt/2	Hwt	i-o	Cr	Cl	t feet	s
		300	15	15	15	40	1.2	0.84	50	0	#DIV/0!	#DIV/0!	125	424	#DIV/0!	#DIV/0!	1.20	#DIV/0!	#DIV/0!	#DIV/0!	0	424	0	0.000

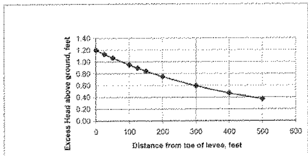
Geotechnical data (above) presented in this spreadsheet was provided by Geotechnical Engineer, Scott Loehr, and is used to develop the Hydraulic Gradient at various distances from the toe. Verification of these numbers is done separately.

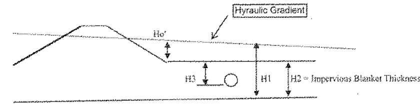


Levee Elev.	889.7
Ground Elev.	888.5
Blanket Base Elev.	873.5
Bedrock Elev.	833.5

5.3	Pipe Dept (ft)
883.2	Pipe Elev.
12	Pipe Diameter (in)
ml	Soil Type
120	Soil Unit Weight, γsoil (pcf)

Ground Elev = Landside Average Ground Surface Used as Reference Datum





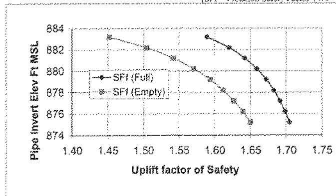
d=Landside Distance from Toe Feet	No Berm Calcs Excess Head Feet, Ho'	Invert Elev of pipe 12 -in steel	Design Base Blanket Feet, MSL	Ground Elev Feet, MSL	H3 Feet	H2 Feet	H1 Feet	P3 Psf	Ws lb	Wc lb	S lb	U lb	Wg lb	SFf (Full)	SFf (Empty)
0	1.20	883.2	873.5	888.5	5.3	15	16.2	357.2	3	49	516	357	0	[illegible]	[illegible]
25	1.13	883.2	873.5	888.5	5.3	15	16.1	355.7	3	49	516	356	0	[illegible]	[illegible]
50	1.07	883.2	873.5	888.5	5.3	15	16.1	354.2	3	49	516	354	0	[illegible]	[illegible]
100	0.95	883.2	873.5	888.5	5.3	15	15.9	351.6	3	49	516	352	0	[illegible]	[illegible]
125	0.89	883.2	873.5	888.5	5.3	15	15.9	350.4	3	49	516	350	0	[illegible]	[illegible]
150	0.84	883.2	873.5	888.5	5.3	15	15.8	349.3	3	49	516	349	0	[illegible]	[illegible]
200	0.75	883.2	873.5	888.5	5.3	15	15.7	347.2	3	49	516	347	0	[illegible]	[illegible]
300	0.59	883.2	873.5	888.5	5.3	15	15.6	343.6	3	49	516	344	0	[illegible]	[illegible]
400	0.47	883.2	873.5	888.5	5.3	15	15.5	341.0	3	49	516	341	0	[illegible]	[illegible]
500	0.37	883.2	873.5	888.5	5.3	15	15.4	338.9	3	49	516	339	0	[illegible]	[illegible]

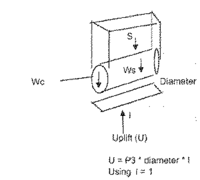
Ws Calc
2.57
Wc Calc
49

See Sample Calculations for list of abbreviations and sample calculations
[illegible]
[illegible]
S = surcharge loads = weight of satuarted soils above = (H3-Pipe Diameter/12)*(Pipe Diameter/12)*1*γsoil
P3 = H3*(H1/H2)*γwater
U = Uplift force on the project area of structure = Area of pipe * P3 = (Pipe Diameter/12)*1*P3
Wg = weight of surcharge water above top surface of structure control by gravity flow
SFf = Flotation Safety Factor (Ws+Wc+S)/(U-Wg)

Use this table to determine the distance from toe at which the Safety Factor is me
Enter the Distance from toe and change the value until the SFf is equal to that required

	Ground Elev 888.5		Distance from toe (ft)		0		
		Ws = 3		Wc = 49 Full		Uplift Safety Extreme Case (1.1 REQ'D)	
Depth Below Ground	Pipe Inv Elev, Ft	Surcharge Load, S, lbs/ft	Uplift (U) Force, lbs/ft	Pipe Weight, Lbs/ft	Full water Wt, Lbs / ft	SFf Full	SFf Empty
	888.5	0		3	49		
5.3	883.2	516	357	3	49	[illegible]	[illegible]
6.3	882.2	636	425	3	49	[illegible]	[illegible]
7.3	881.2	756	492	3	49	[illegible]	[illegible]
8.3	880.2	876	559	3	49	[illegible]	[illegible]
9.3	879.2	996	627	3	49	[illegible]	[illegible]
10.3	878.2	1116	694	3	49	[illegible]	[illegible]
11.3	877.2	1236	762	3	49	[illegible]	[illegible]
12.3	876.2	1356	829	3	49	[illegible]	[illegible]
13.3	875.2	1476	896	3	49	[illegible]	[illegible]

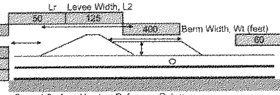




Soldier Crk uplift #10	K-r	K-L	DbL	Dbo	Dbr	Df	H	i-c	Lr	Wt	Safety	L1	L2	Le	Lt	L't	Ho'	Hwt/2	Hwt	i-o	Cr	Cl	t	s
																							feet	
	300	300	15	15	15	65	7.2	0.84	50	0	2.32	50	125	541	716	716	7.20	5.44	5.44	0.36	541	541	0	0.000

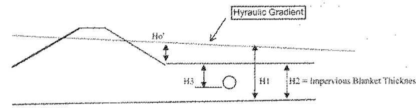
Geotechnical data (above) presented in this spreadsheet was provided by Geotechnical Engineer, Scott Loehr, and is used to develop the Hydraulic Gradient at various distances from the toe. Verification of these numbers is done separately.

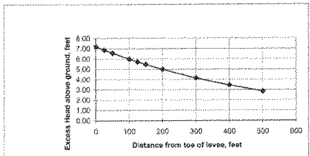
Levee Elev.	889.2
Ground Elev.	882
Blanket Base Elev.	867
Bedrock Elev.	802



60	Berm Height, t (feet)
-5.2	Pipe Dept (ft)
887.2	Pipe Elev.
6	Pipe Diameter (in)
ml	Soil Type
120	Soil Unit Weight, γsoil (pcf)

Ground Elev = Landside Average Ground Surface Used as Reference Datum





d=Landside Distance from Toe Feet	No Berm Calcs Excess Head Feet, Ho'	Invert Elev of pipe 6 -in steel	Design Base Blanket Feet, MSL	Ground Elev Feet, MSL	H3 Feet	H2 Feet	H1 Feet	P3 Psf	Ws lb	Wc lb	S lb	U lb	Wg lb	SFf (Full)	SFf (Empty)
0	7.20	887.2	867	882	-5.2	15	22.2	-480.2	1	12	-342	-240	0	[illegible]	[illegible]
25	6.87	887.2	867	882	-5.2	15	21.9	-473.2	1	12	-342	-237	0	[illegible]	[illegible]
50	6.56	887.2	867	882	-5.2	15	21.6	-466.5	1	12	-342	-233	0	[illegible]	[illegible]
100	5.98	887.2	867	882	-5.2	15	21.0	-453.9	1	12	-342	-227	0	[illegible]	[illegible]
125	5.71	887.2	867	882	-5.2	15	20.7	-448.1	1	12	-342	-224	0	[illegible]	[illegible]
150	5.46	887.2	867	882	-5.2	15	20.5	-442.5	1	12	-342	-221	0	[illegible]	[illegible]
200	4.97	887.2	867	882	-5.2	15	20.0	-432.1	1	12	-342	-216	0	[illegible]	[illegible]
300	4.13	887.2	867	882	-5.2	15	19.1	-413.9	1	12	-342	-207	0	[illegible]	[illegible]
400	3.44	887.2	867	882	-5.2	15	18.4	-398.8	1	12	-342	-199	0	[illegible]	[illegible]
500	2.86	887.2	867	882	-5.2	15	17.9	-386.3	1	12	-342	-193	0	[illegible]	[illegible]

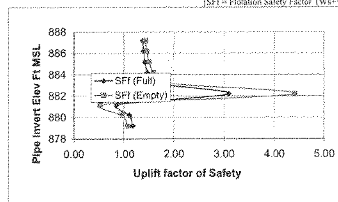
Ws Calc
1.3

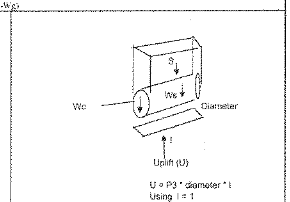
Wc Calc
12.2

See Sample Calculations for list of abbreviations and sample calculations
Ws = weight of structure per foot of length = 1.3 lb per ft 6-inch Diameter dia
Wc = weight of water contained in the structure = [illegible]
S = surcharge loads = weight of satuarted soils above = (H3-Pipe Diameter/12)*(Pipe Diameter/12)*1*γsoil
P3 = H3*(H1/H2)*γwater
U = Uplift force on the project area of structure = Area of pipe * P3 = (Pipe Diameter/12)*1*P3
Wg = weight of surcharge water above top surface of structure control by gravity flow
SFf = Flotation Safety Factor (Ws+Wc+S)/(U-Wg)

Use this table to determine the distance from toe at which the Safety Factor is me
Enter the Distance from toe and change the value until the SFf is equal to that required

	Ground Elev 882		Distance from toe (ft)	0			
		Ws = 1		Wc = 12 Full		Uplift Safety Extreme Case (1.1 REQ'D)	
Depth Below Ground	Pipe Inv Elev, Ft	Surcharge Load, S, lbs/ft	Uplift (U) Force, lbs/ft	Pipe Weight, Lbs/ft	Full water Wt, Lbs / ft	SFf Full	SFf Empty
	882	0		1	12		
-5.2	887.2	-342	-240	1	12	[illegible]	[illegible]
-4.2	886.2	-282	-194	1	12	1.38	1.45
-3.2	885.2	-222	-148	1	12	[illegible]	[illegible]
-2.2	884.2	-162	-102	1	12	[illegible]	[illegible]
-1.2	883.2	-102	-55	1	12	[illegible]	[illegible]
-0.2	882.2	-42	-9	1	12	[illegible]	[illegible]
0.8	881.2	18	37	1	12	0.85	0.52
1.8	880.2	78	83	1	12	[illegible]	0.95
2.8	879.2	138	129	1	12	[illegible]	1.08

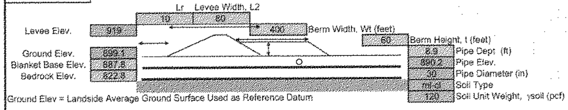




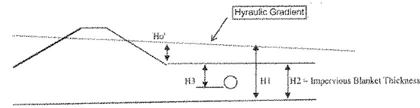
Soldier Crk
uplift #11

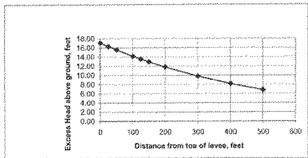
K-r	K-L	DbL	Dbo	Dbr	Df	H	i-c	Lr	Wt	Safety	L1	L2	Le	Lt	L't	Ho'	Hwt/2	Hwt	i-o	Cr	Cl	t	s
																						feet	
400	400	11.3	11.3	11.3	65	19.9	0.64	10	0	0.56	10	80	542	632	632	17.07	17.07	17.07	1.51	542	542	0	0.000

Geotechnical data (above) presented in this spreadsheet was provided by Geotechnical Engineer, Scott Loehr, and is used to develop the Hydraulic Gradient at various distances from the toe. Verification of these numbers is done separately.



Ground Elev = Landside Average Ground Surface Used as Reference Datum





d=Landside Distance from Toe Feet	No Berm Calcs Excess Head Feet, Ho'	Invert Elev of pipe 30 -in steel	Design Base Blanket Feet, MSL	Ground Elev Feet, MSL	H3 Feet	H2 Feet	H1 Feet	P3 Psf	Ws lb	Wc lb	S lb	U lb	Wg lb	SFf (Full)	SFf (Empty)
0	17.07	890.2	887.8	899.1	8.9	11.3	28.4	1394.1	31	306	1920	3485	0	0.65	0.56
25	16.30	890.2	887.8	899.1	8.9	11.3	27.6	1356.3	31	306	1920	3391	0	0.67	0.58
50	15.56	890.2	887.8	899.1	8.9	11.3	26.9	1320.2	31	306	1920	3301	0	0.68	0.59
100	14.19	890.2	887.8	899.1	8.9	11.3	25.5	1252.8	31	306	1920	3132	0	0.72	0.62
125	13.55	890.2	887.8	899.1	8.9	11.3	24.9	1221.4	31	306	1920	3053	0	0.74	0.64
150	12.94	890.2	887.8	899.1	8.9	11.3	24.2	1191.4	31	306	1920	2978	0	0.76	0.66
200	11.80	890.2	887.8	899.1	8.9	11.3	23.1	1135.3	31	306	1920	2838	0	0.80	0.69
300	9.81	890.2	887.8	899.1	8.9	11.3	21.1	1037.6	31	306	1920	2594	0	0.87	0.75
400	8.16	890.2	887.8	899.1	8.9	11.3	19.5	956.4	31	306	1920	2391	0	0.94	0.82
500	6.78	890.2	887.8	899.1	8.9	11.3	18.1	888.8	31	306	1920	2222	0	1.02	0.88

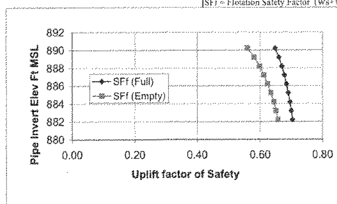
Ws Calc
31

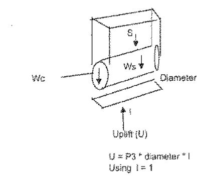
Wc Calc
306

See Sample Calculations for list of abbreviations and sample calculations
[illegible]
[illegible]
S = surcharge loads = weight of satuarted soils above = (H3-Pipe Diameter/12)*(Pipe Diameter/12)*1*γsoil
P3 = H3*(H1/H2)*γwater
U = Uplift force on the project area of structure = Area of pipe * P3 = (Pipe Diameter/12)*1*P3
Wg = weight of surcharge water above top surface of structure control by gravity flow
SFf = Flotation Safety Factor (Ws+Wc+S)/(U-Wg)

Use this table to determine the distance from toe at which the Safety Factor is me
Enter the Distance from toe and change the value until the SFf is equal to that required

	Ground Elev 899.1	Distance from toe (ft)		0		Uplift Safety Extreme Case (1.1 REQ'D)	
		Ws = 31		Wc = 306 Full			
Depth Below Ground	Pipe Inv Elev, Ft	Surcharge Load, S, lbs/ft	Uplift (U) Force, lbs/ft	Pipe Weight, Lbs/ft	Full water Wt, Lbs / ft	SFf Full	SFf Empty
	899.1	0		31	306		
8.9	890.2	1920	3485	31	306	0.65	0.56
9.9	889.2	2220	3877	31	306	0.66	0.58
10.9	888.2	2520	4269	31	306	0.67	0.60
11.9	887.2	2820	4660	31	306	0.68	0.61
12.9	886.2	3120	5052	31	306	0.68	0.62
13.9	885.2	3420	5443	31	306	0.69	0.63
14.9	884.2	3720	5835	31	306	0.70	0.64
15.9	883.2	4020	6227	31	306	0.70	0.65
16.9	882.2	4320	6618	31	306	0.70	0.66





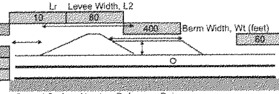
Soldier Crk uplift #12	K-r	K-L	DbL	Dbo	Dbr	Df	H	i-c	Lr	Wt	Safety	L1	L2	Lc	Lt	L't	Ho'	Hwt/2	Hwt	i-o	Cr	Cl	t	s
																							feet	
	400	400	11.3	11.3	11.3	65	19.9	0.84	10	0	0.56	10	80	542	632	632	17.07	17.07	17.07	1.51	542	542	0	0.000

Geotechnical data (above) presented in this spreadsheet was provided by Geotechnical Engineer, Scott Loehr, and is used to develop the Hydraulic Gradient at various distances from the toe. Verification of these numbers is done separately.

Lr Levee Width, L2

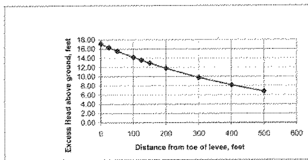
Levee Elev.	919
Ground Elev.	899.1
Blanket Base Elev.	887.8
Bedrock Elev.	822.8

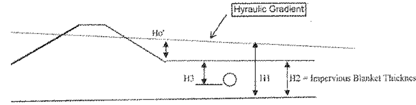
Lr: 10; Levee Width, L2: 80; Berm Width, Wt (feet): 400; Berm Height, t (feet): 60



9.1	Pipe Dept (ft)
890	Pipe Elev.
12	Pipe Diameter (in)
ml-cl	Soil Type
120	Soil Unit Weight, γsoil (pcf)

Ground Elev = Landside Average Ground Surface Used as Reference Datum





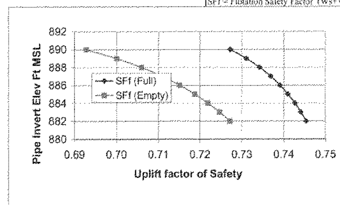
d=Landside Distance from Toe Feet	No Berm Calcs Excess Head Feet, Ho'	Invert Elev of pipe 12 -in steel	Design Base Blanket Feet, MSL	Ground Elev Feet, MSL	H3 Feet	H2 Feet	H1 Feet	P3 Psf	Ws lb	Wc lb	S lb	U lb	Wg lb	SFf (Full)	SFf (Empty)
0	17.07	890	887.8	899.1	9.1	11.3	28.4	1425.4	16	49	972	1425	0	0.73	0.69
25	16.30	890	887.8	899.1	9.1	11.3	27.6	1386.8	16	49	972	1387	0	0.75	0.71
50	15.56	890	887.8	899.1	9.1	11.3	26.9	1349.9	16	49	972	1350	0	0.77	0.73
100	14.19	890	887.8	899.1	9.1	11.3	25.5	1281.0	16	49	972	1281	0	0.81	0.77
125	13.55	890	887.8	899.1	9.1	11.3	24.9	1248.8	16	49	972	1249	0	0.83	0.79
150	12.94	890	887.8	899.1	9.1	11.3	24.2	1218.1	16	49	972	1218	0	0.85	0.81
200	11.80	890	887.8	899.1	9.1	11.3	23.1	1160.8	16	49	972	1161	0	0.89	0.85
300	9.81	890	887.8	899.1	9.1	11.3	21.1	1060.9	16	49	972	1061	0	0.98	0.93
400	8.16	890	887.8	899.1	9.1	11.3	19.5	977.9	16	49	972	978	0	1.06	1.01
500	6.78	890	887.8	899.1	9.1	11.3	18.1	908.8	16	49	972	909	0	[illegible]	1.09

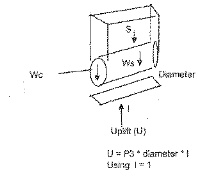
Ws Calc
15.5
Wc Calc
49

See Sample Calculations for list of abbreviations and sample calculations
Ws = weight of structure per foot of length = [illegible]
Wc = weight of water contained in the structure = [illegible]
S = surcharge loads = weight of satuarted soils above = (H3-Pipe Diameter/12)*(Pipe Diameter/12)*1*γsoil
P3 = H3*(H1/H2)*γwater
U = Uplift force on the project area of structure = Area of pipe * P3 = (Pipe Diameter/12)*1*P3
Wg = weight of surcharge water above top surface of structure control by gravity flow
SFf = Flotation Safety Factor (Ws+Wc+S)/(U-Wg)

Use this table to determine the distance from toe at which the Safety Factor is me
Enter the Distance from toe and change the value until the SFf is equal to that required

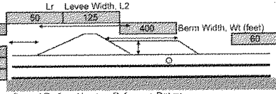
	Ground Elev 899.1	Distance from toe (ft)	0			Uplift Safety Extreme Case (1.1 REQ'D)	
		Ws = 16		Wc = 49 Full			
Depth Below Ground	Pipe Inv Elev, Ft	Surcharge Load, S, lbs/ft	Uplift (U) Force, lbs/ft	Pipe Weight, Lbs/ft	Full water Wt, Lbs / ft	SFf Full	SFf Empty
	899.1	0		16	49		
9.1	890	972	1425	16	49	0.73	0.69
10.1	889	1092	1582	16	49	0.73	0.70
11.1	888	1212	1739	16	49	0.73	0.71
12.1	887	1332	1895	16	49	0.74	0.71
13.1	886	1452	2052	16	49	0.74	0.72
14.1	885	1572	2209	16	49	0.74	0.72
15.1	884	1692	2365	16	49	0.74	0.72
16.1	883	1812	2522	16	49	0.74	0.72
17.1	882	1932	2679	16	49	0.75	0.73





Waterworks uplift #13	K-r	K-L	DbL	Dbo	Dbr	Df	H	i-c	Lr	Wt	Safety	L1	L2	Le	Lt	L't	Ho'	Hwt/2	Hwt	i-o	Cr	Cl	t feet	s
	600	600	12.75	12.75	12.75	65	10.1	0.84	50	0	1.33	50	125	705	880	880	9.88	8.09	8.09	0.63	705	705	0	0.000

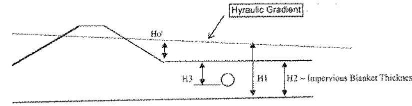
Geotechnical data (above) presented in this spreadsheet was provided by Geotechnical Engineer, Scott Loehr, and is used to develop the Hydraulic Gradient at various distances from the toe. Verification of these numbers is done separately.

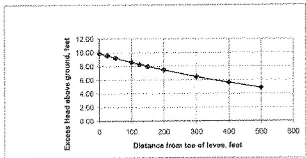


Levee Elev. 898.1
Ground Elev. 888
Blanket Base Elev. 875.25
Bedrock Elev. 810.25

3	Pipe Dept (ft)
885	Pipe Elev.
10	Pipe Diameter (in)
ml	Soil Type
120	Soil Unit Weight, γsoil (pcf)

Ground Elev = Landside Average Ground Surface Used as Reference Datum





d=Landside Distance from Toe Feet	No Berm Calcs Excess Head Feet, Ho'	Invert Elev of pipe 10 -in steel	Design Base Blanket Feet, MSL	Ground Elev Feet, MSL	H3 Feet	H2 Feet	H1 Feet	P3 Psf	Ws lb	Wc lb	S lb	U lb	Wg lb	SFf (Full)	SFf (Empty)
0	9.88	885	875.25	888	3	12.75	22.6	332.3	10	34	217	277	0	0.94	0.82
25	9.54	885	875.25	888	3	12.75	22.3	327.2	10	34	217	273	0	0.96	0.83
50	9.20	885	875.25	888	3	12.75	22.0	322.3	10	34	217	269	0	0.97	0.84
100	8.57	885	875.25	888	3	12.75	21.3	313.1	10	34	217	261	0	1.00	0.87
125	8.28	885	875.25	888	3	12.75	21.0	308.7	10	34	217	257	0	1.01	0.88
150	7.99	885	875.25	888	3	12.75	20.7	304.5	10	34	217	254	0	1.03	0.89
200	7.44	885	875.25	888	3	12.75	20.2	296.4	10	34	217	247	0	1.06	0.92
300	6.46	885	875.25	888	3	12.75	19.2	282.0	10	34	217	235	0	[illegible]	0.96
400	5.60	885	875.25	888	3	12.75	18.4	269.5	10	34	217	225	0	[illegible]	1.01
500	4.86	885	875.25	888	3	12.75	17.6	258.6	10	34	217	215	0	[illegible]	1.05

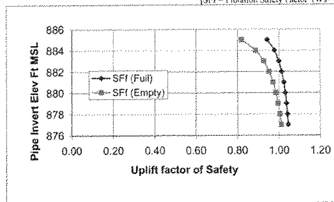
Ws Calc
10

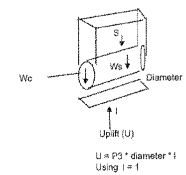
Wc Calc
34

See Sample Calculations for list of abbreviations and sample calculations
Ws = weight of structure per foot of length = 10 lb per ft 10-inch Diameter ...
Wc = weight of water contained in the structure = ... = 34 ...
S = surcharge loads = weight of satuarted soils above = (H3-Pipe Diameter/12)*(Pipe Diameter/12)*1*γsoil
P3 = H3*(H1/H2)*γwater
U = Uplift force on the project area of structure = Area of pipe * P3 = (Pipe Diameter/12)*1*P3
Wg = weight of surcharge water above top surface of structure control by gravity flow
SFf = Flotation Safety Factor (Ws+Wc+S)/(U-Wg)

Use this table to determine the distance from toe at which the Safety Factor is me
Enter the Distance from toe and change the value until the SFf is equal to that required

Depth Below Ground	Ground Elev 888 Pipe Inv Elev, Ft	Surcharge Load, S, lbs/ft	Distance from toe (ft) 0 Ws = 10 Uplift (U) Force, lbs/ft	Wc = 34 Full Pipe Weight, Lbs/ft	Full water Wt, Lbs / ft	Uplift Safety Extreme Case (1.1 REQ'D) SFf Full	SFf Empty
	888	0		10	34		
3	885	217	277	10	34	0.94	0.82
4	884	317	369	10	34	0.98	0.88
5	883	417	461	10	34	1.00	0.92
6	882	517	554	10	34	1.01	0.95
7	881	617	646	10	34	1.02	0.97
8	880	717	738	10	34	1.03	0.98
9	879	817	831	10	34	1.04	1.00
10	878	917	923	10	34	1.04	1.00
11	877	1017	1015	10	34	1.04	1.01





Chapter A-5

STRUCTURAL ANALYSIS

A-5 TOPEKA STRUCTURAL RELIABILITY ANALYSIS

A-5.1 INTRODUCTION

An input requirement of the HEC-FDA program model is the reliability or probability of failure for flood risk management features with water at various elevations. The structural features of the levee units included in this study consist of floodwalls, pump stations, closure structures for openings in levees and floodwalls, gatewells, reinforced box culverts, drainage structures, and retaining walls integral to the integrity of the levee system. The structural analysis involved an assessment of the existing condition of the structures. The assessment was based on visual observation, dated construction plans, historical data, discussions with the Corps of Engineers and Levee District personnel (those familiar with and involved in the inspection, operation, and maintenance of the levee units), detailed engineering analysis, and engineering judgment. The results of this portion of the study will be used in the development of probabilities of failure as required for input into the HEC-FDA model. Probability of failure analysis will not be used for design.

A-5.2 STRUCTURAL RELIABILITY METHODOLOGY

The following structural methodology was developed by the Kansas City District during the course of the Phase 1 – Kansas Citys Levees Feasibility Study. The subsequent criterion was accepted by representatives of the U.S. Army Corps of Engineers Headquarters in the Fall of 2005. The approved structural reliability methodology used in the course of this study is summarized below.

A-5.3 DETERMINISTIC CRITERIA

A series of screening criteria are used to determine if a probabilistic analysis is necessary for a given structure. Summarized below are the current stability and strength criterion developed from and based on current design standards. If analysis shows the existing structure to meet the criterion (derived from current design criterion), the structure is assumed reliable and a 99.8% reliability is assigned. If the structure does not meet this criterion a reliability analysis is performed.

A-5.3.1 Stability Requirements

Structural stability criterion can be seen in Table A-5-1. It is based upon the EM 110-2-2100-*Stability Analysis of Concrete Structures*, dated 01 December 2005, with the exception of the extreme load condition. There is some concern with the extreme load condition categories as specified in EM 110-2-2100. The Missouri River L-142 Design Criteria Issue Resolution Paper (2002) addressed these issues and put forth more stringent guidelines for recommended extreme load condition stability criteria. That criterion is used herein.

Table A-5-1: Stability Criterion

Recommended Sliding Stability Factor of Safety		
Load Condition Category	**Return Period**	**Factor of Safety**
Usual	10 yrs	2
Unusual	300 yrs	1.5
Extreme	Top of Levee	1.3*

Recommended Rotational Stability Percent of Base in Compression		
Load Condition Category	**Return Period**	**Percent of Base in Compression**
Usual	10 yrs	100%
Unusual	300 yrs	75%
Extreme	Top of Levee	25% *

Recommended Maximum Allowable Bearing Capacity % Increase in Allowable Bearing Capacity		
Load Condition Category	**Return Period**	**% Increase in Allowable Bearing Capacity**
Usual	10 yrs	0%
Unusual	300 yrs	15%
Extreme	Top of Levee	50%

Recommended Flotation Stability Factor of Safety		
Load Condition Category	**Return Period**	**Factor of Safety**
Usual	10 yrs	1.3
Unusual	300 yrs	1.2
Extreme	Top of Levee	1.1

* Stability requirements increased from value in EM 110-2-2100

A-5.3.2 Strength Requirements

a. Unfactored loads and unreduced strengths were used in the analysis. Factored loads and reduced strengths are used for design and are not appropriate for a probability of failure analysis. This implies that if an existing structure has a calculated Factor of Safety of less then 1.0 (Capacity/Demand), the structure has ceased to function as designed.

b. For new structures designed with the Strength Design Method, loads are increased by multiplying service loads by appropriate load factors and nominal strengths are decreased by corresponding strength reduction factors. Load factors required by EM 1110-2-2104, *Strength Design for Reinforced-Concrete Hydraulic Structures* include a dead and live load factor (LF) of 1.7 and a hydraulic factor (HF) of 1.3. Combining these gives a total load factor (TF) of 2.2. The strength reduction factor for flexure (ϕ), the typical controlling failure mechanism, is 0.90. Dividing the load factor by the strength reduction factor gives an overall factor of safety of about 2.45 for a new design.

c. When considering an allowable factor of safety for existing structures, several allowable reductions can be taken into account. EM 1110-2-2104 allows for a 25% reduction in load for short duration loads with a low probability of occurrence (SD = 0.75), which would apply to flood events with a return period of greater than 300 years. A "performance" factor (PF) is proposed to take into account the successful response of the existing structure to design or near design loads. If an existing structure has performed well under load and not shown visible signs of distress, a 15% reduction in factor of safety is acceptable as a threshold for requiring an upgrade to the structure. Combining the design load factors with the frequency and performance factors [((LF x HF) / ϕ) x SD x PF)] produces an approximate 1.5 Factor of Safety for existing hydraulic structures under extreme loading conditions.

d. For structures subjected to earthen loads without extreme water loadings, such as unsubmerged box culverts and gatewells, the hydraulic load and extreme loading reduction factors would not apply. The resulting allowable factor of safety would include a 1.7 live load factor (LF), a 0.90 flexural strength reduction factor (ϕ), and a 15% factor of safety reduction for known performance of existing structures (PF = 0.85). Combining these load factors and strength reductions [(LF/ϕ) x PF] would result in a 1.6 allowable factor of safety for existing structures under normal (non-hydraulic) load conditions.

Table A-5-2: Strength Criterion

Recommended Minimum Strength Factors of Safety		
Load Condition Category	**Return Period**	**Factor of Safety**
Non-Hydraulic	N/A	1.6
Extreme	Top of Levee	1.5

A-5.4 UNCERTAINTY ANALYSIS

a. For structural features not meeting deterministic strength and stability criterion, a risk and uncertainty analysis was performed. The method adopted for calculating a probability of failure is that outlined for geotechnical engineering in "Factors of Safety and Reliability in Geotechnical Engineering", by J. Michael Duncan, published in the Journal of Geotechnical and Geoenvironmental Engineering, April 2000. The use of this method provides consistency between the structural and geotechnical analyses.

b. To produce a probability of failure curve, the critical section of each feature not meeting criteria was analyzed (factor of safety determined) using mean material strengths and/or mean soil properties. Next, the parameters were varied to plus and minus one standard deviation from the mean one at a time and the factor of safety was recomputed. A Taylor Series expansion was then used to compute a probability of failure. A 2% probability of failure was used as an appropriate non-failure threshold. If a probability of failure greater than 2% resulted, then the water elevation was lowered in 1-foot increments and the feature was reanalyzed until the probability of failure obtained was less than 2%.

c. The Taylor Series Method (TSM) of analysis was used in the calculation of structural risk and uncertainty. The TSM is appropriate when data is normally distributed, when parameters display a linear relationship, and when degradation over time is not a consideration. Because of the limited availability of data and with no information to suggest otherwise, an assumption of normal distributions for input data is reasonable and consistent with guidance provided in ETL 1110-2-547 (paragraph B-6.c). Examples of non-linear behavior for which the TSM should not be used include overturning stability analysis when the resultant is outside the kern of the base. Examples of degradation over time would include scour around piles, reactive concrete, sliding movement, and deteriorating drainage systems that affect uplift. All available historic data, site inspections, and engineering judgment do not show time dependent deterioration of structures to be a concern for the Topeka Levee Systems.

A-5.4.1 Risk Calculation

a. For strength calculations, uncertainty is measured by applying a mean and standard deviation to the concrete and steel strengths. The selected mean and normal standard deviation are based on engineering judgment and information published in *Reliability Based Design in Civil Engineering* by Milton E. Harr.

b. For stability calculations, uncertainty is considered by applying a mean and standard deviation to the soil unit weight and shear strength, and is based on values provided by the geotechnical engineers. The uncertainty inherent in determining the soil parameters provides a means to find a probability of failure. From experience on the Missouri River Levee Project L-142 Criteria Study (KCD-COE), it was determined through analysis that the unit weight and the soil shear strength have a noticeable effect on a floodwall's factor of safety. Varying the concrete density has only a minor effect on the factor of safety.

c. Failure is defined as the capacity to demand ratio (factor of safety) less than 1.0, or in other words when the demand (loads) exceed the capacity (structural or geotechnical).

A-5.4.2 Structural Material Properties

a. For the screening portion of the Topeka Levee Systems feasibility study the following structural properties were used. The American Concrete Institute recommended the use of a 3,000 psi concrete strength around the 1940's through 1960's, the typical timeframe of construction for most of the levee structures in the study. For earlier concrete strengths little information exists. It is currently assumed that 2500 psi concrete strengths are appropriate. If additional research information is discovered this value will be updated.

b. Knowing the time period of construction (~1940's – 1960's) and based upon the Portland Cement Association's pamphlet *Engineered Concrete Structures*, 1997, an assumed reinforcing steel design yield strength, F_y, of 40 ksi is used for most computations, unless known or stated otherwise. For earlier structures (~1900's), the Concrete Reinforcing Steel Institute in *Engineering Data Report 48* suggests 33 ksi steel is typical.

c. Based on FEMA 310, the mean strength (or expected strength) for Risk and Uncertainty calculations shall be taken as 125% of the design strength. For reinforced concrete structures Harr suggests a 14% standard deviation.

Concrete Strength Variation (14%)
- 1940's-1950's: $\mu - \sigma = 3225$, $\mu = 3750$, $\mu + \sigma = 4275$ (3000 psi min)
- 1900's-1920's: $\mu - \sigma = 2150$, $\mu = 2500$, $\mu + \sigma = 2850$ (2000 psi min)

Steel Strength Variation (14%)
- 1940's-1950's: $\mu - \sigma = 43$, $\mu = 50$, $\mu + \sigma = 57$ (40 ksi min)
- 1900's-1920's: $\mu - \sigma = 35.5$, $\mu = 41.25$, $\mu + \sigma = 47.0$ (33 ksi min)

A-5.4.3 Soil Material Properties

a. The soil properties used to compute loads on structures for the Topeka Feasibility study are located in Table A-5-3. The values posted were obtained from the *Topeka Feasibility Study Phase I – Existing Conditions Geotechnical Appendix* in consultation with the geotechnical engineers of record. These simplified values were generalized conservatively for use in typical structural calculations.

Table A-5-3: Soil Properties

Parameter	Soldier Creek Unit	North Topeka Unit	Waterworks Unit	South Topeka Unit	Oakland Unit	Auburndale Unit
Friction Angle	26.5	26.5	26.5	22.0	19.0	26.5
Cohesion	0	0	0	0	0	0
Moist unit wt.	120	120	120	120	120	120
Saturated unit wt.	120	120	120	120	120	120

Note: Soil to structure friction and cohesion interaction were typically neglected for stability and strength calculations.

b. Geotechnical members of the project team provided standard deviations of 8% and 10% of the mean for both soil unit weight and soil shear strength respectively.

A-5.5 STRUCTURAL ANALYSIS

The following structural features were analyzed for the Topeka feasibility study. Features specific to only one levee unit are mentioned below briefly and are described in greater detail in the section relating to the levee unit in which the feature is located. Features unique to a levee unit and analyzed in a manner different then described below are also more thoroughly discussed in the related levee unit section.

A-5.5.1 Floodwalls on Spread Footings

a. Spread footing floodwalls were analyzed for sliding, bearing capacity and overturning stability, along with wall stem and foundation strengths. Each floodwall cross-section was analyzed using the Corps of Engineers CASE project program CTWALL. CTWALL computes a sliding factor of safety, percent base in compression, and maximum bearing pressure. Sliding factors of safety and percent base in compression were compared to required design minimums. The ratio of bearing pressure to allowable soil bearing capacity as supplied from geotechnical team members was compared to allowable maximums.

b. CTWALL output includes a free body diagram detailing the horizontal and vertical forces acting on the wall cross section. These forces were entered into a MathCAD worksheet developed by the Kansas City District to check shear and flexural strengths. The failure of floodwall stems or foundations was based on a capacity/demand ratio of less than one.

c. For floodwalls not meeting the minimum strength and stability factors of safety, a reliability analysis was conducted for the floodwall cross section displaying the lowest (controlling) factor of safety. The resulting reliability curve for the critical cross section is then defined as the representative curve for the entire reach of floodwall. (For example, a hypothetical floodwall has 5 different cross sections, Sections A through E. Section C has the lowest factor of safety. The resulting reliability curve for Section C would be used to define the reliability of the entire hypothetical floodwall.) Failure was based on a capacity/demand ratio (structural or geotechnical) of less than one.

A-5.5.2 Retaining Walls

Retaining walls located in the line of flood risk management and critical to the function of the levee were analyzed in a method consist with that of spread footing floodwalls.

A-5.5.3 Stoplog and Sandbag Closure Structures

a. All stoplog closure structures in the Topeka levees system have spread footing foundations. Stoplog closure structures were analyzed in a simplified manner similar to spread footing floodwalls. All Topeka stoplog gaps are one gap wide and do not have intermediate posts. Stoplog structure stability was analyzed using CTWALL in conjunction with a typical stoplog wall cross section. Free body pressures from CTWALL are used to check reinforcing steel in the closure structure foundation and stem walls. Because these simplified strength calculations revealed no foundation or wall stem strength concerns, and because no levee raises are purposed, foundation rigidity, stoplog strengths and stoplog post slots were not checked.

b. Routine levee inspections of sandbag gaps have revealed no foundation slab issues for the Topeka units. Strength and stability calculations were not performed for sandbag closure structures. If strength or uplift concerns are experienced during flood events, it can reasonably be assumed that flood fighting efforts (additional sandbags) would be successful in addressing any uplift problems.

A-5.5.4 Floodwalls on Piles

The only floodwall on piles is located in the South Topeka unit. A more detailed description of the analysis of floodwalls on piles is located in the South Topeka section of this report.

A-5.5.5 Pump Stations

The structural evaluation of pump stations focused on floatation stability along with foundation wall and floor strengths. The potential for pump station uplift was computed using a Kansas City developed MathCAD worksheet based on EM 110-2-2100. Stability Analysis of Concrete Structures taking into consideration site specific hydraulic grade lines supplied by Geotechnical project team members. Foundation wall and floor capacities were calculated using MathCAD worksheets based on plate mechanics and each component's length to width aspect ratios. The CASE project program CASTR was used when combined axial bending capacity computations were necessary. For pump stations not meeting strength and floatation factors of safety, reliability calculations were performed.

A-5.5.6 Gatewells, Reinforced Concrete Boxes, and Drainage Structures

Gatewells, reinforced concrete boxes, and other drainage closure structures were all analyzed in a manner similar to the pump station evaluations. MathCAD worksheets evaluated floatation stability and structural component strengths. Because of the length to width aspect ratios of these structures, plate mechanics were not used. Instead wall and floor component capacities were assessed using one-way beam analysis. For structures not meeting the minimum factors of safety, reliability analysis was conducted.

A-5.6 SUMMARY OF RESULTS BY LEVEE UNIT

The following structural features were analyzed for the Topeka feasibility study.

A-5.6.1 Auburndale Unit

a. Located on the right bank of the Kansas River, the Auburndale unit begins at the intersection of Interstate Highway No. 70 and the end of the Waterworks unit levee. The levee extends eastward along the highway, with the highway fill acting as levee, gradually diverging from the highway and stretching east, southeast to the intersection of the Ward-Martin Creeks Pumping Plant. The levee is incorporated into the access road from the intersection of the access road and Ward-Martin Creeks Pump Plant until approximately levee Sta. 30+00, where it again transitions back into a zoned portion of the Highway 70 embankment fill, continuing on to Sta. 58+80, the beginning of the South Topeka unit. The unit was designed in 1958 and constructed between the years 1961 and 1962.

b. Auburndale structures considered for this study included four gatewell closure structures, one large multi-box reinforced concrete box running through the levee, and two pump stations.

A-5.6.1.1 Gatewell Closure Structures

Four Auburndale gatewells were analyzed for water to top of structure. All required factors of safety were meet and a 99.8% reliability was assigned.

Table A-5-4: Auburndale Gatewell Reliability

Auburndale Gatewells with water to top of levee				
Station	Uplift Factor of Safety (> 1.1 Req'd)	Strength Factor of Safety (> 1.5 Req'd)	Controlling Structural Mechanism	Assigned Reliability
1+90	1.383 (dry)	1.559	Neg. Wall Reinforcing Steel w/ Fixed End Supports	99.8%
25+10	1.339 (dry)	1.706	Neg. Wall Reinforcing Steel w/ Fixed End Supports	99.8%
37+20	1.413 (dry)	1.801	Neg. Wall Reinforcing Steel w/ Fixed End Supports	99.8%
40+00	1.446 (dry)	2.885	Neg. Wall Reinforcing Steel w/ Fixed End Supports	99.8%

A-5.6.1.2 Reinforced Concrete Box

A quadruple (4-14.5'x12') reinforced concrete box draining Ward Martin creek runs under Interstate No. 70 through the line of flood risk management. Analysis results are based on water to top of levee with no water in the box and are summarized below. All required factors of safety were meet and a 99.8% reliability was assigned.

Table A-5-5: Auburndale Reinforced Box Culvert

Auburndale Reinforced Box Culvert with water to top of levee				
Station	Uplift Factor of Safety (> 1.1 Req'd)	Strength Factor of Safety (> 1.5 Req'd)	Controlling Structural Mechanism	Assigned Reliability
28+30	1.43 (dry)	2.63	Shear in Roof Slab	99.8%

A-5.6.1.3 Pump Stations

a. Two Auburndale pump stations were constructed as part of the Federal project in the 1960's. The Waite Street Station (as builts dated 1970) and Ward Martin Creek Station (as builts dated 1963) both handle interior drainage only.

b. Table A-5-6 below summarizes reliability criteria findings for the two stations. All results are computed with water to top of levee. Column three displays uplift factors of safety with no water in the wet well. Column four shows the level of water required in the wet well to meet the minimum 1.1 required uplift factor of safety. Based on each pump stations individual pump station shutoff elevations, column five shows the actual minimum level of water likely to present in the well.

Table A-5-6: Auburndale Pump Stations

Auburndale Pump Stations with water at top of levee						
Station	Station Name	Uplift Factor of Safety (> 1.1 Req'd)	Water Req'd to meet 1.1 Uplift Factor of Safety (ft)	Water Available (ft)	Strength Factor of Safety (> 1.5 Req'd)	Comments
22+60	Waite Street	0.97 (Dry)	1.5	2	2	**No Corrective Measures Necessary**
28+30	Ward Martin Creek	0.84 (Dry)	8.5	6.5	1.74	**No Corrective Measures at this Time. To be investigated further at time of Plans and Specifications.**

c. The Waite Street Pump Station requires 1.5ft of water in the wet well to meet a required 1.1 minimum factor of safety. Based on pump shut off data, 2ft of water could be available. Consequently, no corrective measures are assumed necessary and a 99.8% reliability is assigned.

d. The Ward Martin Creek Pump Station requires 8.5ft of water in the wet well area to meet the 1.1 minimum required uplift factor of safety, yet based on the station pump operating curves only 6.5 ft of water is guaranteed to be present at any given time. Uplift calculations with 6.5ft of water in the wet well generated an uplift factor of safety greater then 1.0 so at this point it is assumed no action is necessary. At time of plans and specifications the pump station operating curves may be reanalyzed to determine if 8.5 ft of water can be stored in the wet well without impacts to interior ponding and flooding.

A-5.6.2 Oakland Unit

a. The Oakland Unit is located along the Kansas River downstream of South Topeka Unit and continuing along the left bank of Shunganunga Creek. Flood risk management features consist of 10 miles of earthen levee, one sandbag gap, and 5.5 miles of channel improvement. The Oakland Unit was designed in 1960 and constructed during the period between 1965 and 1969.

b. Oakland unit structures considered included thirty-four gatewell closure structures, twenty-six manhole and drop inlet structures, one sandbag closure gap, one floodwall section, one landside toe retaining wall, and one pump stations.

A-5.6.2.1 Gatewell Closure Structures

Analysis results are based on water to top of levee with no water in the gatewell and are summarized below. All required factors of safety were meet and a 99.8% reliability was assigned.

Table A-5-7: Oakland Gatewell Reliability

Oakland Gatewells with water to top of levee				
Station	Uplift Factor of Safety (> 1.1 Req'd)	Strength Factor of Safety (> 1.5 Req'd)	Controlling Structural Mechanism	Assigned Reliability
2+08	1.4 (dry)	1.52	Neg. Wall Reinforcing Steel w/ Fixed End Supports	99.8%
5+45	1.4 (dry)	1.67	Neg. Wall Reinforcing Steel w/ Fixed End Supports	99.8%
7+46	1.3 (dry)	1.74	Neg. Wall Reinforcing Steel w/ Fixed End Supports	99.8%
7+58	1.4 (dry)	1.50	Neg. Wall Reinforcing Steel w/ Fixed End Supports	99.8%
22+93	1.3 (dry)	1.60	Pos. Wall Reinforcing Steel w/ Yielded End Supports	99.8%
40+68	1.4 (dry)	1.55	Neg. Wall Reinforcing Steel w/ Yielded End Supports	99.8%
62+61	1.2 (dry)	1.90	Neg. Wall Reinforcing Steel w/ Fixed End Supports	99.8%
70+75	1.3 (dry)	1.83	Pos. Wall Reinforcing Steel w/ Yielded End Supports	99.8%
118+87	1.4 (dry)	1.80	Neg. Wall Reinforcing Steel w/ Fixed End Supports	99.8%
144+65	1.3 (dry)	1.64	Neg. Wall Reinforcing Steel w/ Fixed End Supports	99.8%
220+00	1.3 (dry)	1.94	Pos. Wall Reinforcing Steel w/ Yielded End Supports	99.8%
241+30	1.4 (dry)	1.96	Neg. Wall Reinforcing Steel w/ Fixed End Supports	99.8%
264+91	1.4 (dry)	2.49	Neg. Wall Reinforcing Steel w/ Fixed End Supports	99.8%

309+54	1.3 (dry)	1.66	Neg. Wall Reinforcing Steel w/ Fixed End Supports	99.8%
345+97	1.4 (dry)	1.59	Neg. Wall Reinforcing Steel w/ Fixed End Supports	99.8%
378+15	1.4 (dry)	3.41	Neg. Wall Reinforcing Steel w/ Fixed End Supports	99.8%
398+00	1.4 (dry)	1.97	Neg. Wall Reinforcing Steel w/ Fixed End Supports	99.8%
429+00	1.3 (dry)	1.74	Neg. Wall Reinforcing Steel w/ Fixed End Supports	99.8%
442+30	1.4 (dry)	2.18	Neg. Wall Reinforcing Steel w/ Fixed End Supports	99.8%
448+64	1.4 (dry)	2.19	Neg. Wall Reinforcing Steel w/ Fixed End Supports	99.8%
458+44	1.4 (dry)	1.93	Neg. Wall Reinforcing Steel w/ Fixed End Supports	99.8%
462+13	1.4 (dry)	1.85	Neg. Wall Reinforcing Steel w/ Fixed End Supports	99.8%
462+26	1.4 (dry)	2.38	Neg. Wall Reinforcing Steel w/ Fixed End Supports	99.8%
468+41	1.4 (dry)	1.99	Neg. Wall Reinforcing Steel w/ Fixed End Supports	99.8%
474+75	1.5 (dry)	3.35	Neg. Wall Reinforcing Steel w/ Fixed End Supports	99.8%
479+23	1.4 (dry)	3.03	Neg. Wall Reinforcing Steel w/ Fixed End Supports	99.8%
484+80	1.3 (dry)	1.56	Neg. Wall Reinforcing Steel w/ Fixed End Supports	99.8%
493+06	1.3 (dry)	1.58	Neg. Wall Reinforcing Steel w/ Fixed End Supports	99.8%
500+60	1.4 (dry)	2.37	Neg. Wall Reinforcing Steel w/ Fixed End Supports	99.8%
505+88	1.3 (dry)	1.97	Pos. Wall Reinforcing Steel w/ Yielded End Supports	99.8%
512+48	1.3 (dry)	2.27	Neg. Wall Reinforcing Steel w/ Fixed End Supports	99.8%
517+54	1.5 (dry)	3.50	Neg. Wall Reinforcing Steel w/ Fixed End Supports	99.8%
521+68	1.5 (dry)	3.55	Neg. Wall Reinforcing Steel w/ Fixed End Supports	99.8%

A-5.6.2.2 Drop Inlet and Manhole Collector Structures

a. A series of some twenty-four drop inlet and manhole collector box structures located just landward of the levee toe were analyzed. Analysis results are based on water to top of levee (full HGL) with no water in the gatewell and are summarized below.

Table A-5-8: Oakland Manholes and Drop Inlets

Oakland Manholes and Drop Inlets with water to top of levee				
Station	Uplift Factor of Safety (> 1.1 Req'd)	Strength Factor of Safety (> 1.5 Req'd)	Controlling Structural Mechanism	Assigned Reliability
0+00	1.4 (dry)	4.8	Neg. Wall Reinforcing Steel w/ Fixed End Supports	99.8%
1+50	1.3 (dry)	4.5	Neg. Wall Reinforcing Steel w/ Fixed End Supports	99.8%
2+06	1.4 (dry)	4.5	Neg. Wall Reinforcing Steel w/ Fixed End Supports	99.8%
3+11	1.4 (dry)	4.7	Neg. Wall Reinforcing Steel w/ Fixed End Supports	99.8%
5+81	1.2 (dry)	2.2	Pos. Wall Reinforcing Steel w/ Yielded End Supports	99.8%
7+07	1.4 (dry)	3.8	Neg. Wall Reinforcing Steel w/ Yielded End Supports	99.8%
7+46	1.3 (dry)	2.2	Neg. Wall Reinforcing Steel w/ Fixed End Supports	99.8%
8+36	1.4 (dry)	4.8	Pos. Wall Reinforcing Steel w/ Yielded End Supports	99.8%
9+07	1.4 (dry)	5.1	Neg. Wall Reinforcing Steel w/ Fixed End Supports	99.8%
40+83	1.8 (dry)	15.8	Neg. Wall Reinforcing Steel w/ Fixed End Supports	99.8%
75+50	0.93 (dry)	1.9	Pos. Wall Reinforcing Steel w/ Yielded End Supports	3.75 ft of Water Req'd for 1.1 Uplift Factor Of Safety
118+87	1.1 (dry)	2.2	Neg. Wall Reinforcing Steel w/ Fixed End Supports	99.8%
343+95	1.1 (dry)	2.7	Neg. Wall Reinforcing Steel w/ Fixed End Supports	99.8%
442+30	1.1 (dry)	2.1	Neg. Wall Reinforcing Steel w/ Fixed End Supports	99.8%
448+64	1.1 (dry)	2.3	Neg. Wall Reinforcing Steel w/ Fixed End Supports	99.8%
458+44	1.4 (dry)	4.1	Neg. Wall Reinforcing Steel w/ Fixed End Supports	99.8%
462+13	1.2 (dry)	1.9	Neg. Wall Reinforcing Steel w/ Fixed End Supports	99.8%
462+26	1.2 (dry)	2.4	Neg. Wall Reinforcing Steel w/ Fixed End Supports	99.8%
468+41	1.3 (dry)	3.4	Neg. Wall Reinforcing Steel w/ Fixed End Supports	99.8%

474+75	1.3 (dry)	3.1	Neg. Wall Reinforcing Steel w/ Fixed End Supports	99.8%
479+23	1.1 (dry)	1.5	Neg. Wall Reinforcing Steel w/ Fixed End Supports	99.8%
484+80	1.5 (dry)	2.2	Neg. Wall Reinforcing Steel w/ Fixed End Supports	99.8%
500+60	1.4 (dry)	1.8	Neg. Wall Reinforcing Steel w/ Fixed End Supports	99.8%
505+88	1.4 (dry)	1.8	Neg. Wall Reinforcing Steel w/ Fixed End Supports	99.8%
512+48	1.6 (dry)	4.8	Neg. Wall Reinforcing Steel w/ Fixed End Supports	99.8%
521+68	1.4 (dry)	4	Neg. Wall Reinforcing Steel w/ Fixed End Supports	99.8%

b. The 5.5'x 4.5' drop inlet buried to a 6.5 ft depth at station 75+50 fails to meet uplift criteria. Almost 4ft of water would be necessary to meet the minimum required 1.1 uplift factor of safety, while only 1.5ft are required for a factor of safety greater then 1.0. Because the 4ft water requirement may be unreasonable, a cost has been included for the addition of foundation heel extensions. Because of the relatively minor cost contribution of the repair (<$25K), and the rather significant probability of failure curve developed for the East Oakland Pump Station, a reliability curve for the drop inlet was not developed for economic input.

A-5.6.2.3 Pump Stations

a. The East Oakland Pump Station was constructed as part of the Federal Project (as builts dated 1970) to handle interior drainage.

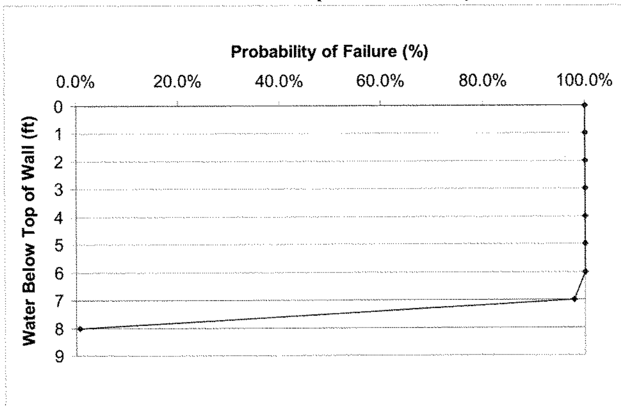
b. Table A-5-9 below summarizes reliability criteria findings. All results are computed with water to top of levee. Column three displays uplift factors of safety with no water in the wet well. Column four shows the level of water required in the wet well to meet the minimum 1.1 required uplift factor of safety. Based on the pump stations pump shutoff elevation, column five shows the actual minimum level of water likely to present in the well.

Table A-5-9: East Oakland Pump Station

East Oakland Pump Station with water at top of levee						
Station	Station Name	Uplift Factor of Safety (> 1.1 Req'd)	Water Req'd to meet 1.1 Uplift Factor of Safety (ft)	Water Available (ft)	Strength Factor of Safety (> 1.5 Req'd)	Comments
220+00	East Oakland	0.76 (Dry)	7.25	2	1.68	**Foundation Heel Extensions Req'd**

c. The East Oakland Pump station fails to meet a minimum uplift factor of safety. Using a varying hydraulic gradeline (based on possible variations in the foundation blanket thickness, blanket permeability, and foundation permeability) supplied by geotechnical team members, the reliability curve below was developed for input into HEC-FDA. To correct possible uplift concerns, extensive temporary excavation will be required to facilitate the addition of foundation heel extensions to allow for additional soil loading to counteract uplift pressures.

FIGURE 1 – East Oakland Pump Station Probability of Failure



A-5.6.2.4 Spread Footing Floodwall and Retaining Wall

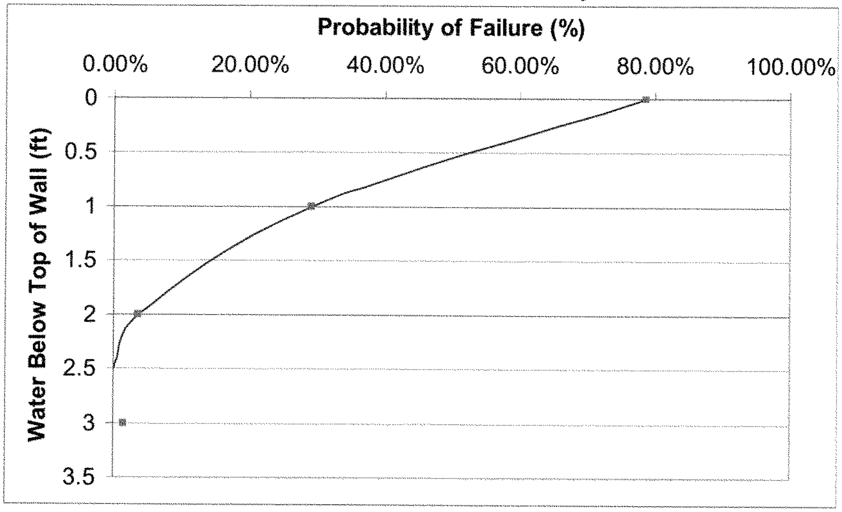
a. One floodwall runs from station 485+86 to 491+01. Exposed wall heights vary from 7ft to 9ft. Wall strength and stability calculations are summarized below.

Table A-5-10: Oakland Spread Footing Floodwall

Oakland Spread Footing Floodwall with water to top of levee						
Station	Wall Cross Section	Overturning % Base in Compression (> 25% Req'd)	% Bearing Capacity (Demand/Capacity) (150% Max Increase)	Sliding Factor of Safety (>1.3 Req'd)	Wall Strength Factor of Safety (>1.5 Req'd)	Comments
489+50	Sec B-B	38.0 %	43.5 %	0.76	1.95	2 ft of Additional Fill Req'd Behind Floodwall to meet sliding requirements
489+81	Sec A-A	45.8 %	43.5 %	0.85	1.56	2 ft of Additional Fill Req'd Behind Floodwall to meet sliding requirements

b. Both wall sections failed to meet sliding stability. Wall cross section B-B (see Table A-5-10 Sta 489+50) was determined to be the critical wall cross section (lowest factor of safety) for which a probability of failure was calculated. The risk and uncertainty analysis (using the procedure described earlier in this chapter) yielded the curve shown below. The graph in FIGURE 2 was used for HEC-FDA input data for probability of failure vs. water elevation. (The squares on the graph are the actual data point used to develop the curve.)

FIGURE 2 - Oakland Floodwall Probability of Failure



c. Subsequent analysis of the critical section revealed two feet of additional fill behind the wall would be sufficient to meet minimum sliding requirements for both wall section types. Site visits showed sufficient landside real estate is available for placement of the two feet of additional fill from approximately station 485+86 to 491+01.

A-5.6.2.5 Retaining Walls

One retaining wall located at the toe of the levee runs from station 0+51 to 1+75. Wall strength and stability calculations are summarized below. Results are based on water to top of levee. All factors of safety are met and a 99.8% reliability is assigned.

Table A-5-11: Oakland Retaining Wall

Oakland Retaining Wall with water to top of levee						
Station	Wall Cross Section	Overturning % Base in Compression (> 25% Req'd)	% Bearing Capacity (Demand/Capacity) (150% Max Increase)	Sliding Factor of Safety (>1.3 Req'd)	Wall Strength Factor of Safety (>1.5 Req'd)	Comments
1+00	Sec A-A	100 %	24.2 %	1.58	1.7	99.8 % Reliability

A-5.6.2.6 Levee Opening Closure Structures

One sandbag gap is located at Station 337+87. No deficiencies were observed and a 99.8% reliability is assumed.

A-5.6.3 North Topeka Unit

a. The North Topeka Unit is located along the left bank of the Kansas River beginning on Soldier Creek and extending upstream along the left bank of the Kansas River to approximate river mile 82. The flood risk management unit includes 9.3 miles of earthen levee. The North Topeka Unit was designed in 1961 and constructed between 1964 and 1967 for the purpose of protecting the North Topeka area.

b. North Topeka structures considered included fourteen gatewell closure structures, two reinforced concrete box structures, one sandbag closure gap, one floodwall section with stoplog gap, and three pump stations.

A-5.6.3.1 Gatewell Closure Structures

Information was available for only eight of the fourteen gatewell closure structures located along the North Topeka unit. Because no problems were discovered with any of the other North Topeka gatewells (or any other Topeka unit's gatewells) and site inspections revealed on issues, it is assumed that the gatewells for which information was not located are also acceptable. Non-Destructive Testing may be necessary to determine material strengths, reinforcing details, and wall thicknesses to validate this assumption when plans and specifications are prepared.

Table A-5-12: North Topeka Gatewell Reliability

North Topeka Gatewells with water to top of levee				
Station	Uplift Factor of Safety (> 1.1 Req'd)	Strength Factor of Safety (> 1.5 Req'd)	Controlling Structural Mechanism	Assigned Reliability
81+50	1.2 (dry)	1.51	Neg. Wall Reinforcing Steel w/ Fixed End Supports	99.8%
104+00	No Information			
172+00	1.42	2.03	Neg. Wall Reinforcing Steel w/ Fixed End Supports	99.8%
177+41	No Information			
210+00	No Information			
215+50	1.33	1.78	Neg. Wall Reinforcing Steel w/ Fixed End Supports	99.8%
260+88	No Information			
277+00	No Information			
295+75	1.49	3.49	Neg. Wall Reinforcing Steel w/ Fixed End Supports	99.8%
299+20	1.35	1.64	Neg. Wall Reinforcing Steel w/ Fixed End Supports	99.8%
325+15	1.3	1.6	Pos. Wall Reinforcing Steel w/ Yielded End Supports	99.8%
364+60	1.27	2.75	Neg. Wall Reinforcing Steel w/ Fixed End Supports	99.8%
375+00	No Information			
493+70	1.2	1.6	Neg. Wall Reinforcing Steel w/ Fixed End Supports	99.8%

A-5.6.3.2 Reinforced Concrete Boxes

One active and one abandoned reinforced concrete box crosses the North Topeka unit. Results shown in Table A-5-13 are based on water to top of levee with no water in the box. All factors of safety are met and a 99.8% reliability is assumed.

Table A-5-13: North Topeka Reinforced Box Culverts

North Topeka Reinforced Box Culvert with water to top of levee				
Station	Uplift Factor of Safety (> 1.1 Req'd)	Strength Factor of Safety (> 1.5 Req'd)	Controlling Structural Mechanism	Assigned Reliability
92+68	Abandoned, Filled in Place			99.8%
392+05	2	1.5	Pos. Wall Reinforcing Steel w/ Yielded End Supports	99.8%

A-5.6.3.3 Pump Stations

a. Three pump stations are located along the North Topeka unit. The exact date of construction for the Fairchild Pump station is unknown (probably 1920's) and the station is no longer used. Quincy and Soldier Creek pump stations were constructed as part of the Federal project in the 1960's (as-builts dated 1969) for interior drainage.

b. Table A-5-14 below summarizes reliability criteria findings. All results are computed with water at the top of levee. Column three displays uplift factors of safety with no water in the wet well. Column four shows the level of water required in the wet well to meet the minimum 1.1 required uplift factor of safety. Based on each pump stations individual pump station shutoff elevations, column five shows the actual minimum level of water likely to present in the well.

Table A-5-14: North Topeka Pump Stations

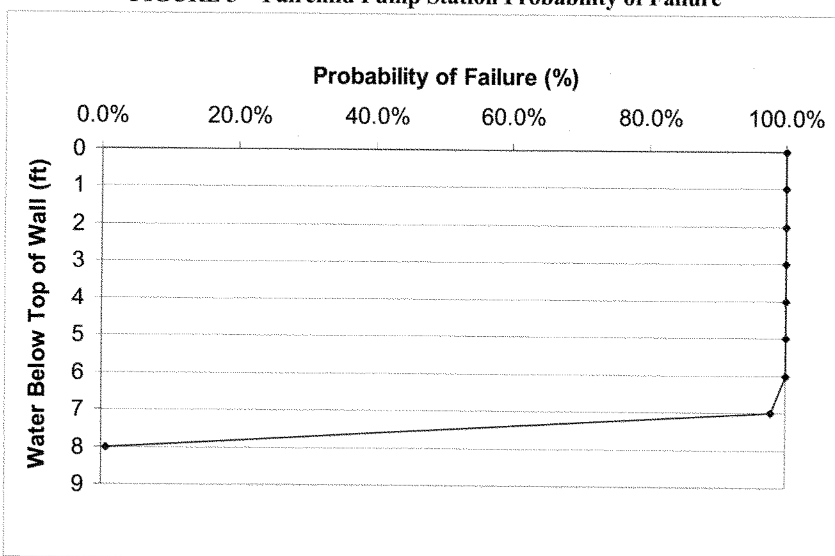
North Topeka Pump Stations with water at top of levee						
Station	Station Name	Uplift Factor of Safety (> 1.1 Req'd)	Water Req'd to meet 1.1 Uplift Factor of Safety (ft)	Water Available (ft)	Strength Factor of Safety (> 1.5 Req'd)	Comments
325+15	Soldier Creek	0.93 (Dry)	4.25	4.05	1.57	**No Corrective Measures Necessary**
364+60	Fairchild	0.72 (Dry)	9.4	No Information Available		**Station to be abandoned in place. Fill substructure and outlet lines with flowable fill.**
392+05	Quincy	1.13 (Dry)	N/A	N/A	1.53	**No Corrective Measures Necessary**

c. Without water in the wet well, the Solider Creek pump station fails to meet uplift criteria. Calculations show approximately 4.25 ft of water in the wet well would be required to achieve a 1.1 uplift Factor of Safety. The pumps shutoff when water drops to 4 ft of water in the well, and with 4ft of water in the wet well, an uplift factor of safety greater then 1.0 is calculated. At time of plans and specifications the pump station operating curves may be reanalyzed to determine if 4.25ft of water can be stored in the wet well without impacts to interior ponding and flooding.

d. Little information has been located for the Fairchild pump station. Pump station uplift calculations are based on field measurements of exterior footprint dimensions, interior sump dimensions, and assumptions for floor member thickness. Using these dimensions and varying hydraulic gradelines (based on possible variations in blanket thickness, blanket permeability, and foundation permeability) supplied by geotechnical team members, very low reliabilities were calculated for the Fairchild pump station for water at any elevation on the levee. The Fairchild pump station is no longer in use and will be abandoned in place by filling both the pump station substructure and outlet works with flowable fill.

e. The relatively small estimated cost for the fix (~$40K) can be justified by the prevention of only minimal damages. Consequently, a refined reliability curve has not been developed for the Fairchild pump station. Instead the reliability curve developed for the more reliable East Oakland pump station will also be used to define the Fairchild station.

FIGURE 3 – Fairchild Pump Station Probability of Failure



A-5.6.3.4 Spread Footing Floodwall

A floodwall starts at station 300+28 and extends to station 301+06 with exposed wall heights up to approximately 7feet. Wall strength and stability calculations are summarized below. All required factors of safety were met and a 99.8% reliability was assigned.

Table A-5-15: North Topeka Spread Footing Floodwall

Spread Footing Floodwall with water to top of levee						
Station	Wall Cross Section	Overturning % Base in Compression (> 25% Req'd)	% Bearing Capacity (Demand/Capacity) (150% Max Increase)	Sliding Factor of Safety (>1.3 Req'd)	Wall Strength Factor of Safety (>1.5 Req'd)	Comments
300+28	Sec B	86.4 %	27.8 %	3.87	2.08	99.8 % Assigned Reliability

A-5.6.3.5 Levee Opening Closure Structures

A single railroad stoplog closure gap structure is located in the North Topeka floodwall. Results are summarized below. All required factors of safety were met and a 99.8% reliability was assigned.

Table A-5-16: North Topeka Levee Opening Closure Structures

North Topeka Closure Structures with Water to Top of Wall					
Station	Overturning % Base in Compression (> 25% Req'd)	% Bearing Capacity (Demand/Capacity) (150% Max Increase)	Sliding Factor of Safety (>1.3 Req'd)	Wall Strength Factor of Safety (>1.5 Req'd)	Comments
29+55	Sandbag Closure Gap, No Deficiencies Observed				99.8% Assigned Reliability
300+68	86.4 %	27.8 %	3.45	2.09	99.8 % Reliability

A-5.6.4 Soldier Creek Unit

a. The Soldier Creek Unit is located along Soldier Creek, beginning at Kansas River mile 81.9 and extending northwesterly to the vicinity of the Silver Lake channels and levees. The purpose of this unit is to provide flood risk management for north Topeka against a peak Soldier Creek discharge of approximately 50,000 cfs. The Soldier Creek unit includes 17.9 miles of levee, 9.2 miles of channel improvement, and approximately 4.3 miles of tributary tie back levees along the left bank of Soldier Creek. The project was designed in 1958 and constructed between the years 1958 and 1962.

b. Nineteen gatewell closure structures were considered.

A-5.6.4.1 Gatewell Closure Structures

a. Analysis results are based on water to top of levee with no water in the gatewell and are summarized below. All required factors of safety were met and a 99.8% reliability was assigned.

Table A-5-17 – Soldier Creek Gatewell Reliability

Soldier Creek Gatewells with water to top of levee				
Station	Uplift Factor of Safety (> 1.1 Req'd)	Strength Factor of Safety (> 1.5 Req'd)	Controlling Structural Mechanism	Assigned Reliability
Right Bank				
-1+75	1.4 (dry)	2.27	Neg. Wall Reinforcing Steel w/ Fixed End Supports	99.8%
39+80	1.5 (dry)	3.94	Neg. Wall Reinforcing Steel w/ Fixed End Supports	99.8%
62+15	1.5 (dry)	3.94	Neg. Wall Reinforcing Steel w/ Fixed End Supports	99.8%
75+20	1.5 (dry)	3.43	Neg. Wall Reinforcing Steel w/ Fixed End Supports	99.8%
93+55	1.5 (dry)	3.16	Neg. Wall Reinforcing Steel w/ Yielded End Supports	99.8%
115+00	1.5 (dry)	4.42	Neg. Wall Reinforcing Steel w/ Fixed End Supports	99.8%
138+49	1.5 (dry)	3.95	Neg. Wall Reinforcing Steel w/ Fixed End Supports	99.8%
162+90	1.5 (dry)	3.49	Neg. Wall Reinforcing Steel w/ Fixed End Supports	99.8%
191+50	1.4 (dry)	1.92	Neg. Wall Reinforcing Steel w/ Fixed End Supports	99.8%
210+82	1.2 (dry)	2.18	Neg. Wall Reinforcing Steel w/ Fixed End Supports	99.8%
244+96	1.4 (dry)	1.88	Neg. Wall Reinforcing Steel w/ Fixed End Supports	99.8%
264+10	1.4 (dry)	3.57	Neg. Wall Reinforcing Steel w/ Fixed End Supports	99.8%
344+65	1.4 (dry)	2.04	Neg. Wall Reinforcing Steel w/ Fixed End Supports	99.8%

375+50	1.4 (dry)	2.36	Neg. Wall Reinforcing Steel w/ Fixed End Supports	99.8%
399+20	1.4 (dry)	1.97	Neg. Wall Reinforcing Steel w/ Fixed End Supports	99.8%
Left Bank				
138+05	1.4 (dry)	2.31	Neg. Wall Reinforcing Steel w/ Fixed End Supports	99.8%
277+90	1.4 (dry)	2.12	Neg. Wall Reinforcing Steel w/ Fixed End Supports	99.8%
330+25	1.4 (dry)	1.84	Neg. Wall Reinforcing Steel w/ Fixed End Supports	99.8%
Tieback				
2+87 TB3	No Information			99.8% Assumed

b. Information was not available for one of the nineteen gatewell closure structures located along the Soldier Creek unit. Because no problems were discovered with any of the other Soldier Creek gatewells (or any other Topeka unit gatewells) and site inspections revealed no issues, it is assumed that the gatewells for which information was not located are also acceptable. Non-Destructive Testing may be necessary to determine material strengths, reinforcing details, and wall thicknesses to validate this assumption when plans and specifications are prepared.

A-5.6.5 South Topeka Unit

a. The South Topeka Unit is located along the right bank of the Kansas River between the Auburndale Unit at the west upper end (river mile 85.5) and Santa Fe Railroad bridge at mile 83.8 at the lower end. The unit consists of 1.4 miles of earthen levee, 1,944 feet of pile founded floodwall and two stoplog gaps. The unit was designed in 1966 and constructed between the years of 1970 and 1973, though incorporated portions of the unit predate the 1940's.

b. South Topeka structures considered for this study included eight gatewell closure structures, six riverside closure gates, forty-six manhole and drop inlet structures, two reinforced concrete box structures, four pump stations, one pile founded floodwall, and two stoplog closure gaps, and associated spread footing transition walls.

A-5.6.5.1 Gatewell Closure Structures

Information was only available for four of the eight gatewell closure structures located along the South Topeka unit. The four gatewells for which information could not be found are located in the pile founded floodwall. Significant concerns about the floodwall reliability have led to a recommendation that the floodwall be removed and replaced. Because the four gatewells are integral with the floodwall, in the process of replacing the floodwall, the four gatewells will also require replacement.

Table A-5-18: South Topeka Gatewell Reliability

South Topeka Gatewells with water to top of levee				
Station	Uplift Factor of Safety (> 1.1 Req'd)	Strength Factor of Safety (> 1.5 Req'd)	Controlling Structural Mechanism	Assigned Reliability
16+07	1.3 (dry)	1.8	Neg. Wall Reinforcing Steel w/ Fixed End Supports	99.8%
19+81	1.2 (dry)	1.5	Pos Wall Reinforcing Steel w/ Yielded End Supports	99.8%
67+55	1.3 (dry)	1.7	Neg. Wall Reinforcing Steel w/ Fixed End Supports	99.8%
69+22	No Information, To Be Replaced with Floodwall			
75+62	No Information, To Be Replaced with Floodwall			
86+09	No Information, To Be Replaced with Floodwall			
86+55	No Information, To Be Replaced with Floodwall			
88+09	1.5 (dry)	3.4	Neg. Wall Reinforcing Steel w/ Fixed End Supports	99.8%

A-5.6.5.2 Manholes and Drop Inlets

a. An elaborate system of some forty-six manholes, drop inlets, and relief wells form an underseepage relief system along the South Topeka levee unit. A summary of results follows.

Table A-5-19: South Topeka Manholes

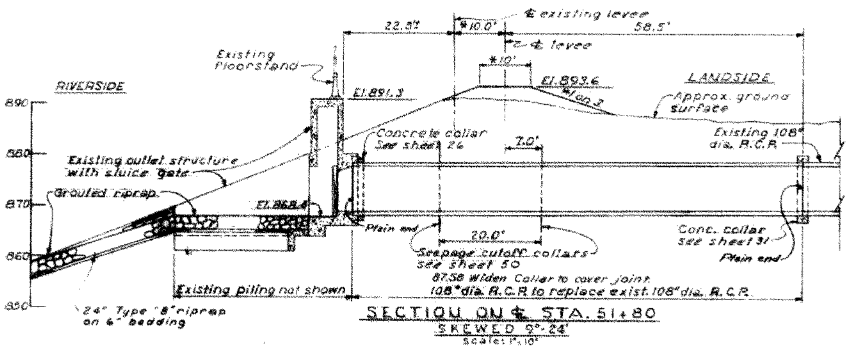
South Topeka Manholes with Water at Top of Levee				
Station	Uplift Factor of Safety (> 1.1 Req'd)	Water Req'd to meet 1.1 Uplift Factor of Safety (ft)	Strength Factor of Safety (> 1.5 Req'd)	Comments
16+07	0.84 (Dry)	11 ft	4.4	**Heel Extension Required**
73+69	1.47 (Dry)		2.1	
73+98	1.38 (Dry)		2.4	
74+02	1.47 (Dry)		2.7	
74+16	1.51 (Dry)		1.8	
75+01	1.37 (Dry)		2.5	
75+10	1.24 (Dry)		2.1	
75+13	1.32 (Dry)		2.4	
75+20	1.43 (Dry)		1.6	
75+48	1.68 (Dry)		2.1	
75+84	1.19 (Dry)		2.2	
76+09	1.33 (Dry)		2.2	
76+25	1.32 (Dry)		1.7	
76+32	1.10 (Dry)		2.1	
76+75	1.10 (Dry)		2.0	
77+22	1.97 (Dry)		2.0	
77+50	1.10 (Dry)		2.0	
77+91	1.10 (Dry)		1.9	
78+20	1.31 (Dry)		2.5	
78+25	1.10 (Dry)		2.1	
79+18	1.00 (Dry)	1.9 ft	1.8	
79+25	0.99 (Dry)	3.1 ft	1.9	
79+25a	1.32 (Dry)		2.5	
80+15	1.33 (Dry)		2.6	
80+25	1.06 (Dry)	1 ft	2.0	
81+04	1.20 (Dry)		2.6	
81+30	1.06 (Dry)	1.1 ft	1.9	
84+10	0.89 (Dry)	8.2 ft	2.1	**Heel Extension Required**
84+10a	0.88 (Dry)	8 ft	2.2	**Heel Extension Required**
85+57	0.96 (Dry)	4.7 ft	1.5	**Heel Extension Required**
86+34	0.99 (Dry)	3.0 ft	1.1	
86+65	1.01 (Dry)	1.5 ft	2.0	
87+15	1.01 (Dry)	1.5 ft	2.1	
87+65	1.01 (Dry)	1.5 ft	2.1	
88+15	1.01 (Dry)	1.5 ft	2.2	
88+60	1.01 (Dry)	1.5 ft	2.2	
88+69	0.99 (Dry)	2.5 ft	2.5	
89+15	1.00 (Dry)	1.5 ft	2.5	
89+66	1.00 (Dry)	1.4 ft	2.5	
89+73	1.03 (Dry)	1.7 ft	2.0	
90+15	1.01 (Dry)	1.4 ft	2.6	
90+65	1.00 (Dry)	1.4 ft	2.7	
91+02	1.23 (Dry)		1.6	
91+29	1.00 (Dry)	1.3 ft	3.0	
91+40	0.98 (Dry)	2.8 ft	2.0	
93+30	1.00 (Dry)	2.8 ft	1.7	

b. Uplift calculations are based on fifty percent relief well efficiency as supplied by geotechnical engineers. It is assumed that up to three feet of water will be allowed in the collector system to meet uplift requirements. Four manhole boxes fail to meet uplift criteria with three foot of standing water (Sta. 16+07, 84+10, 84+10a, and 85+57). Costs have been included for adding foundation heel extensions to each manhole. Because of the high probabilities of failure developed for the South Topeka floodwall and due to the relatively low cost of repair (<$25K), reliability curves were not developed for manhole uplifts.

A-5.6.5.3 Riverside Sluice Gates

a. The South Topeka unit has six riverside closure gates consisting of manually operated sluice gates located in gatewells riverside of the centerline of levee. A typical gate (Sta 51+80) is shown below.

FIGURE 4 – Typical South Topeka Closure Gate



b.

Table A-5-20 below summarizes reliability criteria findings. All results are computed with water to top of levee. Column two displays uplift factors of safety with no water in the outlet structure. Column three shows the level of water required in the structure to meet the minimum 1.1 required uplift factor of safety.

Table A-5-20: South Topeka Riverside Sluice Gates

South Topeka Riverside Sluice Gates with Water at Top of Levee					
Station	Uplift Factor of Safety (> 1.1 Req'd)	Water Req'd to meet 1.1 Uplift Factor of Safety (ft)	Strength Factor of Safety (> 1.5 Req'd)	Comments	Reliability
19+81	See RCB Calculations				
22+71	Previously Abandoned in place with Grout				
46+74	See RCB Calculations				
51+80	1.08	1 ft	Not Calculated	Limited Information	Assumed 99.8 %
88+69	Located in Floodwall (To be Replaced)				
91+02	Located in Floodwall (To be Replaced)				

c. Of the six closure gates studied, one was previously abandoned in place with grout. No further action is recommended for this structure. Two of the riverside gatewell closure structures are located in the pile founded floodwall. Significant concerns have been determined for the floodwall foundation and it is recommended the floodwall be removed and replaced. As a result, to facilitate construction of the floodwall, the two riverside gates will also need to be removed and replaced with gatewells. Reliabilities were not calculated for the two closure structures. Uplift calculations were performed for a fourth closure structure, but because of insufficient information, strength calculations were not conducted. Because only 1ft of water is required in the structure to meet uplift criteria with water to top of levee and no other closure structures studied exhibited strength concerns, the gate structure is considered sufficient and assigned a 99.8% reliability. A summary of calculations for the other two structures is included in the Reinforced Concrete Box portion of this report.

A-5.6.5.4 Reinforced Concrete Boxes

Two reinforced concrete boxes cross the South Topeka unit. Analysis results are based on water to top of levee with no water in the box. All minimum required factors of safety are met and a 99.8% reliability was assigned.

Table A-5-21: South Topeka Reinforced Box Culverts

South Topeka Reinforced Box Culvert with Water to Top of Levee					
Station	Uplift Factor of Safety (> 1.1 Req'd)	Water Req'd to meet 1.1 Uplift Factor of Safety (ft)	Strength Factor of Safety (> 1.5 Req'd)	Controlling Structural Mechanism	Assigned Reliability
19+81	1.3 (dry)	N/A	1.7	Floor Flexural Steel	99.8%
46+74	1.4 (dry)	N/A	4.3	Floor Flexural Steel	99.8%

A-5.6.5.5 Pump Stations

a. Four pump stations are located along the South Topeka Levee Unit. City Park pump station predates the Federal project and handles interior drainage. The Kansas Avenue pump station was constructed with the Federal Project (as-builts dated 1974) to pump intercepted flows from the collector system and relief wells. Morrell pump station predates the Federal project (possible original construction in 1947) and was modified in the Federal project to intercept collector system and relief well flows. Madison Street pump station was constructed by the City of Topeka, but was closely coordinated with the late '60s/early 70's Federal project to handle interior drainage.

b. Table A-5-22 below summarizes reliability criteria findings. All results are computed with water to top of levee. Column three displays uplift factors of safety with no water in the wet well. Column four shows the level of water required in the wet well to meet the minimum 1.1 required uplift factor of safety. Based on each pump stations individual pump station shutoff elevations, column five shows the actual minimum level of water likely to present in the well.

Table A-5-22: South Topeka Pump Stations

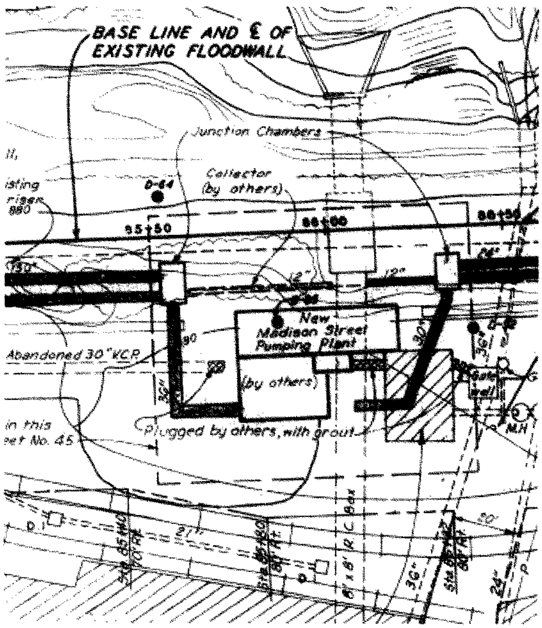
South Topeka Pump Stations with Water at Top of Levee						
Station	Station Name	Uplift Factor of Safety (> 1.1 Req'd)	Water Req'd to meet 1.1 Uplift Factor of Safety (ft)	Water Available (ft)	Strength Factor of Safety (> 1.5 Req'd)	Comments
68+85	City Park	1.48 (Dry)	N/A	N/A	1.57	**No Corrective Measures Necessary**
75+84	Kansas Avenue	1.2 (Dry)	N/A	N/A	0.90	**31% Prob. Of Failure: Wall Stiffener Required**
84+07	Morrell	0.87 (Dry)	4	No Information		**Assumed Sufficient No Corrective Measures Necessary**
86+00	Madison Street	1.0 (Dry)	1.5	3.5	1.52	**No Corrective Measures Necessary**

c. The City Park Pump Station meets uplift and strength requirements and a 99.8% reliability is assumed. At the Kansas Avenue pump station, the exterior foundation wall vertical steel fails to meet the required 1.5 factor of safety. Adding a mid-span stiffener wall will reduce the effective length by half, successfully reducing the edge plate moments to within an allowable range. Because of the high probabilities of failure developed for the South Topeka floodwall and due to the relatively low cost of repair (~ <$50K) for the pump station, a reliability curve was not developed for the Kansas Avenue Pump Station.

d. Uplift calculations for the Morrell Pump station are based on field measurements of foundation wall thicknesses and assumed floor thickness and super structure weights. Computations show 4ft of required in the wet well to meet uplift criteria. Pump station operation curves have not been found, but it is assumed 4ft of water is reasonable. No information is available for strength calculations but site visits revealed no foundation cracking or distress and reinforcing is assumed sufficient. At the time of plans and specifications preparation, these assumptions may require verification.

e. The Madison Street Pump Station meets uplift and strength screening criteria and a 99.8% reliability was assigned. The Madison Street Pump Station uplift factor of safety including 3.5ft of water in the wet well and a conservative value for skin friction (μ=0.15) was calculated as 1.2. The availability of 3.5 ft of water in the well is based on the existing pump shut off when water drops to 3.5ft.

FIGURE 5 – Madison Street Pump Station



A-5.6.5.6 Spread Footing Floodwall

Two sections of transition floodwalls for stoplog gaps are located along the South Topeka Unit from stations 1+34 to 3+33 and 50+72 to 51+70 with typical exposed stem wall heights of 9ft. Wall section properties with water to top of levee are summarized below. All factors of safety are met and a 99.8% reliability was assigned.

Table A-5-23: South Topeka Spread Footing Floodwall

South Topeka Spread Footing Floodwall with Water to Top of Levee						
Station	Wall Cross Section	Overturning % Base in Compression (> 25% Req'd)	% Bearing Allowable (Demand/Capacity) (150% Max Increase)	Sliding Factor of Safety (>1.3 Req'd)	Wall Strength Factor of Safety (>1.5 Req'd)	Comments
1+45	Sec A	72.0 %	23.6 %	2.22	1.7	99.8 % Reliability
51+00	Sec A	70.6 %	38.6 %	2.37	2.05	99.8 % Reliability

A-5.6.5.7 Levee Opening Closure Structures

a. Two stoplog closure structures are located in the floodwall reaches and were analyzed with water to top of wall. Results are summarized below.

Table A-5-24: South Topeka Levee Opening Closure Structures

South Topeka Closure Structures with Water to Top of Wall					
Station	Overturning % Base in Compression (> 25% Req'd)	% Bearing Allowable (Demand/Capacity) (150% Max Increase)	Sliding Factor of Safety (>1.3 Req'd)	Wall Strength Factor of Safety (>1.5 Req'd)	Comments
2+30	91.2 %	27.3 %	2.3	1.5	99.8 % Reliability
51+20	Stoplog gap integrated into RR Bridge Abutment. Stability not an issue.			4.26	99.8 % Reliability

b. Both stoplog gaps meet all deterministic criteria and a 99.8 % reliability was assumed.

A-5.6.5.8 Pile Founded Floodwall

a. The timber pile founded floodwall extends from approximately station 74+41 to 93+86. The concrete wall and the timber piles were analyzed and found to be reliable for strength. However, the timber piles were found to have unacceptable reliability due to their soil based axial capacity.

The complete discussion of this floodwall can be found in Chapter A-6. Background information, discussion of structural and geotechnical evaluations, and the results for the wall are included. See Chapter A-6 Exhibit 11 for the reliability results.

b. A potential timber pile axial failure could result in excessive floodwall deflections, water infiltration through opened wall joints, scour around the openings, and rapid wall failure. Based on review of existing information and preliminary analysis, it has been concluded that the South Topeka floodwall is unreliable and cannot reasonably be made reliable by modifications to the existing structure. Consequently, a new floodwall will be required to replace the existing floodwall to address reliability concerns. Due to real estate constraints and the extensive landside underseepage collector system, it is recommended to construct the new wall in the same footprint as the old wall. See Chapter A-6 for a discussion of the required sequence for in-line replacement.

A-5.6.6 Waterworks Unit

a. The Waterworks Unit is located along the right bank of the Kansas River to provide flood risk management for the western side of Topeka. The levee unit includes 1,998 feet of earthen levee and 1,662 feet of floodwall. The project was designed in 1957 and constructed during 1959.

b. Waterworks structures considered for this study included one gatewell closure, one sandbag closure gap, four stoplog closure gaps, and fifteen different floodwall cross sections making up the floodwall.

A-5.6.6.1 Gatewell Closure Structures

One Waterworks gatewell was analyzed for water to top of structure. All required factors of safety were met and a 99.8% reliability was assigned.

Table A-5-25: Waterworks Gatewell Reliability

Waterworks Gatewell with water to top of levee				
Station	Uplift Factor of Safety (> 1.1 Req'd)	Strength Factor of Safety (> 1.5 Req'd)	Controlling Structural Mechanism	Assigned Reliability
1+90	1.2 (dry)	1.51	Wall Shear Strength	99.8%

A-5.6.6.2 Spread Footing Floodwall

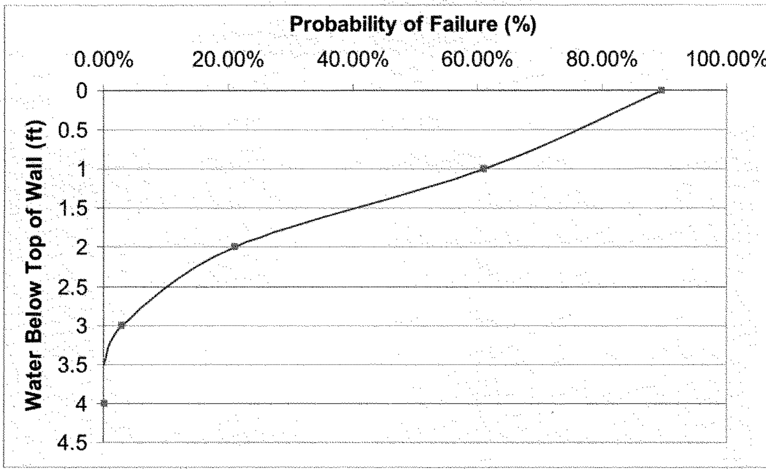
a. The 1600 linear foot spread footing floodwall has an average exposed wall height of between eight and twelve feet. A sheetpile cutoff wall is embedded in the heel of the floodwall along with a relief well system. Wall section properties are summarized below.

Table A-5-26: Waterworks Spread Footing Floodwall

Waterworks Spread Footing Floodwall with water to top of levee						
Station	Wall Cross Section	Overturning % Base in Compression (> 25% Req'd)	% Bearing Allowable (Demand/Capacity) (150% Max Increase)	Sliding Factor of Safety (>1.3 Req'd)	Wall Strength Factor of Safety (>1.5 Req'd)	Comments
0+58	Sec P	100 %	46.0 %	3.13	1.82	99.8 % Assigned Reliability
1+50	Sec N	69.4 %	81.6 %	0.78	1.72	2 ft of Additional Fill Req'd Behind Floodwall to meet sliding requirements
2+75	Sec M	85.7 %	81.6 %	1.37	1.76	99.8 % Assigned Reliability
6+64	Sec B	93.4 %	65.2 %	1.28	2.32	99.8 % Assigned Reliability
8+50	Sec L	92.0 %	65.0 %	2.42	1.71	99.8 % Assigned Reliability
9+30	Sec K	100 %	53.0 %	1.86	2.25	99.8 % Assigned Reliability
10+70	Sec H	100 %	43.2 %	1.67	1.53	99.8 % Assigned Reliability
11+50	Sec G	94.9%	53.4 %	1.87	2.97	99.8 % Assigned Reliability
12+00	Sec U	84.9 %	93.6 %	1.69	1.38	99.8% Calc. Reliability
12+58	Sec T	85.9 %	84.5 %	1.55	1.58	99.8 % Assigned Reliability
13+20	Sec F	94.2 %	53.6 %	1.15	2.14	2 ft of Fill Behind Floodwall
14+50	Sec A	96.0 %	52.2 %	1.05	2.15	2 ft of Fill Behind Floodwall
15+10	Sec E	95.3 %	53.2 %	1.06	2.11	2 ft of Fill Behind Floodwall
15+50	Sec S	90.3 %	52.9 %	0.96	2.14	2 ft of Fill Behind Floodwall
16+15	Sec C	89.7 %	53.9 %	0.97	2.1	2 ft of Fill Behind Floodwall

b. Six analyzed floodwall cross sections failed to meet sliding stability. Section N (Station 1+50) was determined to be the critical wall cross section (lowest factor of safety for sliding) for which a probability of failure was calculated. The risk and uncertainty analysis (using the procedure described earlier in this chapter) yielded the curve shown below. The displayed data points represent the calculated probabilities versus water elevation while the continuous line represents values input into the HEC-FDA model.

FIGURE 6 - Waterworks Floodwall Probability of Failure



c. Subsequent analysis of the critical section revealed two feet of additional fill behind the wall would be sufficient to meet minimum sliding requirements. Based on site visits two foot of fill extended for a distance of 5ft from centerline of floodwall and then tapered at a 1 on 3 slope can easily be placed behind the floodwall. Fill was assumed required between stations 0+78 to 7+00 and 10+00 to 16+50 for a total of 1272 linear feet. At time of plans and specifications more exact stationing will be determined.

A-5.6.6.3 Levee Opening Closure Structures

a. Four stoplog closure structures in the Waterworks floodwall were analyzed with water to top of wall. Results are summarized below.

Table A-5-27: Waterworks Levee Opening Closure Structures

Waterworks Closure Structures with water to top of wall					
Station	Overturning % Base in Compression (> 25% Req'd)	% Bearing Allowable (Demand/Capacity) (150% Max Increase)	Sliding Factor of Safety (>1.3 Req'd)	Wall Strength Factor of Safety (>1.5 Req'd)	Comments
11+10	Sandbag Closure Gap, No Deficiencies Observed				
0+58	69.4 %	69.0 %	0.78	1.73	Stoplog Gap has been filled Wall Cross Section same as Sec. N
9+30	75.7 %	85.9 %	1.04	1.7	Wall Alignment Restrains Sliding Potential
13+07	68.6 %	90.2 %	0.8	1.3	Minimal Gap, Backfill behind gap sidewalls to address sliding stability. 99.8% Calculated Strength Reliability.
15+95	56.7 %	86.8 %	0.75	1.6	Backfill behind gap sidewalls to address sliding stability.

b. The stoplog gap at station 0+58 was filled in the past, and has a similar geometry to floodwall cross Section N. Two feet of additional will be added behind the wall to address stability concerns. The stoplog gap at station 9+30 is configured such that an adjoining floodwall monolith forms a ninety degree at the end of the stop log monolith, effectively acting as a stiffener preventing lateral movement of the wall. The gap at 13+07 is of such small size that sufficient length of approach wall is available to allow for placement of 2 feet of backfill behind the floodwall monolith. The Gap at 15+95 is located in an L-shaped monolith, also allowing for enough length to effectively place two additional feet of fill behind the wall. Because Section N had a lower sliding factor of safety then the gap at station 13+07, the probability of failure curve developed for Section N was used to define the reliability of the entire wall, including all the stoplog gaps located in the wall.

Chapter A-6

SOUTH TOPEKA FLOODWALL

A-6 SOUTH TOPEKA – PILE FOUNDED FLOODWALL (Sta. 74+41 to 93+86)

A-6.1 FLOODWALL BACKGROUND INFORMATION

The existing South Topeka pile-founded floodwall was constructed in 1939. The wall is a concrete cantilever type supported on creosote treated timber piles with a 15-foot steel sheet pile cutoff under the riverside edge of the base. The floodwall is approximately 2,000 feet long and extends 11 to 13 feet above the landside surface. This floodwall replaced a pile founded floodwall constructed in 1908. 1938 construction drawings provide detailed cross-sections of the floodwall; however, the drawings do not explicitly provide the pile diameter, pile depth, or material properties.

A-6.1.1 Floodwall "Roofing"

a. Portions of the original 1908 floodwall were "encompassed" (buried) in the 1939 levee construction. Construction of the City Park Pump Station (Sta. 68+84) in 1956 uncovered a portion of the buried floodwall and discovered significant "roofing" under the old pile foundation system, suggesting the possibility of void areas and seepage paths in the levee (Exhibit 3).

b. Construction photos (possibly of the Kansas Avenue Pump Station, ~1968) and three Corps of Engineers' test pit excavations mentioned in the 8 September 1964 meeting minutes reference similar roofing concerns for the 1939 floodwall (Photo 1 & Exhibit 1).

Photo 1 – Floodwall "Roofing"

c. To address the underseepage concerns associated with the roofing issue, a 23-24 March 1964 meeting suggested the ideas of either a new/reconditioned toe drain or some form of subsurface grouting (either a grout curtain wall or grouting the roofing void) (Exhibit 4). By the time of a 15 November 1966 meeting a series of seepage interceptors, relief wells and pumped wells were recommended to address wall underseepage and nearby basement uplift concerns (Exhibit 5).

A-6.1.2 Floodwall Sheetpile Cutoff Wall and Uplift Assumptions

The 8 September 1964 meeting refers to the sheetpile condition and size. "The sheet pile wall is reasonably impervious. The interlocks being corroded and filled in the past 25 years." (Exhibit 1).

Uplift due to full river head was assumed at the sheet piling and static head from the bottom of the base to the ground surface was assumed at the landside toe, plus 2 additional feet of head to provide for losses into the toe drain and for discharging slightly above ground surface manholes in the toe drain. Based on the previously described roofing void, uplift under the base from the sheet pile to the landward toe is assumed equal. Since the void is in direct communication with the toe drain, pressure in the void cannot be higher then the landside uplift described above.

A-6.2 STRUCTURAL ANALYSIS

A-6.2.1 Floodwall Analysis Assumptions

a. Several assumptions were made for the analysis based on the drawings, correspondence, historical construction practices, and engineering judgment. The assumptions were as follows:

- **12 in. Pile Diameter.** This assumption was largely based on drawn to scale construction drawing sections. In addition, it is supported by photographic evidence of piles exposed during a 1960's excavation (Photo 2) and is consistent with the expected 10"-12" range for 1930's era construction.
- **25 ft. Pile Length.** Typical driven depths for timber piles of this era were anywhere from 20 to 35 feet. The manufactured length of timber piles was documented in the range of 30 to 60 feet. The construction drawings note a minimum penetration of 20 ft, and therefore, 25 ft was assumed.
- **2500 psi Concrete and 33 ksi Reinforcing Steel.** Based on historical material information.
- **Southern Pine Piles.** Southern pine was chosen as a typical pile species and to provide middle ground values of common pile species.
- **No degradation of the piles.**
- **Sheet Pile Loading.** The sheet piles were assumed to carry no load.
- **Pinned pile heads.**

Photo 2 –Photo with exposed pile

A-6.2.2 Wall and Pile Load Analysis

Four floodwall cross sections were examined representing all the floodwall section geometries. A Mathcad sheet was used to determine the loads acting on the pile group and to verify the pile loads calculated using the Corps' Computer-Aided Structural Engineering (CASE) computer program Pile Group Analysis (CPGA). The loads on the pile cap or pile group were input into CPGA to provide pile loads and check the piles for combined axial and bending loads. In addition, Mathcad was used to check the capacity of the stem and pile cap.

A-6.2.3 Reliability Analysis Methodology

The reliability of a typical pile founded floodwall would ideally be based on the following evaluations:

a. Concrete Strength
    1) Concrete compressive strength
    2) Concrete shear strength
    3) Reinforcing steel strength
b. Piles
    1) Pile Normal Stress (Combined Bending & Axial) & Pile Shear Stress
    2) Axial Capacity (soil based)
    3) Pile Lateral Deflection

For each mechanism listed above, the reliability is usually analyzed in the method described in the Chapter A-5.2 to 5.4. The following paragraphs explain how these failure modes were addressed specifically for this floodwall.

a. Concrete Strength
See Chapter A-5

b. Pile Normal Stress (Combined Bending & Axial) & Pile Shear Stress
The pile structural capacity was evaluated initially based on the traditional allowable load methodology using CPGA to compute axial, horizontal, and bending loads on the piles. The analysis found that shear loads exceeded the allowable shear stresses for one section. By exceeding the allowable stresses, the piles did not meet the factor of safety inherent to allowable loads which suggested a reliability concern. Therefore, a reliability analysis was performed.

For reliability, failure was defined as a Factor of Safety (capacity to demand ratio) less than one as described in Chapter A-5. Capacity was based on LRFD reference strength values. Strength reduction values (ϕ) were not used, but design adjustment factors and a time effect factor were included (see paragraph material properties paragraph below for more information). The demand, D, was be computed using unfactored loads.

<u>Material properties for pile stress reliability calculations:</u>

- Reference shear strength of 300 psi was taken from LRFD Manual for Wood Construction. The values in the LRFD manual are derived according to the principles of ASTM D5457. Strength reduction values were not used.
- The LRFD reference strength was multiplied by a time effect factor, λ, of 0.9 to account for the load duration. This value was chosen for a flood to represent a

length of loading that falls somewhere between a short duration load (wind, λ= 1.0) and an intermediate load duration (snow, λ= 0.8).

- Design adjustment factors for shear, C_t and C_u (for temperature and treatment), were equal to one.
- The Standard Deviation was found using the standard deviation from ASTM D 2555 Clear Wood Strength Values factored by the ratio of LRFD Strength over Clear Wood Strength from ASTM D 2555.

c. Axial Capacity

The ultimate axial capacity was computed and compared to the unfactored load to produce a factor of safety. A factor of safety of less than one was considered failure. An in-depth discussion and results for this failure mechanism is given in section A-6.3.

d. Lateral Deflection

The lateral deflection of the floodwall was not investigated due to the limited knowledge of foundation parameters and the piles as well as the poor results of the axial capacity analysis. A lateral deflection analysis would likely show significant deflections for the loading condition with water to the top of the wall.

A-6.2.4 Results

Results are provided in section A-6.4.

A-6.3 GEOTECHNICAL ANALYSIS

A-6.3.1 Axial Capacity of Timber Piles for Floodwall

A-6.3.1.1 Introduction

An analysis of the existing pile founded floodwall which comprises part of the flood protection in the South Topeka unit was investigated for the axial load capacity of the existing timber piles. The relief wells installed in 1969/1970 were considered in the calculation of underseepage pressures for the loading condition analyzed.

A-6.3.1.2 Foundation conditions

The floodwall comprises the flood protection for South Topeka from approximately station 74+40 AH to the downstream end of the protection at approximately station 94+00. As noted in boring logs and previous analyses, the floodwall is founded on a significant amount of highly variable fill materials over a relatively thin natural blanket. In fact, over some reaches the natural blanket is believed to be non-existent. The fill and blanket materials range in thickness from approximately 20 to 25 feet. The heterogeneous fill consists of everything from cinders and bricks to lean clays to organic materials. The top of bedrock is relatively constant through this reach at elevation 810, so the aquifer varies in thickness from approximately 45 to 50 feet. See **Exhibit 6** for excerpts from the November 1969 Construction Drawings that provide a plan and profile along the floodwall.

A-6.3.1.3 Underseepage Control Modifications

Underseepage control was added to the project in the late 1960's and early 1970's, apparently due to historic underseepage problems during the 1951 flood and may also be related to the revised protection design discharge (which effectively raised the level of protection to the top of the wall). The underseepage control included relief wells and a buried collector system along the entire reach of the wall. There are a total of 27 fully penetrating relief wells. The buried collector system is located at the landside toe of the floodwall and is intended to intercept any seepage through any pervious fill material that may exist in the heterogeneous fill under the floodwall. Both the wells and the collector system drain underground to the Madison Street pump plant which was constructed at the same time period. See **Exhibit 6** for relief well locations and buried collector system details.

A-6.3.1.4 Deterministic Axial Pile Capacity Analysis for Design Loading

a. Analyzed Sections

Evaluation of the foundation identified a reach from station 83+00 to 87+00 that had a relatively consistent 15 feet of CL and ML material overlying 10 feet of OL and other organic materials. These materials were considered to comprise the blanket. This reach was considered to be the critical reach with respect to the axial capacity of the piles because this is the thickest reach of blanket and due to the relative low strength of the OL materials compared to other material comprising the fill and blanket. In addition, no relief wells exist between stations 81+30 and station 86+65 so the underseepage pressures in the aquifer are also the highest through the reach of the South Topeka floodwall. A second, more typical section that is similar to most of the rest of the floodwall foundation was evaluated at station 89+00 for comparison. For station 89+00 a 25-foot thick blanket comprised of only CL and ML materials was estimated. The blanket and fill materials at both sections were assumed to be impervious relative to the aquifer, though in some areas this may not be the case.

b. Hydraulic Grade Lines

Because of the sand aquifer, the hydraulic grade line is required at the sections being analyzed to determine the pore pressures developed in the foundation soils during the design loading condition. The hydraulic grade lines at the two sections were computed taking into account the relief wells by using the method of image wells. The approach was in accordance with EM 1110-2-1914, Design, Construction, and Maintenance of Relief Wells. The section at station 84+50 is located midway between two wells spaced over 500 feet apart, and the section at station 89+00 is located in a reach of wells at the more common spacing of about 50 feet. The excess head above the landside toe ground surface at station 84+50 was computed to be 10 feet and at station 89+00 to be 6 feet. See **Exhibit 7** for plots from the analysis.

c. Effect of Buried Collector

In addition to evaluating the effects of the relief wells, a rough flow net was drawn to determine the effect of the buried collector system on the hydraulic grade line since it is in contact with the aquifer. The flow net was evaluated only qualitatively, but revealed only a minor effect on the overall flow regime, and the effect was localized to the buried collector location. Because of this, the effect of the buried collector was ignored. A copy of this work is not included in this document.

d. Timber Piles

The exact details of the wooden piles are unknown. Through research, old photographs, the original construction drawings and evaluation of construction practices in the 1930's, a reasonable estimate of what was constructed was determined. Research showed that timber piles were typically manufactured in 30 to 60 foot lengths, had a top diameter of about 12 inches, and tapered about 0.1 inches per foot. It had been previously deduced during the feasibility study that the wooden piles were 25 feet in length. The modulus of elasticity for the piles was taken as 1.5×10^6 psi.

e. Soil Parameters

The soil parameters used for this analysis were taken from previous work in the feasibility study except for the organic blanket material which was estimated based upon typical values. A detailed discussion on the evaluation of available data for the undrained shear strength of the CL-ML material can be found in section A-6.3.3. The following table summarizes the parameters used in the analysis.

Table A-6-1: Soil Parameters

Soil	Saturated Unit Weight	Shear Strength			
		Undrained		Drained	
	γ (pcf)	c (psf)	ϕ (degrees)	c' (psf)	ϕ' (degrees)
CL-ML	110	600	0	0	24
Organics	100	400	0	0	17
Sand	115	N/A	N/A	0	33

The effective unit weight of the blanket materials was computed using the hydraulic grade line at the bottom of the blanket with water to the top of the wall for both sections, and the results are as follows. Calculations are provided in **Exhibit 8**.

Table A-6-2: Effective Unit Weights of Soils under Steady Seepage Conditions

Soil	Effective Unit Weight	
	Station 84+50	Station 89+00
	γ (pcf)	γ (pcf)
CL-ML	22.6	32.6
Organics	12.6	N/A
Sand	52.6	52.6

f. **Analysis**

The axial capacity analysis of the piles was performed using the Corps of Engineers EM 1110-2-2906, Design of Pile Foundations. Because of the taper of the piles, the capacity of the pile in tension was reduced by 50% from the computed capacity in compression. Allowable axial capacities were computed from guidance also found in EM 1110-2-2906, however one could easily argue that due to the significant unknowns of the foundation materials that the required factors of safety should be even higher. All hand calculations are provided in **Exhibit 8**. The results of the analysis are provided in

Table A-6-3 and table A-6-4. It is unknown what the original design criteria were. The drained loading condition is the controlling loading condition. The wall section at station 83+75 (type B) was used to evaluate the reach between station 83+00 and 87+00 (It should be noted that the station is referred to as 84+50 in the exhibits, but was changed to 83+75 in the text to correlate to the actual wall section used in the analysis). It was considered to be the most critical wall section because the footing was constructed at a higher elevation than other wall types through this reach. Given the thickness of the blanket and fill was assumed to be constant through this reach, these piles would have the shortest lengths in the aquifer and subsequently the lowest axial capacity. In addition, this location has the highest hydraulic gradient in the selected reach.

Table A-6-3: Axial Capacity for Undrained Loading Conditions

Station	Ultimate Axial Capacity (kips)		Allowable Axial Capacity (kips)			
			Unusual Loading (FS = 2.25)		Extreme Loading (FS = 1.7)	
	Compression	Tension	Compression	Tension	Compression	Tension
83+75	39.1	19.6	17.4	8.7	23.0	11.5
89+00	53.8	43.7	23.9	12.0	31.6	15.8

Table A-6-4: Axial Capacity for Drained Loading Conditions

Station	Ultimate Axial Capacity (kips)		Allowable Axial Capacity (kips)			
			Unusual Loading (FS = 2.25)		Extreme Loading (FS = 1.7)	
	Compression	Tension	Compression	Tension	Compression	Tension
83+75	28.0	14.0	12.4	6.2	16.5	8.2
89+00	43.7	21.8	19.4	9.7	25.7	12.8

It should be noted that the conditions between station 83+00 and 87+00 could be marginally improved with the installation of additional relief wells to reduce the excess pore pressures developed during the design loading condition.

g. Applied Loads

Loads on the piles were computed using the computer program CPGA and are shown in Table A-6-4. the most landward pile has the highest axial compression load and the most riverward pile has the highest axial tension load.

Table A-6-4: Maximum Loads in Piles

Station	Max Axial Load in Compression (kips)	Max Axial Load in Tension (kips)	Lateral Load (kips)	Maximum Bending Moment (in-k)
83+75	23.0	4.0	9.0	202
89+00	25.0	3.0	9.0	220

h. Results

The drained loading condition gave the lower axial capacity for the piles at both sections. The maximum axial load on the floodwall at station 89+00 meets the minimum factor of safety for the extreme loading condition, so the wall is probably acceptable at this location. The maximum axial load on the floodwall at station 83+75 does exceed the minimum factor of safety for the extreme loading condition in compression (FS = 1.2), and approaches the ultimate capacity of the pile. The tension capacity, however, is acceptable. Because the results of this analysis show the wall at station 83+75 does not meet the minimum factor of safety for the design loading condition with water to the top of the wall, a reliability analysis was performed on a single pile for axial loading at this location.

A-6.3.2 Reliability Analysis for Axial Capacity

A-6.3.2.1 Design Parameters

The design parameters varied in the reliability analysis included shear strength of soils, blanket thickness, and pile length. Initially the soil unit weight was also varied in the analyses; however it was found to have a very small effect and was subsequently removed. Because there was no data to determine either expected values or statistical parameters, the values determined for the deterministic analysis were considered expected values. Published values for coefficient of variation (COV) from ETL 1110-2-561 Table D-2, dated July 2005, were utilized for the statistical parameters, except the published coefficient of variation values were judgmentally increased to account for the additional uncertainty of the input data. Published values for the coefficient of variation were not available for blanket thickness or pile length, so these parameters were also estimated based upon judgment. Table A-6-5 lists the parameters used in the analysis.

Table A-6-5: Parameters used in the Reliability Analysis

Parameter	Expected Value E[V]	COV	E[V](1-COV)	E[V](1+COV)
Sand Shear Strength	33°	15%	28°	38°
CL-ML Shear Strength	600 psf	60%	240 psf	960 psf
Organic Soil Shear Strength	400 psf	60%	160 psf	640 psf
CL-ML Blanket Thickness	15 feet*	25%	11.25 feet	18.75 feet
Organic Soil Blanket Thickness	10 feet	25%	7.5 feet	12.5 feet
Pile Length	25 feet	20%	20 feet	30 feet

*The top of the pile is a constant 7.5 feet below the ground surface.

A-6.3.2.2 Analysis Method

The pile reliability analysis procedure started at the design loading condition of water at the top of the floodwall, and for each subsequent loading condition the water level was decreased in 1-foot intervals until the computed probability of failure was negligible. The general analysis procedure is as follows:

For each water loading condition the hydraulic grade line was determined considering the effects of the relief wells.

The effective unit weight of the blanket materials was computed using the excess pore pressures determined from the hydraulic grade line. It should be noted that the hydraulic grade line for each loading condition was computed only for the expected value of blanket thickness, and not recalculated for the case of varying the blanket thicknesses. The effect was considered to be minor.

For each loading condition a series of axial capacity calculations were performed, with one run using expected values and the remaining runs each varying one parameter by plus or minus one standard deviation. Again, axial capacity calculations were made utilizing EM 1110-2-2906.

Including the expected values, this amounted to 13 sets of calculations for each loading condition. Miscellaneous hand calculations are provided in **Exhibit 9** and the axial capacity runs for all the loading conditions are provided in **Exhibit 10**. A total of nine analyses for each of the loading conditions were performed in this manner, from water at the top of the wall to water 8 feet below the top of the wall.

A-6.3.2.3 Analysis Results

The reliability relationship vs. loading condition from the above analysis was plotted and is provided in **Exhibit 11**. The calculations show nearly a 45% probability of failure for the loading condition of water to the top of the wall. The probability of failure drops to 0% with water approximately 5 feet below the top of the wall. The largest effect on reliability for the analysis was the pile length.

A-6.3.3 South Topeka Feasibility Study Soils Investigation Review

A-6.3.3.1 Introduction

After completion of a reliability analysis for the axial capacity of a single timber pile, some recent soils data was discovered. This data was evaluated to validate assumptions in the previous analysis, namely the shear strength of the blanket material. Documentation of this evaluation is provided in **Exhibit 12**.

A-6.3.3.2 South Topeka Information

Only one boring was drilled in the South Topeka Levee Unit, DU-89, located at station 64+00 in the levee reach of the unit. It was drilled through the crest of the levee at this location. The levee is approximately 9 feet tall at this location. There was very limited data from this boring, Atterberg limits and field torvane tests.

1) Atterberg Limits

The soils tested from this boring had liquid limits ranging from 22 to 47, and plasticity indices ranging from 5 to 31. All soils classified as CL or ML to a depth of 30 feet.

2) Field Torvane Tests

Three torvane tests were performed on undisturbed samples in the field, which provide a direct indication of undrained shear strength. The samples were taken under the centerline of the levee section of South Topeka. The results ranged from 800 psf to 1800 psf, with an average of 1300 psf. These samples came from under the footprint of the levee and through consolidation have probably increased the shear strength since construction of the levee. These field test results provide a relative measure of shear strength, however probably overestimate actual blanket strengths at the floodwall. These data probably also reflect an increase in shear strength due to the consolidation of the blanket materials under the weight of the levee.

A-6.3.3.3 Other Topeka Information

The subsurface investigation was not limited to the South Topeka unit for the feasibility study, and significant information was collected for the other units in the Topeka flood protection system. In conjunction with this investigation was laboratory testing of the soils. An attempt was made to only compare testing of materials similar to those found in the South Topeka unit.

a. Unconfined Compression Tests

Three unconfined compression tests were performed for the study, one from the Soldier Creek unit and two from the Oakland unit. The Soldier Creek unit is on a tributary to the Kansas River and on the North side of the Kansas unit. The Oakland unit is on the South side of the Kansas River and adjacent to the South Topeka unit to the East. The undrained shear strengths from the tests ranged from 540 psf to 910 psf, with an average of 725 psf. It should be noted, however, that the two samples from the Oakland unit were CH material.

b. Cone Penetration Test (CPT) Investigation

In addition to traditional drilling and sampling, numerous cone penetration holes were pushed in the Oakland unit. Pile capacity can be directly obtained from CPT data, unfortunately though the majority of the holes were only pushed 15 to 20 feet deep. The blanket in the reach being evaluated was also much thinner than in the South Topeka reach, on the order of 5 to 12 feet thick. Due to the limited depth of the investigation, tip resistance could not be determined, so the evaluation was limited to sleeve friction in the blanket. The evaluation was limited to a reach between station 80+00 and 105+00. This part of the levee is located adjacent to the river similar to the Topeka unit.

There are two methods to compute the ultimate skin friction for a pile from CPT sleeve friction data published by the Federal Highway Administration, the Nottingham and Schmertmann method and the Laboratoire des Ponts et Chaussees (LPC) method. The only difference between the methods is the former applies an α' factor to the measured sleeve friction and the latter does not. The equation for the Nottingham and Schmertmann method is:

$$Q_s = \alpha' f_s A_s$$

Q_s = ultimate skin friction resistance (pounds)
α' = ratio of the pile shaft resistance to cone sleeve friction (from figure 9.23)
f_s = sleeve friction measured from the CPT test (pounds per square foot)
A_s = surface area of pile (square feet)

This equation is similar to the ultimate undrained pile capacity for a cohesive soil.

$Q_s = \alpha S_u A_s$

α = adhesion factor
Su = undrained shear strength (pounds per square foot)

A comparison was even made between α' and α for the two methods, and the numerical values are very similar (see **Exhibit 12)**. Since the ultimate pile capacities should theoretically be the same, it follows that the measured sleeve friction f_s and the undrained shear strength S_u can be directly compared. From the CPT pushed evaluated, the measured sleeve friction values in the blanket ranged from 150 to 730 psf with an average value of 435 psf. The expected undrained shear strength value used in the reliability analysis was 600 psf. If the comparison was made using the LPC method (no reduction factor), the results would probably agree better.

A-6.3.3.4 Soils Investigation Review Conclusion

Based upon the investigation of the recent field and test data for Topeka, it is concluded that the undrained shear strength used for the reliability analysis is reasonable. The strength may be on the low side of and expected value if actual test data were available, however the difference would not likely be enough to significantly change the results of the analysis.

A-6.4 OVERALL RESULTS

The results shown in Table A-6-6 are based on calculations with water to the top of the wall. The given factors of safety are based on unfactored loads and expected strength values, and the probabilities of failure are based on calculations including the variability of those values.

Table A-6-6: Results with Water to Top of Wall

Station		Pile Strength (Meets Allowable?)		Concrete Strength (FS)	Axial Capaicty (FS)	Comments
Begin	End	Normal Stress	Shear Stress			
80+42	83+78	Y	Y	1.7	1.2	45% (axial capacity)
84+20	84+62	Y	Y	1.9	See Note 3	See Note 3
84+62	85+04	Y	N	1.8		
92+60	93+86	Y	Y	1.8		

Table A-6-6 Notes:

1. Screening Criticria:
   a) Pile Strength: Allowable Loads ≥ Service Loads
   b) Concrete Strength: FS ≥ 1.5
   c) Pile Axial Capacity: FS ≥ 1.7
2. Reliability analyses were run only for those failure mechanisms that did not meet the screening criterion.
3. Based on load, soil conditions, and top of pile elevations, 80+42 to 83+78 was found to be the critical case for axial capacity without requiring analyses at other locations. The 45% reliability based on axial capacity noted for 80+42 to 83+78 was found to be the lowest for all failure mechanisms considering all locations. This governing reliability was provided to represent the whole wall in the economics analysis.

A-6.4.1 Uncertainty

Based upon the above analysis it appears that the existing floodwall at station 83+75 in the South Topeka unit has a significant probability of failure at the design loading condition. This is somewhat contingent, however, upon the accuracy of the parameters used in the analysis. The pile length was the most significant parameter in the analysis, and better information concerning the length would have benefited the analysis greatly. This is also contingent upon the idea that overloading of a single pile in a pile group leads to failure. A pile deformation analysis should accompany this work to estimate the magnitude of wall movement due to the applied loads, as a barometer for the measure of failure. Due to the limited knowledge of the soil parameters, however, an analysis of this type would probably not be useful at this time.

It is strongly recommended for PED that better information be obtained. The investigative effort should include a comprehensive drilling, sampling and testing program to better define the geotechnical parameters and subsurface conditions. In addition to that, a field investigation to determine the condition and length of the existing piles should be implemented. It is likely that the timber piles are nearing the end of their dependable life based upon the environment. This fact should be seriously considered in any future analysis.

A-6.4.2 Life Expectancy of Timber Piles

The existing piles for the floodwall are creosote impregnated timber piles of unknown specie. The Timber Piling Council suggests that the life expectancy of a treated timber pile partially above the groundwater is 100 years or longer (http://www.timberpilingcouncil.org/durability.html). The flood protection at South Topeka is at least 70 years old. For this evaluation of existing conditions it was assumed the piles were in perfect condition although this is unlikely.

A-6.4.3 Floodwall Remedy

a. A potential timber pile axial failure could result in excessive floodwall deflections, water infiltration through opened wall joints, scour around the openings, and rapid wall failure. Computed probabilities of failure range from a maximum of 45% with water at the top of the wall to essentially 0% with water 5 feet below the top of wall. It has been concluded that the South Topeka floodwall should be replaced rather than modified because of the high cost associated with adding a row of piles and the timber pile life expectancy. Consequently, a new floodwall will be required to replace the existing floodwall to address reliability concerns.

b. Because of real estate constraints and the extensive landside underseepage collector system, it is recommended to construct the new wall in the same footprint as the old wall. Flood risk management must be maintained during construction of the new floodwall. Cost estimates for the new wall are based on the following construction sequence.

- Stockpile sufficient fill material on site or within access to fill four floodwall monolith openings. (Approximately ~ 5500 cy)
- Demolish one monolith section (~84ft) to allow ease of riverside access. This monolith will be rebuilt at the completion of the project.
- Construct riverside construction and haul road to serve as working platform.
- Demolish three additional floodwall monoliths.
- Drive foundation piles, form and place the two monolith pile caps.
- The following five sequential construction steps will be repeated until the length of the wall has been replaced. See Figure 2 to match the step number with the corresponding monolith.

1. Construct floodwall stem (completing monolith)
2. Demolish next floodwall monolith. (No more then four monoliths will be open at any one time, the first monolith open to allow haul road access and three monoliths in the line of construction sequence.)

3. Drive pile foundation system. (There is always a separation of at least one monolith (~84ft) between piles being driven and freshly poured "green" concrete.)
4. Pour monolith pile cap.
5. Repeat Steps 1-4.

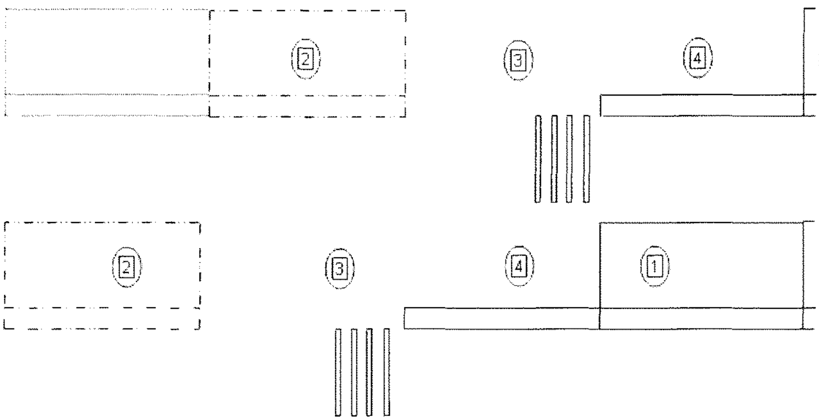


Figure 2 –Floodwall Replacement Construction Sequence

A-6.4.4 Summary of Findings

Based on pile axial failure, computed probabilities of failure range from a maximum of 45% with water at the top of the wall to essentially 0% with water 5 feet below the top of wall. Because of the extensive landside underseepage and relief well system and the aging condition of the timber piles, replacing the floodwall in the footprint of the existing floodwall was determined to be most economical.

CHAPTER A-6

EXHIBITS

Exhibit 1 – Letter of 9 September 1964

Exhibit 2 – Letter of 19 July 1963

Exhibit 3 – Letter of 23 March 1956

Exhibit 4 – Letter of 2 April 1964

Exhibit 5 – Letter of 15 November 1966

Exhibit 6 - Project Plan View and Soil Profile

Exhibit 7 - Hydraulic Grade Lines for Design Loading Condition Station 84+50 and Station 89+00

Exhibit 8 – Hand Calculations for Design Loading Condition Station 84+50 and Station 89+00

Exhibit 9 – Reliability Analysis Miscellaneous Hand Calculations

Exhibit 10 – Pile Axial Capacity Reliability Analysis Excel Files to Determine Probability of Failure

Exhibit 11 – Probability of Failure Curve for the Axial Capacity of a Single Pile

Exhibit 12 - Review of Topeka Feasibility Study Subsurface Investigation and Soils Test Data

Exhibit 1

9 September 1964, Memorandum for File
Subject: MRD Conference, Floodwall, South Topeka Unit, Topeka, KS

Mr. Tomlinson thru Mr. Gillis [illegible]

Mr. Gillis/2753 and
Mr. Spiegel/3080/jc
9 September 1964

MRKED-FL

MEMORANDUM FOR FILES

SUBJECT: MRD Conference, Floodwall, South Topeka Unit, Topeka, Kansas

1. A conference was held in MRD on 8 September 1964, to review the Design Memorandum studies and proposed treatment for the floodwall reach of the South Topeka Unit, located between Kansas Avenue and the beginning of the Oakland Unit (the River Road). This meeting was a followup on the meeting held in this office on 23-24 March 1964, at which these same problems were discussed in less detail. Those in attendance:

MRD	Kansas City District
Asa Shannon	Ralph L. Gillis
Ken Lane	J. H. Tomlinson
Paul Wehlt	R. J. Spiegel
Walt Bramer	

2. The meeting was opened by Mr. Spiegel. He presented topographic print of the downtown area on the south side of the river showing the whole South Topeka Unit. The 1827 and 1854 bank lines had been superimposed on this print showing "old Felix Island" and the chute that formerly went down about Crane Street and back out to the river just downstream of Kansas Avenue. This tended to show some of the problems further exposed by our recent drilling. The general condition of the foundation in this wall area was described with the following being the salient features:

a. There is a layer of fill generally 15 feet or more in thickness under the floodwall. This fill decreases in thickness landward.

b. The natural blanket (predominately silt) shows reasonable continuity landward except in one short reach of the floodwall. It is thin under the floodwall and increases in thickness landward. The natural blanket slopes up in a landward direction from the floodwall.

c. Recent drilling shows the natural blanket to be very thin where intercepted and absent in several reaches riverward of the floodwall (under the sheet pile cutoff).

d. Base of blanket in the vicinity of the basement areas rises to within 2 or 3 feet of basement floor elevations in several instances.

e. The fill under the floodwall and above the natural blanket is a heterogeneous mass of pervious lenses and impervious lenses of all descriptions.

f. The sheet pile wall is reasonably impervious. The interlocks being corroded and filled in the past 25 years.

3. After much discussion, the following areas of agreement were reached in regard to the seepage and foundation problem:

a. The district's pervious drain in a deep trench landward of the wall extending to make contact with the buried natural blanket is necessary and should remain in our consideration.

b. Separate headers for the relief well system and collector drain will be used as proposed. The headers to drain to the pumping plant.

c. The new plant proposed by the city should be used. No adaptation of either existing plant into our system. Contribution to the cities expense of construction based on relative Q from wells and seepage to planned plant Q appears reasonable.

d. We should discuss in the DM why the wells alone will not suffice. (In the meeting we pretty well proved the reasoning, but Asa felt it should be discussed in the DM.)

e. Need more borings landward around the basement areas to pin down the "base of blanket" which is critical to the well design and basement stability.

f. We should present as on alternate relief well plan the case of a minimum number of wells are located around the basement areas rather than along the floodwall. This includes the two unit pumped wells.

g. Discuss the relative dependability of the two relief well plans in the DM.

4. The existing floodwall was discussed as follows:

a. The wall is a concrete cantilever type supported on creosoted timber piles with a 15-foot steel sheet pile cutoff under the riverside edge of the base. It is approximately 2,000 feet long and extends 12 to 13 feet above the landside ground surface.

b. Three test pits dug by the Corps of Engineers and excavation for a sewer under the wall by local interests have revealed the presence of a void under the wall base. The void varies from a hairline crack up to approximately 3/4-inch in thickness. The diverse spacing of the test pits and sewer excavation indicates that the void probably extends the full length of the wall.

c. Two cases of the most severe loading considered possible were discussed. Both cases assume the earth on the riverside of the wall is scoured away to the bottom of the base and the pumping plant to which the toe drain is connected is not working. Uplift due to full river head is assumed at the sheet piling and due to static head from the bottom of the base to the ground surface at the landside toe, plus 2 additional feet of head to provide for losses into the toe drain and for discharging slightly aboveground surface at manholes in the toe drain. For the case of loading considered most likely to prevail, uplift under the base from the sheet pile to the landward toe is assumed equal to the landside tail water as described above. This seems reasonable since pressure from the small amount of seepage through and around the sheet pile will be dissipated in the void under the wall. Since the void is in direct communication with the toe drain, pressure in the void cannot be higher than the landside uplift described above. The resultant of wall loads falls 3.72 feet inside the landside toe (1.72 feet inside the landward pile) and results in compression on the four timber piles varying from 25.8K to 4.0K landward to riverward and tension in the sheet pile amounting to 69 pounds per square foot of sheet pile area. Tension in the sheet pile is not required for wall stability, however, and if it is neglected the load will be taken by the three most landward piles with compression of 31.3K, 18.4K and 4.0K, respectively, on the piles, landward to riverward. The other case discussed was developed to determine the affect on wall stability and pile loads under the most adverse conditions of loading. It assumes that the uplift on the wall base reduces uniformly from full river head at the sheet pile to landside uplift described above at the toe. This assumption would be valid only if the foundation soil were in full and intimate contact with the wall base; a condition that the void under the wall belies. It is, however, in agreement with current design criteria from OCE which permits no drop in uplift pressure under wall bases at steel sheet pile cutoff walls. The resultant of wall loads for this case falls 0.44 feet inside the landside toe (1.56' outside the most landward file), and requires that the sheet pile cutoff wall develop tension of 125 pounds per square foot of surface area to prevent rotation of the wall about the landside toe. Compression in the four timber bearing piles varies from 24.6K to 0.1K landward to riverward.

d. It was explained that by adding 2 feet of concrete on top of the riverside base the resultant of wall loads for the latter case would fall 2.26± ft. inside the landside toe (0.26' inside the landside pile), and tension in the sheet pile would be reduced from 125 p.s.f. to 96 p.s.f. Tension is not required in the sheet pile for stability of the wall and if it is neglected, the load will be carried on the two most landward piles with 42.0K and 3.4K, respectively, on the landward and riverward piles.

e. Computations show that earth at rest, based on a submerged soil weight of 57-1/2 lbs./cu. ft., tan ϕ = 0.5, K=0.5, will produce

100 p.s.f. friction on the sheet pile and cohesion in the nominal amount of 0.05 T/sq. ft. will produce 100 p.s.f. resistance to pull out, making a total of 200 p.s.f. resistance to pull out.

f. It was the consensus of those present that the sheet pile could develop tension in the amounts required for the assumed loading conditions and that no modifications to the wall were required in order to reduce or eliminate this tension.

R. L. GILLIS
Chief, Design Branch

R. J. SPIEGEL
Chief, Levee Section

Copies furnished:
Mr. Leinbach - ED-RH
Mr. McCann - ED-PL
Mr. Tomlinson - ED-DS

Exhibit 2

19 July 1963
Letter Regarding Madison Street Pump Plant

D. S. Leinbach/dr/2769

MRKED-RH

19 July 1963

Mr. Abram Pratt
City Engineer
Topeka City Hall
Topeka, Kansas

Dear Mr. Pratt:

Reference is made to your letter, dated 26 June 1963, regarding the proposed Madison Street Flood Pumping Plant, Topeka, Kansas.

The flood protection system on the south side of the Kansas River that we refer to as the South Topeka Unit was constructed by the Corps of Engineers and completed in 1939. Improvements that we are presently planning consist of raising the leveed portion of the unit to grades equal to floodwall grades and making any structural changes necessary to accomplish this raise.

The proposed Madison Street Pumping Station will serve the storm sewer requirements in connection with the urban renewal project. Our studies of drainage in the area indicate there are three existing storm-water pumping stations serving this area and their total capacity is adequate to serve the total area including the urban renewal sewer. Economic studies might prove that the cost of interconnecting sewers is less than the proposed Madison Street Pumping Station. Since the need for the pumping station arises out of the urban renewal project, it is our opinion that all costs of this improvement should be borne by local interests.

Representatives from this office will meet with City officials early this fall to discuss the proposed plan of construction for the South Topeka Unit.

Your continuing cooperation with members of my staff is appreciated.

Sincerely yours,

Fish

Monseen

LOUIS G. FEIL
Chief, Engineering Division

Copies furnished:
Reading File
Mr. Fish
ED-E
ED-DS
ED-PL
Hydro Planning Section

Exhibit 3

23 March 1956, Memorandum for File
Subject: Inspection of Old Flood Wall, City Park Pumping Plant, Topeka, Kansas

MRDGL 23 March 1956

MEMORANDUM FOR THE FILE

SUBJECT: Inspection of Old Flood Wall, City Park Pumping Plant, Topeka, Kansas.

1. Reference is made to the memorandum of 28 February relative to the condition of the old flood wall encompassed by the levee construction in 1939 at the City Park Pumping Station, Topeka, Kansas.

2. I received a phone call at 10:00 a.m. 22 March from Mr. E. A. Smith, Construction Division, stationed at Forbes Air Force Base, who has apparently been delegated the Corps of Engineers' responsibility for inspection of the construction operations of the City Park Pumping Station. Mr. Smith stated that Mr. Fadden, of Fadden and Bartlet (which firm has the architect-engineer services for this pumping plant) had called him requesting to have a conference at 2:00 p.m. at Topeka relative to the conditions referred to in the above referenced memorandum, and that I be present. Accordingly, Mr. Tomlinson, of the Structures Section, and I met with Mr. Fadden, Mr. Pratt, City Engineer, Mr. Tom Bruce, City Engineer's office, Mr. Smith, and the contractor's superintendent.

3. During my preliminary inspection, I had noted "roofing" conditions under the old wall but had not made a close inspection. A detailed inspection disclosed the "roofing" condition to be even more pronounced than at first indicated. From a point within the excavation beneath the wall, an open space approximately 1" wide can be noted on either side of the excavation for the full width of the base of the wall. Mr. Pratt said that he felt this possibly was due to drying out of the material under the wall. However, a small diameter stick was pushed back into the opening approximately 6 feet before wet soil was noted on the end of the stick. This condition is even more apparent along the landside of the wall where it is exposed by the pumping plant excavation. The material here has slumped away from the base of the wall approximately 4" at the edge of the wall base. The contractor's superintendent stated that the void already existed when the excavation reached this point. However, it is my opinion that the void opened up almost as fast as the adjacent support was removed during the excavation process giving the appearance that the void existed before the excavation started. The material under the wall consists of a loose, organic material, willows and old dump material. This "roofing" condition is apparent on both sides of the excavation under the wall and extends over most of the width of the pumping plant excavation.

4. In view of the above noted conditions I believe that it would be extremely difficult to provide any type of backfill which would effectively seal this space beneath the base of the wall even though the actual opening for the outfall conduit was filled completely with

concrete. Mr. Padden appeared to be in considerable disagreement with the suggestion that a section of the old wall be removed in order that proper backfill can be placed. I told them that an alternate method could probably be worked out which, although not equal to the recommended scheme, might be a satisfactory substitute. This would involve drilling through the base all along the exposed portion of the wall, inserting grout pipes, and after backfill has been completed above the base of the wall, to pressure grout the full length of the exposed portion of the wall. Under this plan, however, it would still be necessary to remove considerable material adjacent to the wall in order to place the grout pipes. I also explained to both Mr. Pratt and Mr. Padden the importance of sloping the pumping excavation as previously recommended in order to provide sufficient working space to properly compact the backfill material. Under the present conditions, almost 100% of the backfill will have to be placed by hand or pneumatic equipment while the recommended slopes would permit most of the backfill to be placed by power equipment. I also raised the question of the source of the impervious material proposed for backfill of the plant. They indicated that they had one source in mind and Mr. Smith stated that he would have the source checked for suitability of material.

5. In view of the foregoing conditions, I advised Mr. Pratt and Mr. Padden that my opinion had not altered relative to the advisability of removing the old flood wall within the excavation area. If, after consideration they wished to investigate some alternate plan, such as the grouting method, this office would be pleased to discuss it with them in more detail. Under these conditions I do not believe any method of filling the excavation with mass concrete under head would result in satisfactory backfill.

R. J. SPIEGEL
Head, Soil Section

RJS/iga

cc: Mr. R. L. Gillis
Mr. J. M. McCann
Mr. K. S. Lane

Exhibit 4

2 April 1964
Subject: South Topeka Unit, Topeka, KS
Flood Protection Project – Conference with MRD to Review Preliminary Studies Prior to Submission of Design Memorandum

U. S. ARMY ENGINEER DISTRICT, KANSAS CITY
CORPS OF ENGINEERS
1800 Federal Office Building
Kansas City, Missouri 64106

MRKED-PL

2 April 1964

SUBJECT: South Topeka Unit, Topeka, Kansas, Flood Protection Project - Conference with MRD to Review Preliminary Studies Prior to Submission of Design Memorandum

1. A conference relative to the South Topeka Unit, Topeka, Kansas, Flood Protection Project was held in the Kansas City District office 23-24 March 1964, with the following in attendance:

A. Shannon, *MRD	D. S. Leinbach, KCD
K. S. Lane, MRD	R. J. Spiegel, KCD
W. Breuer, MRD	W. N. Doyle, KCD
A. Harrison, MRD	Lee Nelson, KCD
Col. Wachendorf, *KCD	P. D. Barber, KCD
L. G. Feil, KCD	P. E. Morris, KCD
C. R. Van Orman, KCD	J. Tomlinson, KCD
R. C. Gillis, KCD	R. L. Browning, KCD
J. F. Redlinger, KCD	G. L. Audsley, KCD
J. M. McCann, KCD	

*Attended 24 March 1964

2. Points resolved:

a. It was agreed that the existing hand placed riprap on the South Topeka Unit should dictate the approximate limits of slope protection proposed. New riprap will consist of repair to the toe and at the top of the proposed levee raise, and some modifications and alterations at drainage structures. Rockfill appearing in the estimate is required for levee stability and not for protection against streamflows.

b. The hydrologic features were considered satisfactory.

c. The area fill proposed upstream of the C.R.I.& P. Railroad bridge and the design sections between the C.R.I.& P. Railroad bridge and Kansas Avenue were considered satisfactory. Additional studies will be made in connection with stability berms.

d. In connection with modifications and/or alterations of the existing floodwall the following was agreed:

(1) The existing floodwall is considered stable under design conditions, regardless of uplift pressures.

MRKED-PL 2 April 1964

SUBJECT: South Topeka Unit, Topeka, Kansas, Flood Protection Project - Conference with MRD to Review Preliminary Studies Prior to Submission of Design Memorandum

(2) Either a new or reconditioned toe drain is considered a necessity.

(3) Additional explorations are considered necessary to better define the problem in the wall area.

(4) Objections were raised relative to relief wells around private buildings. A "line of wells" system next to the wall will be designed.

(5) The use of a header and manhole system for relief wells is satisfactory.

(6) Utilization of existing pumping facilities is satisfactory.

(7) It was agreed that a reasonable amount of pull-out resistance could be assumed for the steel sheet pile cutoff-wall. The amount of resistance allowed should be based on a study of the soil type and values recommended by authorities as a result of pull-out piles.

(8) Tension cannot be assumed for timber bearing piles.

(9) A reasonable reduction can be assumed in the uplift pressures under the wall because of the sheet pile cutoff wall, and the proposed pressure relief well system and the toe drain rehabilitation.

2. Additional studies:

a. If it appears that grouting is economical, consideration should be given to test grouting through the present floodwall base to form cutoff at existing sheet pile cutoff. This would be accomplished by Government forces.

b. Mr. Shannon seemed to favor the proposed excavated trench on the riverside to form an impervious cutoff. A firm proposal for the cutoff will be made after correlation with data obtained from the experiment described in a. above.

c. The advisability of grouting the roofing void under the wall was questioned. This will be discussed and resolved in the Design Memorandum.

d. Mr. Lane appeared to favor the idea of a deep toe collector near the top of blanket in lieu of either the cutoff or grouting.

MRKED-PL 2 April 1964
SUBJECT: South Topeka Unit, Topeka, Kansas, Flood Protection Project - Conference with MRD to Review Preliminary Studies Prior to Submission of Design Memorandum

3. Discussion: Hydraulic Design of Drainage Structures was discussed with Mr. Harrison. The specific items discussed were: (a) use of rounded inlet ends on pipes and conduits to reduce inlet losses where full flow exists and inlet ends are submerged. Mr. Harrison agreed to send Kansas City District details of rounded inlet ends used by Omaha District (b) The use of timber piles to support outlet ends of C.M. pipes and flap gates. It was pointed out to Mr. Harrison that comparative cost estimates for both 24 and 48-inch pipe indicated that the conventional concrete outlet structure used by Kansas City District was cheaper than the pile-supported outlet.

Prepared in
Kansas City District
Corps of Engineers
2 April 1964

Exhibit 5

15 November 1966, Memorandum for Files
Subject: Underseepage Treatment behind Floodwall in South Topeka Unit

MRKED-FL 15 November 1966

MEMORANDUM FOR FILES

SUBJECT: Underseepage Treatment Behind Floodwall in the South Topeka Unit

1. On Tuesday, 8 November 1966, a meeting was held in this office concerning the underseepage treatment for the floodwall portion of the South Topeka Unit. The following were in attendance.

Office, Chief of Engineers

R. O. Barron

Missouri River Division

K. S. Lane
P. K. Wohlt

Kansas City District

J. F. Redlinger
R. E. Spiegel
R. L. Browning
W. H. Cook

2. Mr. Spiegel presented the recommended plan as shown in the D.M. along with several factors that would influence this plan. Mr. Barron was very concerned about the low safety factors in the basements located behind the floodwall. He also stated that seepage safety factors considered adequate for agricultural levee design are not considered adequate for a highly industrial area such as this. He feels that a flood fight in the basements is highly undesirable if not impossible.

3. Photographs of the basements were studied and it was agreed that it would be impractical to place fill in the basements which was suggested as a possibility by OCE and MRD.

4. In order to obtain higher safety factors in the basements, two relief well systems were suggested to be studied.

a. One plan would keep the basic line of protection (relief wells) along the wall and supplement this as required with pumped wells located around the basements.

b. The other plan would have only the minimum number of wells needed to protect the floodwall located along the wall and a proportionately greater number of pumped wells located around the basements to provide the desired safety factors. (This is the plan favored by Mr. J. O. Ackerman, MRD, by telephone 11-15-66.)

MRKED-FL 15 November 1966

6. Originally, Mr. Barron indicated that a safety factor of 1.5 would be desirable in all the basements. In the discussion that followed, Mr. Lane suggested that we might try for safety factors of 1.5 between the wells located along the wall and 1.0 in the basements. In the largest basement, we could go as low as 0.8 without ponded water. Mr. Barron said he would be satisfied if we had a 1.5 S.F. with basements flooded.

7. The power supply for the pump units and the possibility of an electrical failure at the pumping plant were also discussed. An auxiliary power supply could be located at the proposed pumping plant or portable pumps could be provided to pump from individual wells. In the latter case provision should be made to store them in a warehouse on the site.

8. Mr. Barron said that he did not want a cross connection between the gravity header system and the collector system. He felt that if it became necessary to pump the artesian wells, the cross connection would not be desirable.

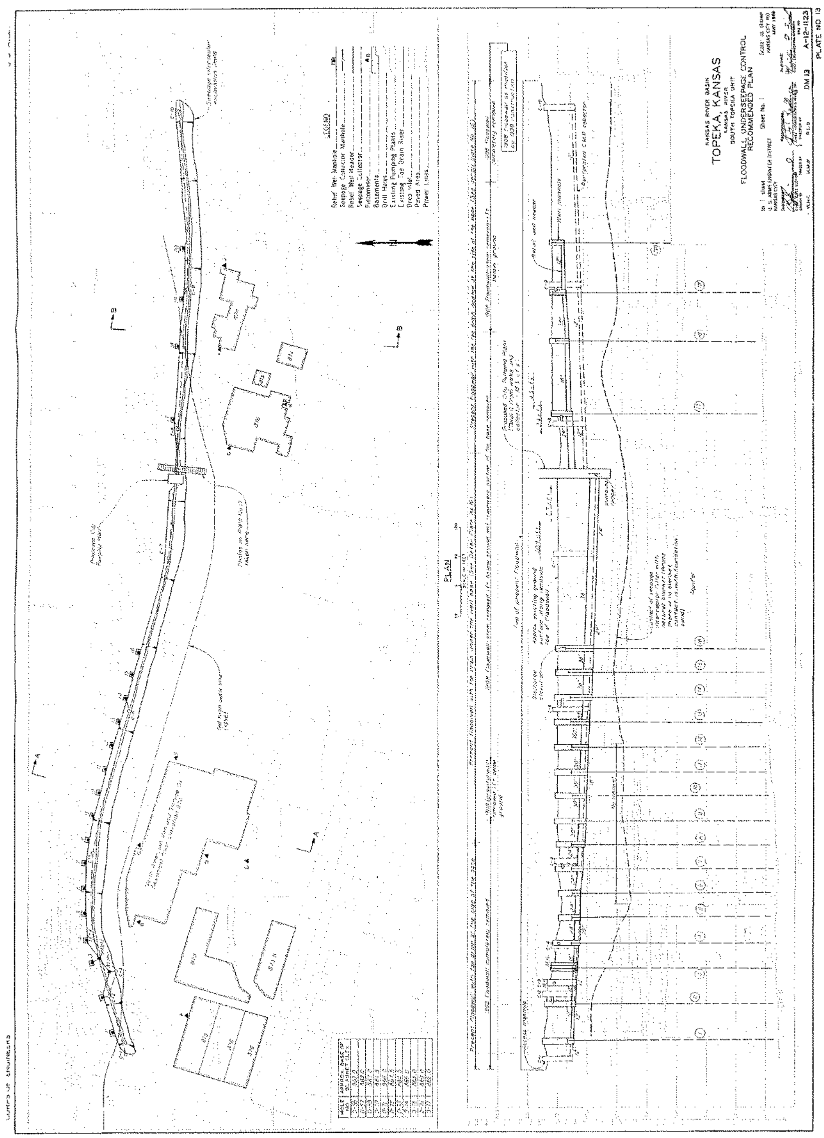
9. After we have analyzed the above plans, we will forward a supplemental design memorandum to OCE through MRD. After sufficient time for review, another conference will be scheduled with all parties represented.

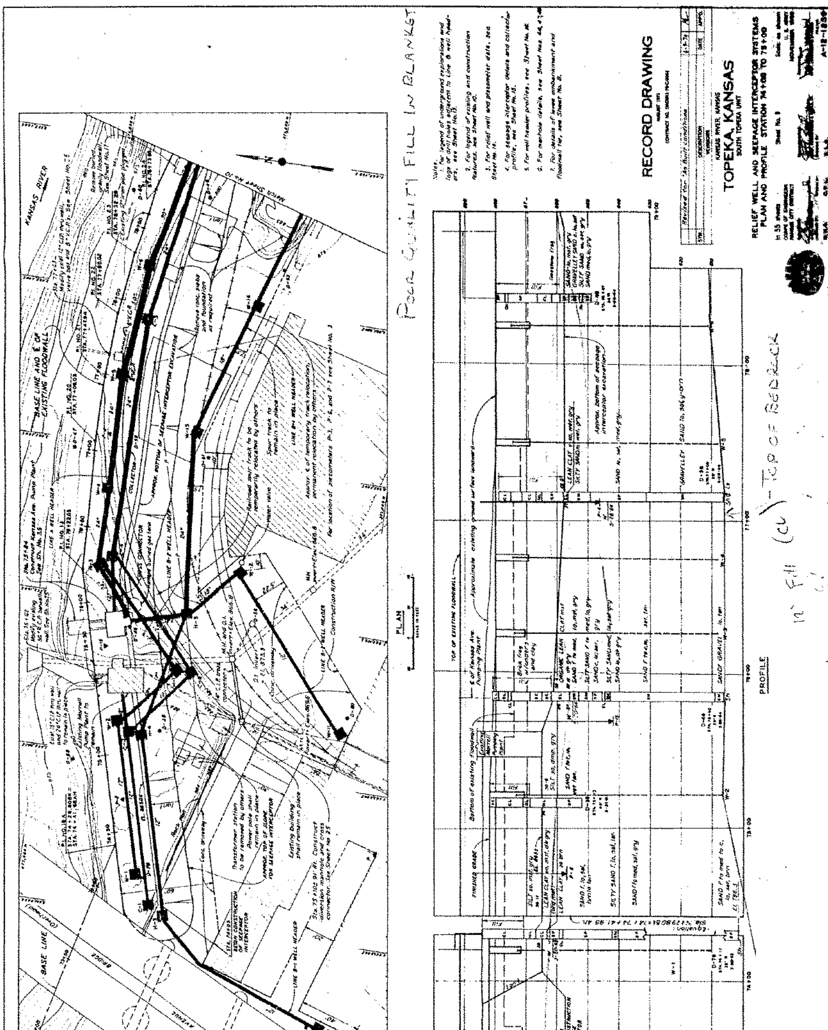
R. J. SPIEGEL
Chief, Levee Section

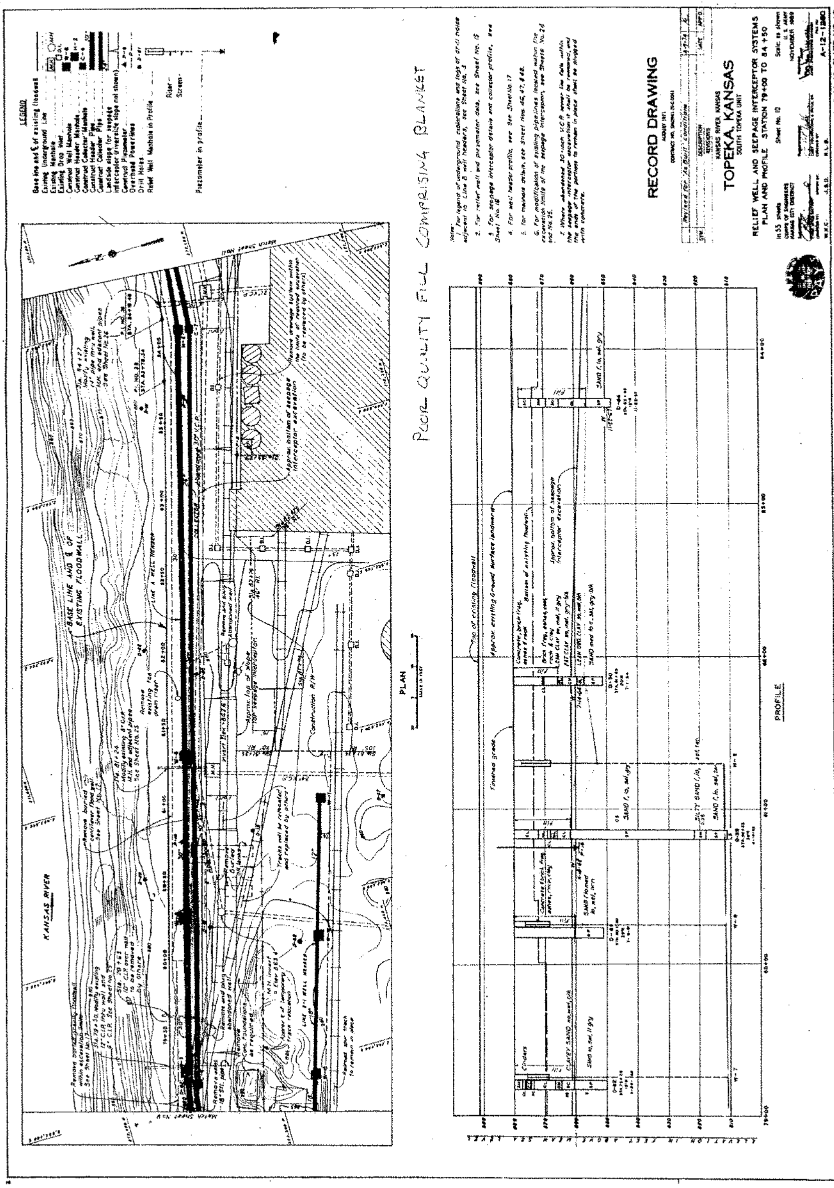
Copies furnished:
ED-FL
ED-DC thru Mr. Gillis
ED-DM (Mr. Reavey)

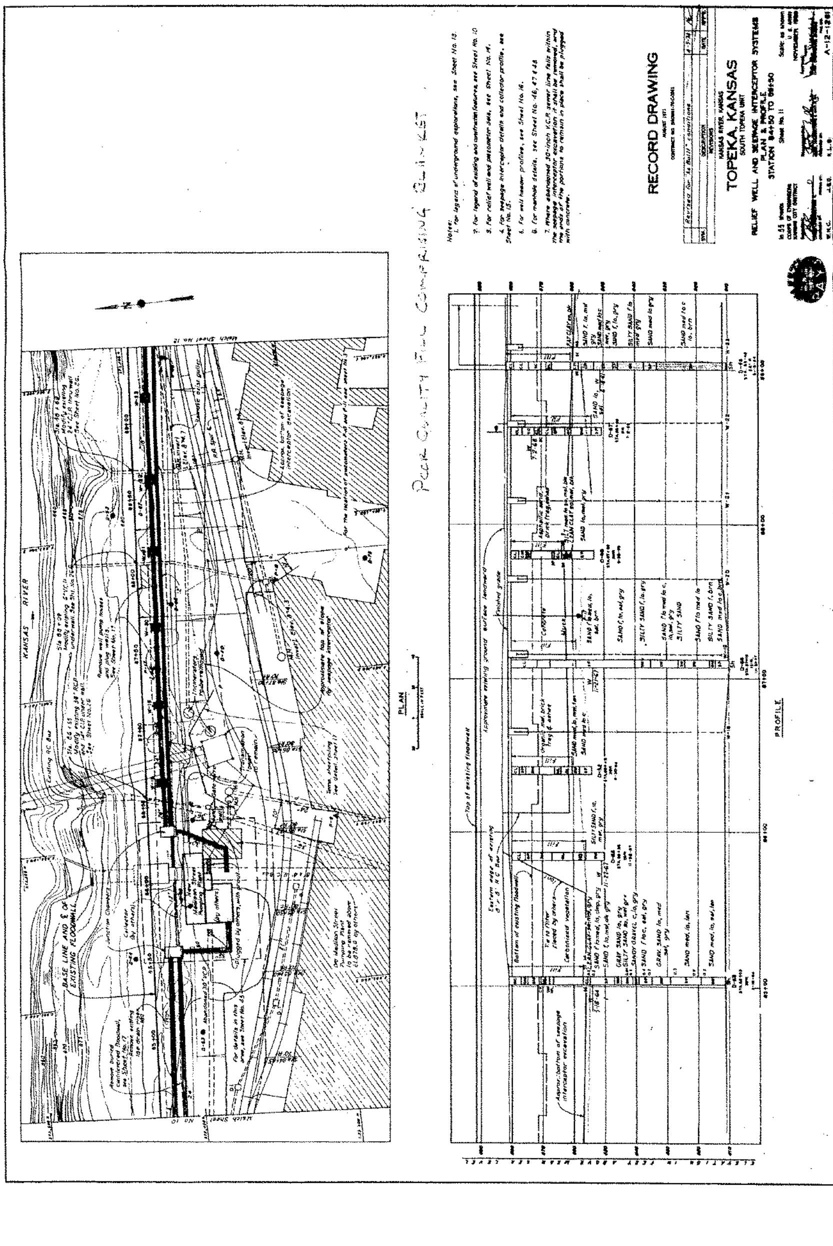
Exhibit 6

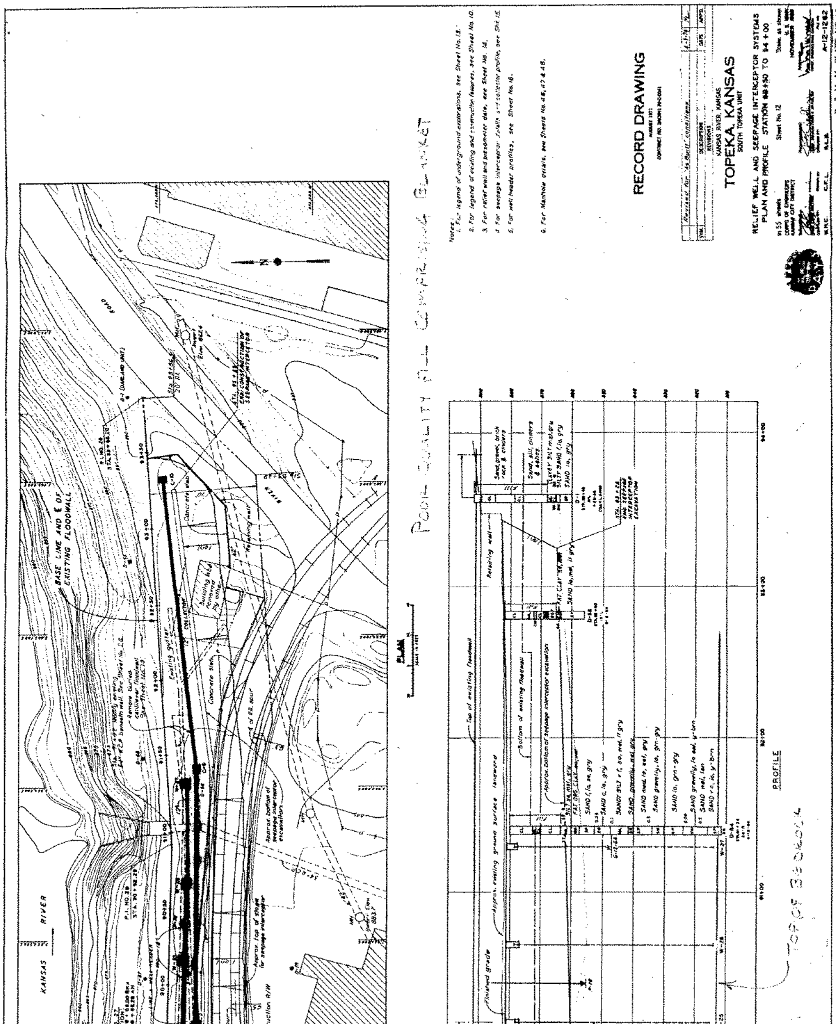
Project Plan View and Soil Profile


KANSAS RIVER BASIN
TOPEKA, KANSAS
KANSAS RIVER
SOUTH TOPEKA UNIT
FLOODWALL UNDERSEEPAGE CONTROL
RECOMMENDED PLAN
Sheet No. 1
U. S. ARMY ENGINEER DISTRICT
KANSAS CITY
DM 13
A-12-1123
PLATE NO 13
PLAN
LEGEND


KANSAS RIVER
PLAN
PROFILE
Poor Quality Fill in Blanket
Top of Red Rock
RECORD DRAWING
TOPEKA, KANSAS
RELIEF WELL AND SEEPAGE INTERCEPTOR SYSTEMS
PLAN AND PROFILE STATION 74+00 TO 78+00
O. & M. M. PLATE NO. 9


LEGEND
KANSAS RIVER
BASE LINE AND ℄ OF EXISTING FLOODWALL
POOR QUALITY FILL COMPRISING BLANKET
PLAN
PROFILE
RECORD DRAWING
KANSAS RIVER KANSAS
TOPEKA, KANSAS
SOUTH TOPEKA UNIT
RELIEF WELL AND SEEPAGE INTERCEPTOR SYSTEMS
PLAN AND PROFILE STATION 79+00 TO 84+50
O. & M. M. PLATE NO.10


RECORD DRAWING
KANSAS RIVER, KANSAS
TOPEKA, KANSAS
SOUTH TOPEKA UNIT
RELIEF WELL AND SEEPAGE INTERCEPTOR SYSTEMS
PLAN & PROFILE
Sheet No. 11
PLAN
PROFILE
KANSAS RIVER
BASE LINE AND ℄ OF EXISTING FLOODWALL
O. & M. M. PLATE NO. 11



RECORD DRAWING
KANSAS RIVER, KANSAS
TOPEKA, KANSAS
SOUTH TOPEKA UNIT
RELIEF WELL AND SEEPAGE INTERCEPTOR SYSTEMS
PLAN AND PROFILE STATION 89+50 TO 94+00
O. & M. PLATE NO. 12
PLAN
PROFILE
KANSAS RIVER
BASE LINE AND ℄ OF EXISTING FLOODWALL

Exhibit 7

Hydraulic Grade Lines for Design Loading Condition
Station 84+50 and Station 89+00

South Topeka Floodwall Analysis
UNDERSEEPAGE ANALYSIS WITHOUT WELLS
Water to top of Flood Protection

Blanket Unit Weight = 105.0 pcf (saturated) (Average Value)

Station	Top of Levee Elevation (msl)	River Side Ground Elevation (msl)	Land Side Ground Elevation (msl)	River Blanket Bottom Elevation (msl)	Land Blanket Bottom Elevation	Top of Bedrock Elevation (msl)	Driving Head (ft) H	Permeability Ratio		Impervious Blanket Thickness (ft)			Pervious Blanket Thickness (ft) d	Seepage Length (ft)			Factor		Effective Seepage Length (ft)		Head at Toe (ft) h_o	Computed Hydraulic Gradient i_o	Critical Hydraulic Gradient i_c	Factor of Safety for Piping (i_c/i_o)	Remarks
								River Side k_f/k_{br}	Land Side k_f/k_{bl}	River Side z_{br}	Levee z_{bp}	Land Side z_{bl}		River Side L_1	Levee L_2	Land Side L_3	c_r	c_l	River Side x_1	Land Side x_3					
83+00 to 87+00	892.0	880	880	855	855	810	12.0	300	300	25	25	25	45	70	10	1000	0.00172	0.00172	69.66	580.95	10.65	0.42	0.68	1.62	

1/5

RELIEF WELL ANALYSIS

k =	0.0036	ft/s
D =	45	ft
h_o =	10.55	ft
TOL =	892	ft elevation
Landside =	880.0	ft elevation
Bottom Blanket =	855	ft elevation
blanket =	25.0	ft
z, Landside Toe =	80	ft
r_w =	1	ft

γ_{sat} =	110	pcf
i_c =	0.76	
FS_{req} =	1.6	
Efficiency =	0.8	
Total Flow =	14.75	cfs

real well locations						
well	x	y	discharge el	Q_w (cfs)	v_w (ft/s)	H_w (ft)
W-7	90	7925	876.0	0.85	0.27	1.00
W-15	170	7925	870.0	1.01	0.32	1.00
W-16	175	8015	870.7	0.92	0.29	1.00
W-8	90	8025	876.3	0.78	0.25	1.00
W-17	180	8104	872.3	0.88	0.28	1.00
W-9	90	8130	877.5	0.77	0.24	1.00
W-18	90	8665	879.1	0.66	0.21	1.00
W-19	90	8715	878.1	0.66	0.21	1.00
W-20	90	8765	877.6	0.66	0.21	1.00
W-21	90	8815	877.3	0.66	0.21	1.00
W-22	90	8855	877.5	0.65	0.21	1.00
W-23	90	8915	877.7	0.65	0.21	1.00
W-24	90	8966	877.9	0.64	0.20	1.00
W-25	90	9015	878.2	0.64	0.20	1.00
W-26	90	9065	878.5	0.66	0.21	1.00
W-27	90	9129	878.6	0.72	0.23	1.00
17				0.00	0.00	0.00
18				0.00	0.00	0.00
19				0.00	0.00	0.00
20				0.00	0.00	0.00

image well locations		
well	x'	y'
W-7	-90	7925
W-15	-170	7925
W-16	-175	8015
W-8	-90	8025
W-17	-180	8104
W-9	-90	8130
W-18	-90	8665
W-19	-90	8715
W-20	-90	8765
W-21	-90	8815
W-22	-90	8855
W-23	-90	8915
W-24	-90	8966
W-25	-90	9015
W-26	-90	9065
W-27	-90	9129
17	0	0
18	0	0
19	0	0
20	0	0

1.00 <---Input H_w AVG after any changes are made to well parameters

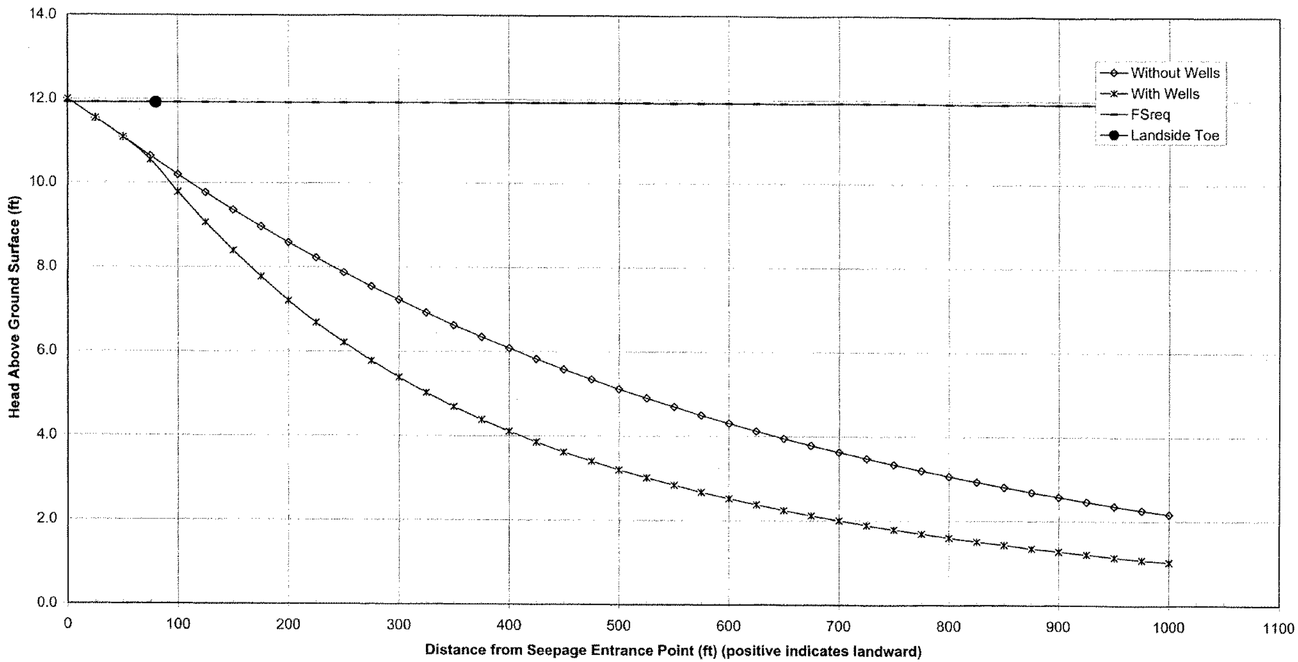
Change y_p in this table to change stationing of HGL Plot Perpendicular to Levee

Point of Interest	x_p	y_p	H_{HGL} (ft)	Drawdown (ft)	h_p (ft)	h_a (ft)	H_w (ft)	i	FS
1	0	8450	12.0	0.0	12.0	11.92	1.00	0.48	1.59
2	25	8450	11.5	0.4	11.5	11.92	1.00	0.46	1.65
3	50	8450	11.1	0.7	11.1	11.92	1.00	0.44	1.72
4	75	8450	10.6	1.1	10.5	11.92	1.00	0.42	1.81
5	100	8450	10.2	1.4	9.8	11.92	1.00	0.39	1.95
6	125	8450	9.8	1.7	9.1	11.92	1.00	0.36	2.10
7	150	8450	9.4	2.0	8.4	11.92	1.00	0.34	2.27
8	175	8450	9.0	2.2	7.8	11.92	1.00	0.31	2.45
9	200	8450	8.6	2.4	7.2	11.92	1.00	0.29	2.65
10	225	8450	8.2	2.5	6.7	11.92	1.00	0.27	2.85
11	250	8450	7.9	2.7	6.2	11.92	1.00	0.25	3.07
12	275	8450	7.5	2.8	5.8	11.92	1.00	0.23	3.30
13	300	8450	7.2	2.8	5.4	11.92	1.00	0.22	3.54
14	325	8450	6.9	2.9	5.0	11.92	1.00	0.20	3.80
15	350	8450	6.6	2.9	4.7	11.92	1.00	0.19	4.07
16	375	8450	6.4	3.0	4.4	11.92	1.00	0.18	4.35
17	400	8450	6.1	3.0	4.1	11.92	1.00	0.16	4.64
18	425	8450	5.8	3.0	3.9	11.92	1.00	0.15	4.95
19	450	8450	5.6	3.0	3.6	11.92	1.00	0.14	5.27
20	475	8450	5.3	2.9	3.4	11.92	1.00	0.14	5.61
21	500	8450	5.1	2.9	3.2	11.92	1.00	0.13	5.97
22	525	8450	4.9	2.9	3.0	11.92	1.00	0.12	6.34
23	550	8450	4.7	2.9	2.8	11.92	1.00	0.11	6.73
24	575	8450	4.5	2.8	2.7	11.92	1.00	0.11	7.14
25	600	8450	4.3	2.8	2.5	11.92	1.00	0.10	7.57
26	625	8450	4.1	2.8	2.4	11.92	1.00	0.10	8.02
27	650	8450	4.0	2.7	2.2	11.92	1.00	0.09	8.49
28	675	8450	3.8	2.7	2.1	11.92	1.00	0.08	8.99
29	700	8450	3.6	2.6	2.0	11.92	1.00	0.08	9.52
30	725	8450	3.5	2.6	1.9	11.92	1.00	0.08	10.07
31	750	8450	3.3	2.5	1.8	11.92	1.00	0.07	10.65
32	775	8450	3.2	2.5	1.7	11.92	1.00	0.07	11.27
33	800	8450	3.1	2.5	1.6	11.92	1.00	0.06	11.91
34	825	8450	2.9	2.4	1.5	11.92	1.00	0.06	12.60
35	850	8450	2.8	2.4	1.4	11.92	1.00	0.06	13.32
36	875	8450	2.7	2.3	1.4	11.92	1.00	0.05	14.08
37	900	8450	2.6	2.3	1.3	11.92	1.00	0.05	14.88
38	925	8450	2.5	2.3	1.2	11.92	1.00	0.05	15.73
39	950	8450	2.4	2.2	1.1	11.92	1.00	0.05	16.62
40	975	8450	2.3	2.2	1.1	11.92	1.00	0.04	17.57
41	1000	8450	2.2	2.1	1.0	11.92	1.00	0.04	18.57

Change y_p and x_p in this table to change stationing of HGL Plot Parallel to Levee

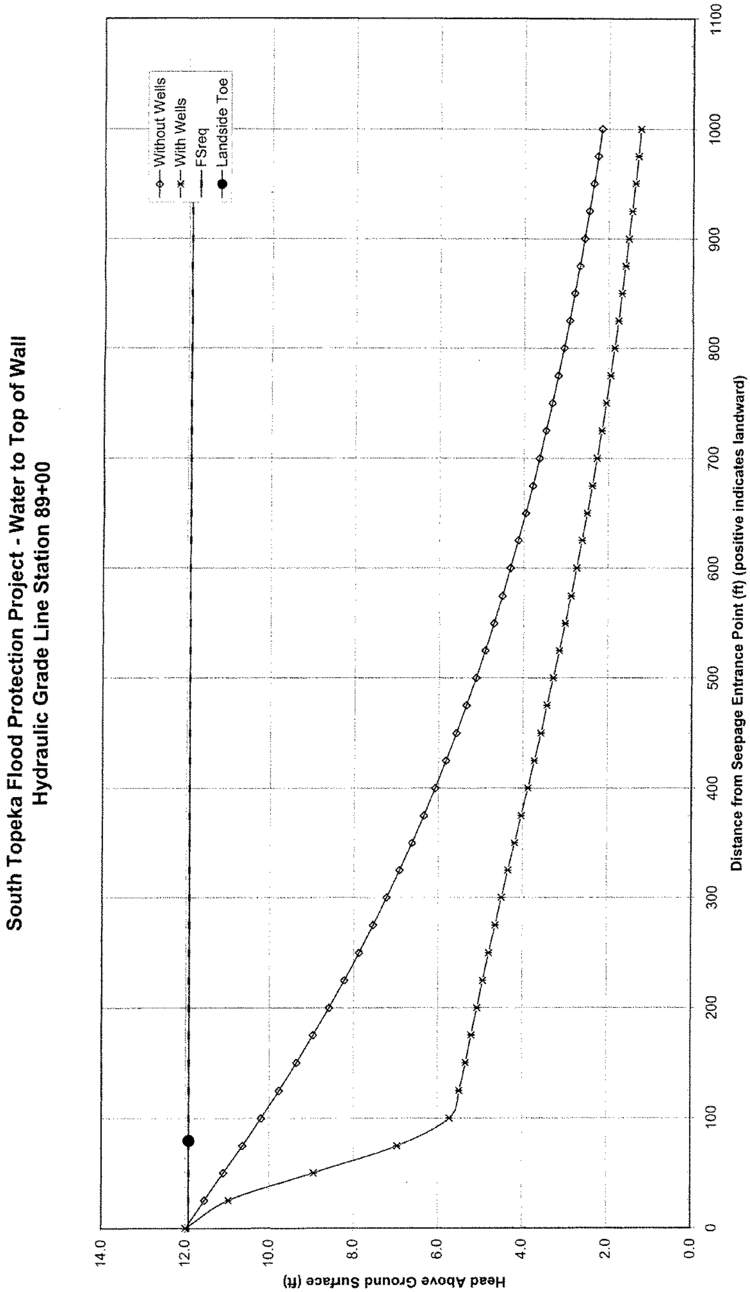
Point of Interest	x_p	y_p	H_{HGL} (ft)	Drawdown (ft)	h_p (ft)	h_a (ft)	H_w (ft)	i	FS_i
1	90	7805	10.4	2.1	9.2	11.92	1.00	0.37	2.07
2	90	7840	10.4	2.7	8.6	11.92	1.00	0.35	2.21
3	90	7875	10.4	3.6	7.8	11.92	1.00	0.31	2.45
4	90	7910	10.4	5.1	6.3	11.92	1.00	0.25	3.02
5	90	7945	10.4	5.3	6.0	11.92	1.00	0.24	3.16
6	90	7980	10.4	5.1	6.3	11.92	1.00	0.25	3.05
7	90	8015	10.4	6.1	5.3	11.92	1.00	0.21	3.59
8	90	8050	10.4	5.3	6.1	11.92	1.00	0.24	3.14
9	90	8085	10.4	4.8	6.6	11.92	1.00	0.26	2.88
10	90	8120	10.4	5.3	6.1	11.92	1.00	0.24	3.12
11	90	8155	10.4	4.1	7.3	11.92	1.00	0.29	2.61
12	90	8190	10.4	3.0	8.4	11.92	1.00	0.33	2.28
13	90	8225	10.4	2.4	9.0	11.92	1.00	0.36	2.12
14	90	8260	10.4	2.0	9.4	11.92	1.00	0.38	2.03
15	90	8295	10.4	1.7	9.7	11.92	1.00	0.39	1.97
16	90	8330	10.4	1.5	9.9	11.92	1.00	0.40	1.93
17	90	8365	10.4	1.4	10.0	11.92	1.00	0.40	1.90
18	90	8400	10.4	1.3	10.1	11.92	1.00	0.40	1.89
19	90	8435	10.4	1.3	10.1	11.92	1.00	0.40	1.89
20	90	8470	10.4	1.3	10.1	11.92	1.00	0.40	1.90
21	90	8505	10.4	1.4	9.9	11.92	1.00	0.40	1.92
22	90	8540	10.4	1.6	9.8	11.92	1.00	0.39	1.96
23	90	8575	10.4	1.9	9.4	11.92	1.00	0.38	2.02
24	90	8610	10.4	2.5	8.9	11.92	1.00	0.36	2.15
25	90	8645	10.4	3.6	7.8	11.92	1.00	0.31	2.44
26	90	8680	10.4	4.5	6.9	11.92	1.00	0.27	2.78
27	90	8715	10.4	6.8	4.7	11.92	1.00	0.19	4.04
28	90	8750	10.4	5.3	6.1	11.92	1.00	0.24	3.13
29	90	8785	10.4	5.4	6.0	11.92	1.00	0.24	3.18
30	90	8820	10.4	6.3	5.1	11.92	1.00	0.20	3.75
31	90	8855	10.4	7.2	4.2	11.92	1.00	0.17	4.58
32	90	8890	10.4	5.2	6.2	11.92	1.00	0.25	3.08
33	90	8925	10.4	5.6	5.8	11.92	1.00	0.23	3.30
34	90	8960	10.4	5.8	5.5	11.92	1.00	0.22	3.45
35	90	8995	10.4	5.1	6.2	11.92	1.00	0.25	3.06
36	90	9030	10.4	5.0	6.3	11.92	1.00	0.25	3.01
37	90	9065	10.4	6.4	5.0	11.92	1.00	0.20	3.80
38	90	9100	10.4	4.0	7.4	11.92	1.00	0.30	2.58
39	90	9135	10.4	4.3	7.1	11.92	1.00	0.28	2.70
40	90	9170	10.4	2.5	8.9	11.92	1.00	0.36	2.15
41	90	9205	10.4	1.8	9.6	11.92	1.00	0.38	1.99

South Topeka Flood Protection Project - Water to Top of Wall
Hydraulic Grade Line Station 83+00 to 87+00
Critical Station = 84+50



3/5

4/5


South Topeka Flood Protection Project - Water to Top of Wall
Hydraulic Grade Line Station 89+00
Without Wells
With Wells
FSreq
Landside Toe
Head Above Ground Surface (ft)
Distance from Seepage Entrance Point (ft) (positive indicates landward)
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
0
100
200
300
400
500
600
700
800
900
1000
1100

5/5

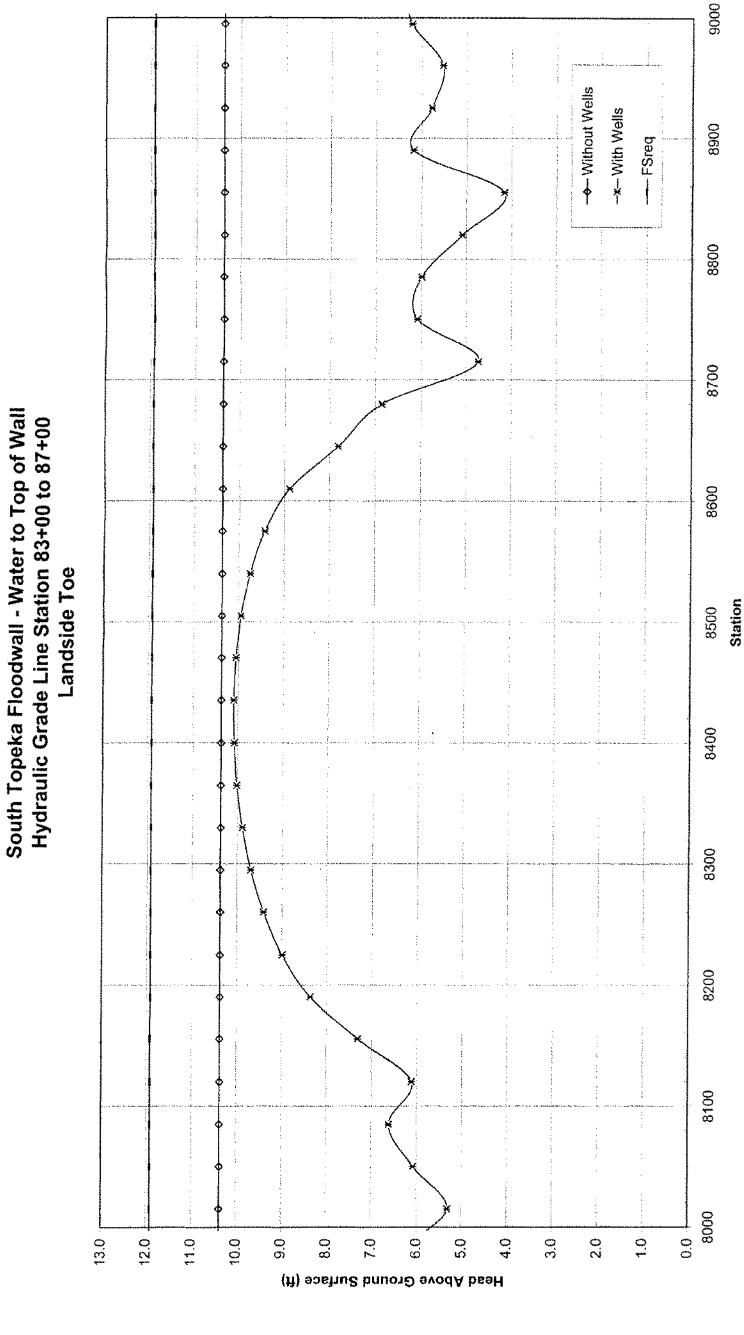

South Topeka Floodwall - Water to Top of Wall
Hydraulic Grade Line Station 83+00 to 87+00
Landside Toe
Head Above Ground Surface (ft)
13.0
12.0
11.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
Station
8000
8100
8200
8300
8400
8500
8600
8700
8800
8900
9000
Without Wells
With Wells
FSreq

Exhibit 8

Hand Calculations for Design Loading Condition Station 84+50 and Station 89+00

4 Oct 2007
RSK

1/8

SOUTH TOPEKA FLOODWALL - BUILT BY THE CORPS IN 1930'S

PILE FOUNDATION ANALYSIS

THE CRITICAL SECTION APPEARS TO BE BETWEEN STA 83+00 AND 87+00

- BLANKET THICKNESS : 25'
- AQUIFER THICKNESS : AVE APP: 50'

LOWER PART OF BLANKET CONTAINS ≈ 10' OF ORGANIC MATERIAL

- THERE IS A BURIED COLLECTOR CONTINUOUS ALONG THE LANDSIDE TOE OF THE WALL. THE COLLECTOR PENETRATES THE BLANKET. THE SYSTEM DRAINS INTO THE MADISON STREET PUMPING PLANT

SOIL STRENGTH PARAMETERS

- PHASE I GEOTECHNICAL REPORT

FILL : DRAINED $\phi' = 24°$, $c = 0$

EMB : DRAINED $\phi' = 26.5°$, $c = 0$

FND CLAY: DRAINED $\phi' = 22°$, $c = 0$

SAND : $\phi' = 33°$

COULD NOT FIND UNDRAINED STRENGTHS IN PREVIOUS DESIGN DOCUMENTATION

USE VALUES FROM FEB 2006 PILE ANALYSIS

FND CLAY: 600 psf

FOR FILL ?? VARIES SIGNIFICANTLY, FOR ORGANICS, USE $S_U = 400$ psf

UNIT WEIGHTS - FROM FEB 2006 PILE ANALYSIS

FND CLAY. $\gamma_{SAT} = 110$ pcf

SAND SP-SM: $\gamma_{SAT} = 115$ pcf

FOR FILL ?? VARIES SIGNIFICANTLY, FOR ORGANICS, USE $\gamma_{SAT} = 100$ pcf

SOUTH TOPEKA FLOODWALL - STA 84+50 6 OCT 2007

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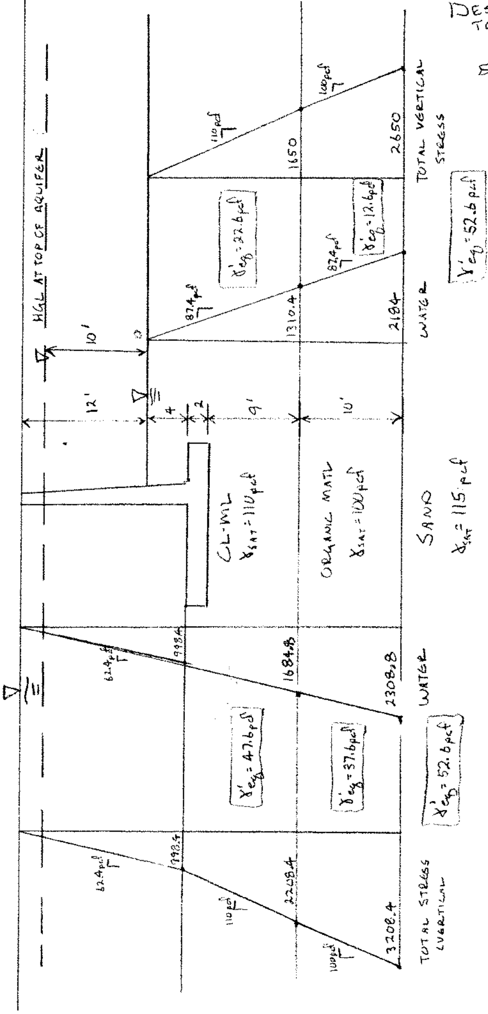
- USE COMPUTED HGL WITH WELLS CASE TO DETERMINE EFFECTIVE UNIT WEIGHTS OF SOIL.

DESIGN LOADING WATER TO TOP OF WALL.

* USE THE LANDSIDE EQUIVALENT UNIT WEIGHTS FOR THE APILE ANALYSIS.



22-141 50 SHEETS
22-142 100 SHEETS
22-144 200 SHEETS
AMPAD

27 Nov. 2007
RSK 1/8

SOUTH TOPEKA FLOODWALL ANALYSIS

· AFTER THE INITIAL RELIABILITY ANALYSIS SHOWED A VERY HIGH PROBABILITY OF FAILURE (92%) WITH WATER TO THE TOP OF THE WALL, THE ASSUMED PARAMETERS WERE SCRUTINIZED CLOSELY.

IN ADDITION TO THIS, THE 1938 CONSTRUCTION DRAWINGS FOR THE FLOODWALL WERE FOUND, PROVIDING PILE SPACING INFORMATION WHICH WAS PREVIOUSLY UNKNOWN.

BASED UPON FURTHER INVESTIGATIONS, THE FOLLOWING CHANGES WILL BE MADE:

1) REVISE PILE DIAMETER
   ORIGINAL: 10" AT TOP AND 4" AT TIP
   NEW: 12" AT TOP AND 9" AT TIP.

2) REVISE K USED IN SAND DUE TO CLOSE SPACING OF PILES NOTED IN THE CONSTRUCTION DRAWINGS THAT WERE FOUND.
   ORIGINAL. K = 1.0
   NEW: K = 1.5

3) REVISE FOOTING DEPTH BASED UPON CONSTRUCTION DRAWINGS
   ORIGINAL: D = 6'
   NEW: D = 7.5' ?

* NOTE: HAND CALCULATIONS WERE PERFORMED AND THE DRAINED ANALYSIS CONTROLS. USE DRAINED ANALYSIS FOR RELIABILITY CALCS.

SINCE THE DRAINED ANALYSIS CONTROLS, NEED DRAINED STRENGTHS OF CLAY AND ORGANICS:
FROM THE RELIABILITY ANALYSIS DONE FOR THE SOUTH TOPEKA LEVEE

FILL & $\phi' = 24°$

ASSUME FOR ORGANICS: $\phi' = 17°$

SOUTH TOPEKA FLOODWALL | 8 JAN 2008 | RSK | 1/4

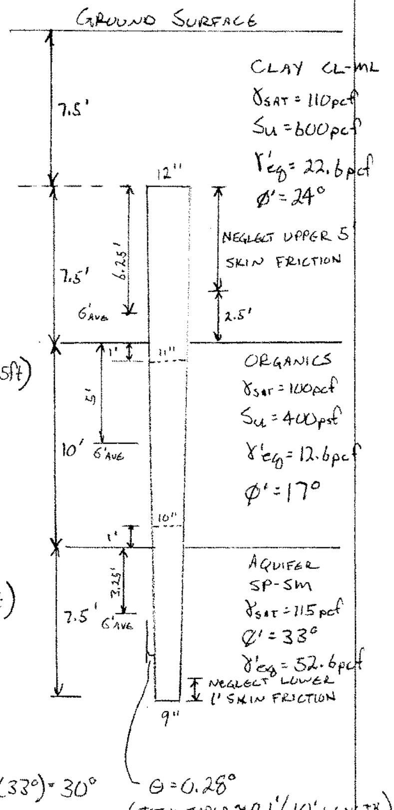
STA 84+50 - AXIAL CAPACITY PILE ANALYSIS WITH WATER TO THE TOP OF WALL

HEIGHT OF WALL = 12'
HGL W/ WELLS = 10'

UNDRAINED ANALYSIS

(USE AVERAGE DIAMETER)

SIDE FRICTION



CLAY

$Q_s = \alpha S_u A_s$

FROM FIG 4-5a, EM 1110-2-2906

$\alpha = 0.9$

$Q_s = (0.9)(600psf)(\pi)(11.25/12ft)(2.5ft)$

$Q_s = \underline{3.98 \text{ kips}}$

ORGANICS

$Q_s = \alpha S_u A_s$

$\alpha = 1.0$

$Q_s = (1.0)(400psf)(\pi)(10.5''/12 ft)(10ft)$

$Q_s = \underline{11.0 \text{ kips}}$

AQUIFER

$Q_s = f_s A_s \qquad f_s = K \sigma_v' \tan \delta$

FROM EM 2906 $\delta = 0.9\phi' = 0.9(33°) = 30°$

FROM EM, $1.0 < K < 2.0$ IN SANDS
DUE TO CLOSELY SPACED PILES, USE $K = 1.5$

$\sigma_v' = (15ft)(22.6pcf) + (10ft)(12.6pcf) + (3.25ft)(52.6pcf) = 635.9psf$

$Q_s = (1.5)(635.9psf) \tan 30° (\pi)(9.5in/12 ft)(6.5ft)$

$Q_s = 8.90 \text{ kips}$

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TOTAL SKIN FRICTION:

BLANKET: $3.98^k + 11.0^k = 15.0^k$
SAND: 8.9^k
TOTAL: 23.9^{kips}

TIP CAPACITY IN SAND

$Q_p = \sigma_v' N_q A_p$

FROM EM 2906 FIG 4.4 ; $N_q = 40$

$\sigma_v' = (15')(22.6pcf) + (10ft)(12.6pcf) + (7.5ft)(52.6pcf) = 859.5\,psf$

$Q_{tp} = (859.5psf)(40)\left(\frac{\pi}{4}\right)\left(\frac{9_{in}}{12}ft\right)^2$

$Q_p = 15.2^{kips}$

TOTAL CAPACITY FOR UNDRAINED LOADING: $23.9^{kips} + 15.2^{kips} = \boxed{39.1^{kips}}$

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35502

8 JAN 2008

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DRAINED ANALYSIS

SIDE FRICTION

CLAY

$Q_s = f_s A_s \qquad f_s = K\sigma_v' \tan\delta$

FROM EM 2906

$\delta = 0.9\phi = 0.9(24°) = 21.6°$

$K = 1.0$

$\sigma_v' = (7.5' + 6.25ft)(22.6pcf) = 310.75\ psf$

$Q_s = (1.0)(310.75\ psf)\tan 21.6° (\pi)(11.25in/12\ ft)(2.5ft)$

$Q_s = 0.9\ kips$

ORGANICS

$Q_s = f_s A_s \qquad f_s = K\sigma_v' \tan\delta$

$\delta = 0.9\phi' = 0.9(17°) = 15.3°$

$K = 1.0$

$\sigma_v' = (15ft)(22.6\ pcf) + (5ft)(12.6pcf) = 402\ psf$

$Q_s = (1.0)(402.0psf)\tan 15.3° (\pi)(10.5in/12\ ft)(10ft)$

$Q_s = 3.02\ kips$

TOTAL SKIN FRICTION:

BLANKET: $0.9^k + 3.0^k = 3.9\ kips$

SAND (FROM PREVIOUS) $= 8.9\ kips$

TOTAL 12.8^k

ULTIMATE DRAINED LOADING CAPACITY

$Q_T = 12.8^k + 15.2^k$ (FROM PREVIOUS) $= \boxed{28.0^k}$

* THE DRAINED LOADING CONDITION CONTROLS

8 JAN 2008

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STA 89+00 - AXIAL PILE ANALYSIS WITH WATER TO THE TOP OF WALL.

THIS ANALYSIS IS BEING PERFORMED BECAUSE THIS SECTION IS FELT TO BE REPRESENTATIVE BUT CONSERVATIVE OF THE "REST OF THE WALL" WITH RESPECT TO FOUNDATION CONDITIONS.

HEIGHT OF WALL = 12'

HGL WITH WELLS = 6'

UNDRAINED ANALYSIS

CLAY

$Q_s = \alpha S_u A_s$

$\alpha = 0.9$

$Q_s = (0.9)(600\text{psf})(\pi)(\frac{10.5\text{in}}{12}\text{ft})(12.5\text{ft})$

$Q_s = 18.6$ kips

AQUIFER

$Q_s = f_s A_s \quad f_s = K \sigma_v' \tan\delta$

FROM PREVIOUS CALCS

$\delta = 30°$; $K = 1.5$

$\sigma_v' = 25\text{ft}(32.6\text{pcf}) + (3.25\text{ft})(52.6\text{pcf})$

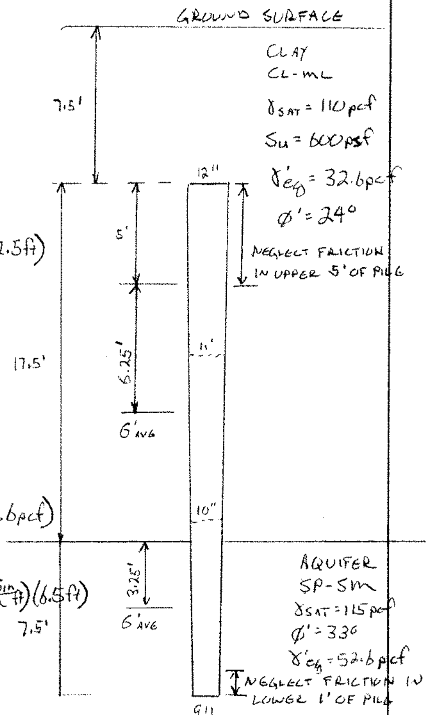
$\sigma_v' = 986.0$ psf

$Q_s = (1.5)(986\text{psf})\tan 30°(\pi)(\frac{9.5\text{in}}{12}\text{ft})(6.5\text{ft})$

$Q_s = 13.8$ kips

TOTAL = $18.6^k + 13.8^k =$

$Q_s = 32.4^{kips}$



8 JAN 2008
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TIP CAPACITY IN SAND

$Q_p = \sigma_v' N_q A_p$

$N_q = 40$ FROM PREVIOUS CALCULATIONS

$\sigma_v' = (25ft)(32.6pcf) + (7.5ft)(52.6pcf) = 1209.5psf$

$Q_p = (1209.5psf)(40)(\frac{\pi}{4})(\frac{9in}{12}ft)^2$

$Q_p = 21.4$ kips

ULTIMATE CAPACITY FOR UNDRAINED LOADING:

$Q_{ult} = 32.4^{kips} + 21.4^{kips} = \boxed{53.8^{kips}}$

DRAINED LOADING CONDITION
(ONLY HAVE TO COMPUTE SIDE FRICTION IN CLAY)

CLAY

$Q_s = f_s A_s \quad f_s = K \sigma_v' \tan \delta$

FROM PREVIOUS CALCULATIONS

$K = 1.0 \quad ; \quad \delta = 21.6°$

$\sigma_v' = (18.75ft)(32.6pcf) = 611.25psf$

$Q_s = (1.0)(611.25psf) \tan 21.6° (\pi)(\frac{10.75"}{12}ft)(12.5ft)$

$Q_s = 8.51$ kips

TOTAL SKIN FRICTION:

$8.51^k + 13.8^{kips} = 22.3^{kips}$

ULTIMATE CAPACITY FOR DRAINED LOADING

$Q_{ult} = 22.3^k + 21.4^k = \boxed{43.7^{kips}}$

∴ AGAIN THE DRAINED LOADING CONDITION CONTROLS

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COMPUTE ALLOWABLE AXIAL CAPACITIES USING EM 1110-2-2906 CRITERIA.

FOR UNUSUAL LOADING ; FS = 2.25

FOR EXTREME LOADING ; FS = 1.7

$$Q_{ALL} = \frac{Q_{ULT}}{FS}$$

WATER TO THE TOP OF THE WALL IS CONSIDERED EXTREME LOADING

* BASED UPON PILE TAPER; ASSUME ULTIMATE CAPACITY IN TENSION IS 50% OF THE ULTIMATE CAPACITY IN COMPRESSION.

ULTIMATE AXIAL CAPACITY

STA	COMPRESSION UNDRAINED (kips)	COMPRESSION DRAINED (kips)	TENSION UNDRAINED (kips)	TENSION DRAINED (kips)
84+50	39.1	28.0	19.6	14.0
89+00	53.8	43.7	26.9	21.8

ALLOWABLE AXIAL CAPACITY FOR EXTREME LOADING

STA	COMPRESSION UNDRAINED (kips)	COMPRESSION DRAINED (kips)	TENSION UNDRAINED (kips)	TENSION DRAINED (kips)
84+50	23.0	16.5	11.5	8.2
89+00	31.6	25.7	15.8	12.8

ALLOWABLE AXIAL CAPACITY FOR UNUSUAL LOADING

STA	COMPRESSION UNDRAINED (KIPS)	COMPRESSION DRAINED (KIPS)	TENSION UNDRAINED (KIPS)	TENSION DRAINED (KIPS)
84+50	17.4	12.4	8.7	6.2
89+00	23.9	19.4	12.0	9.7

TOPS 35502

Exhibit 9

Reliability Analysis
Miscellaneous Hand Calculations

27 Nov 2007

PARAMETERS FOR RELIABILITY ANALYSIS 2/8

SHEAR STRENGTH

SAND (ϕ') $\mu_x = 33°$; COV = 15%

LOWER BOUND; $33° - [(0.15)(33°)] = 28°$

UPPER BOUND; $33° + [(0.15)(33°)] = 38°$

CL-ML (FILL) $\mu_x = 24°$

EM 1110-2-556 RECOMMENDS ≈ 10% COV; DUE TO UNCERTAINTY USE 30%

LOWER BOUND; $24° - [(0.30)(24°)] = 16.8°$

UPPER BOUND; $24° + [(0.30)(24°)] = 31.2°$

ORGANICS; $\mu_x = 17°$

AGAIN, USE COV = 30°

LOWER BOUND; $17° - [(0.30)(17°)] = 11.9°$

UPPER BOUND; $17° + [(0.30)(17°)] = 22.1°$

PILE LENGTH $\mu_x = 25'$

CONSTRUCTION DRAWINGS STATE A MINIMUM DRIVE LENGTH OF 20 FT.

ASSUME COV = 20%

LOWER BOUND; $25' - [(0.2)(25')] = 20'$

UPPER BOUND; $25' + [(0.2)(25')] = 30'$

27 Nov. 2007 3/

BLANKET THICKNESS

ASSUME COV = 25%

CL-ML ; μ_x = 15' (7.5' PILE PENETRATION

LOWER BOUND ; 15' − [(0.25)(15')] = 11.25'

UPPER BOUND ; 15' + [(0.25)(15')] = 18.75'

ORGANIC MATL ; μ_x = 10'

LOWER BOUND ; 10' − [(0.25)(10')] = 7.5'

UPPER BOUND ; 10' + [(0.25)(10')] = 12.5'

SUMMARY

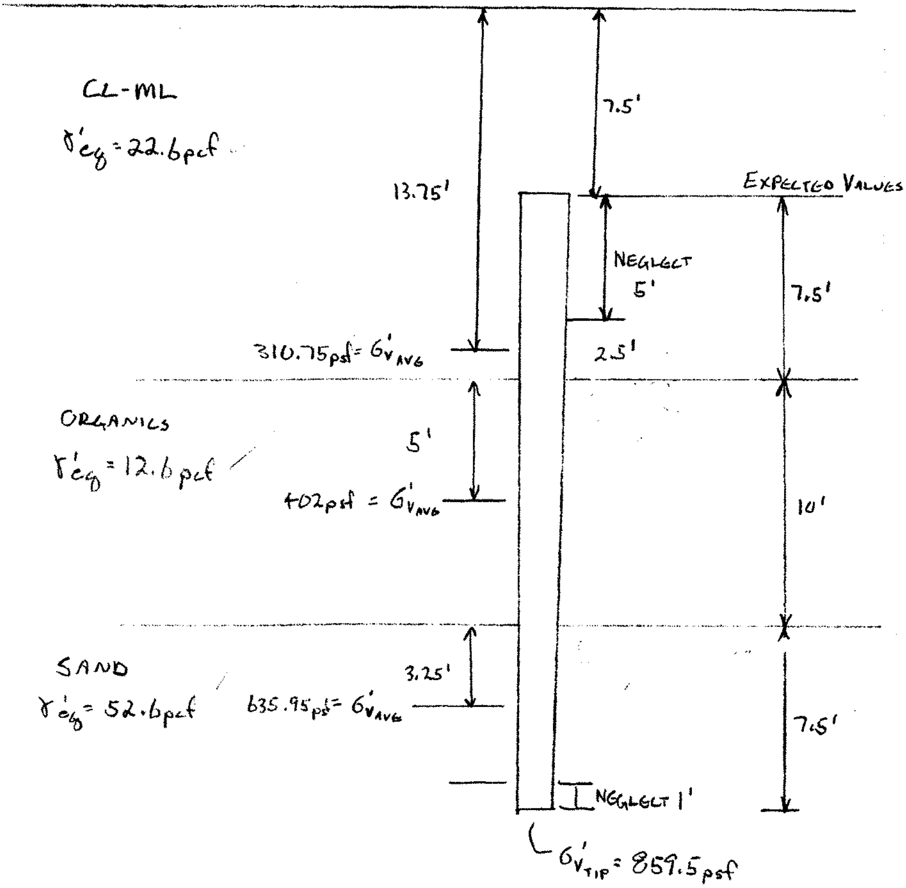
VALUE	SHEAR STRENGTH			BLANKET THICKNESS		PILE LENGTH
	SAND	CL-ML	ORG	CL-ML	ORG	
EXPECTED	33	24	17	15'	10	25
LOW	28	16.8	11.9	11.25'	7.5	20
HIGH	38	31.2	22.1	18.75'	12.5	30

1 Dec 2007

4/8

EXPECTED VALUE OF BLANKET THICKNESS – WATER TO TOP OF WALL

HGL CONSIDERS EFFECTS OF THE WELLS; SEE RELIEF WELL CALCULATIONS



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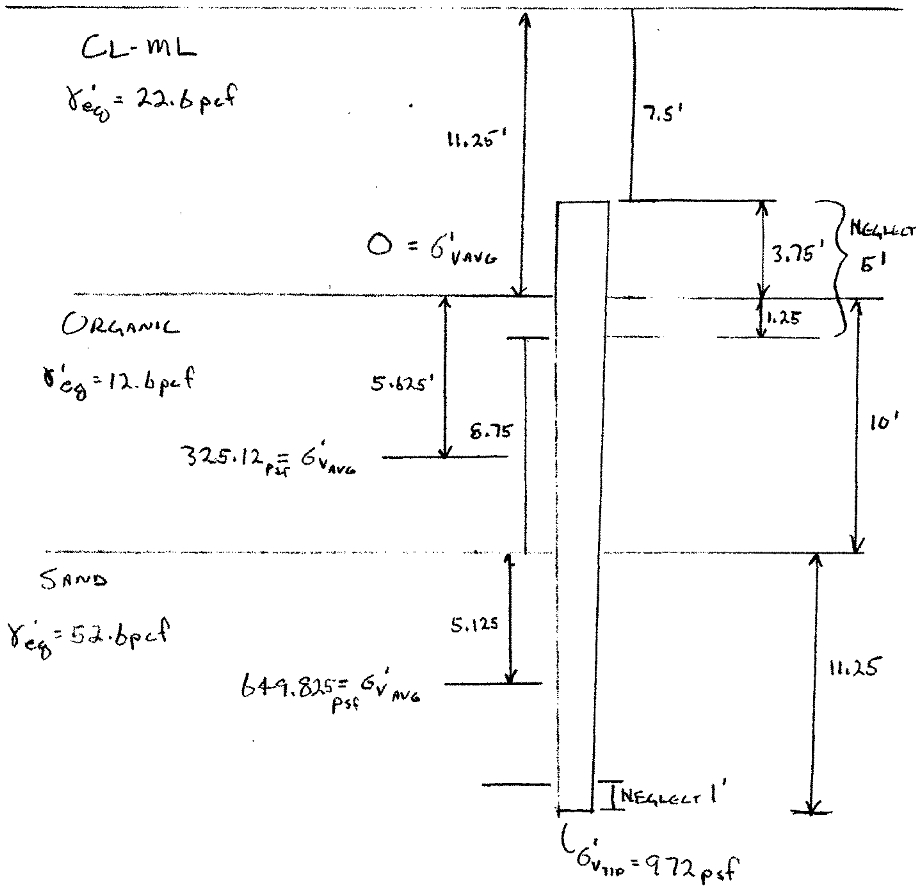
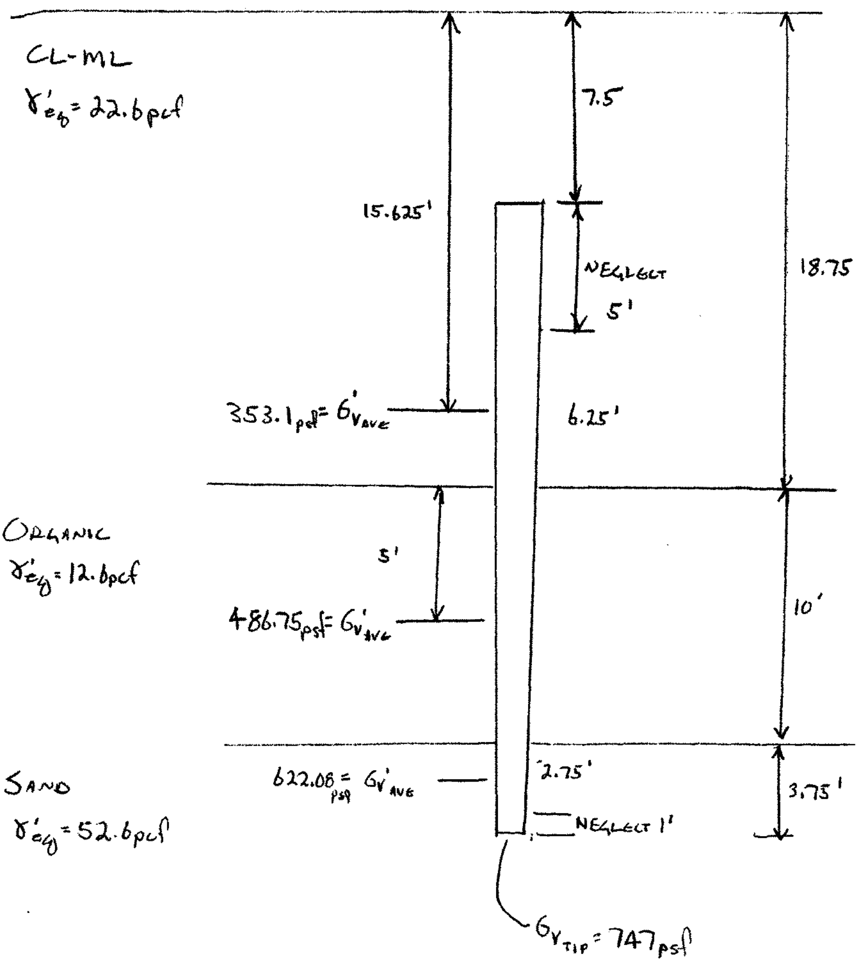
LOWER COV CL-ML THICKNESS - WATER TO TOP OF WALL



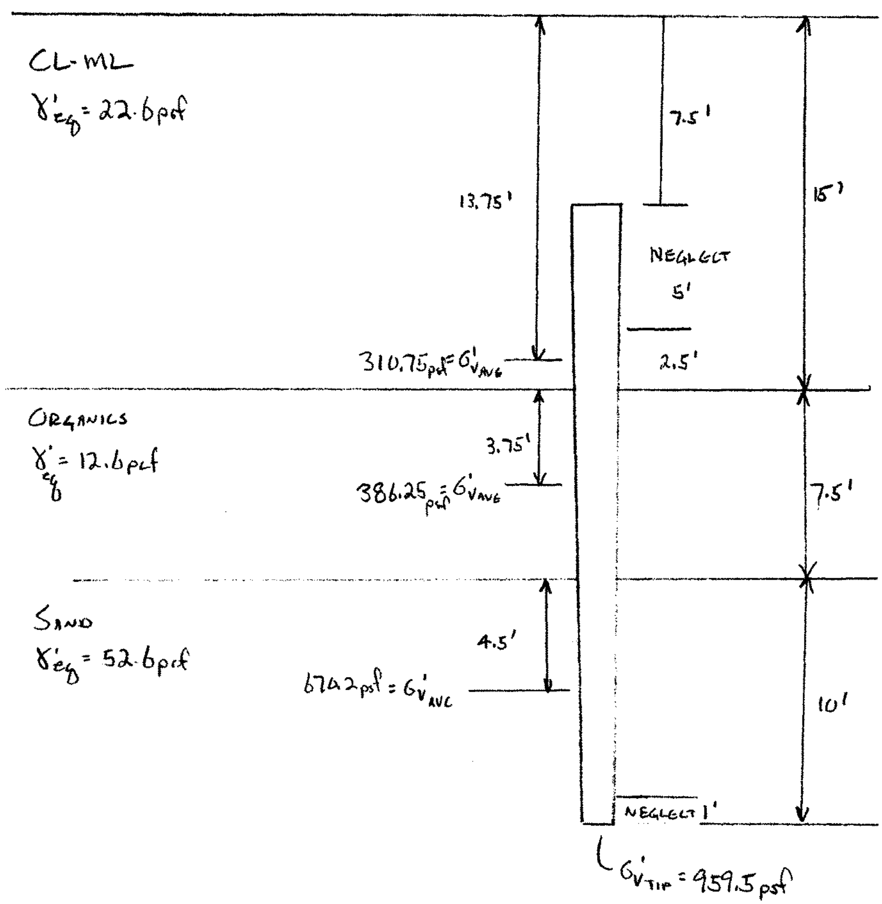
1 Dec 2007 6/8

Upper COV CL-ML Thickness - Water to top of wall



1 DEC 2009 7/

LOW COV ORGANIC THICKNESS - WATER TO TOP OF WALL



1 Dec 2007
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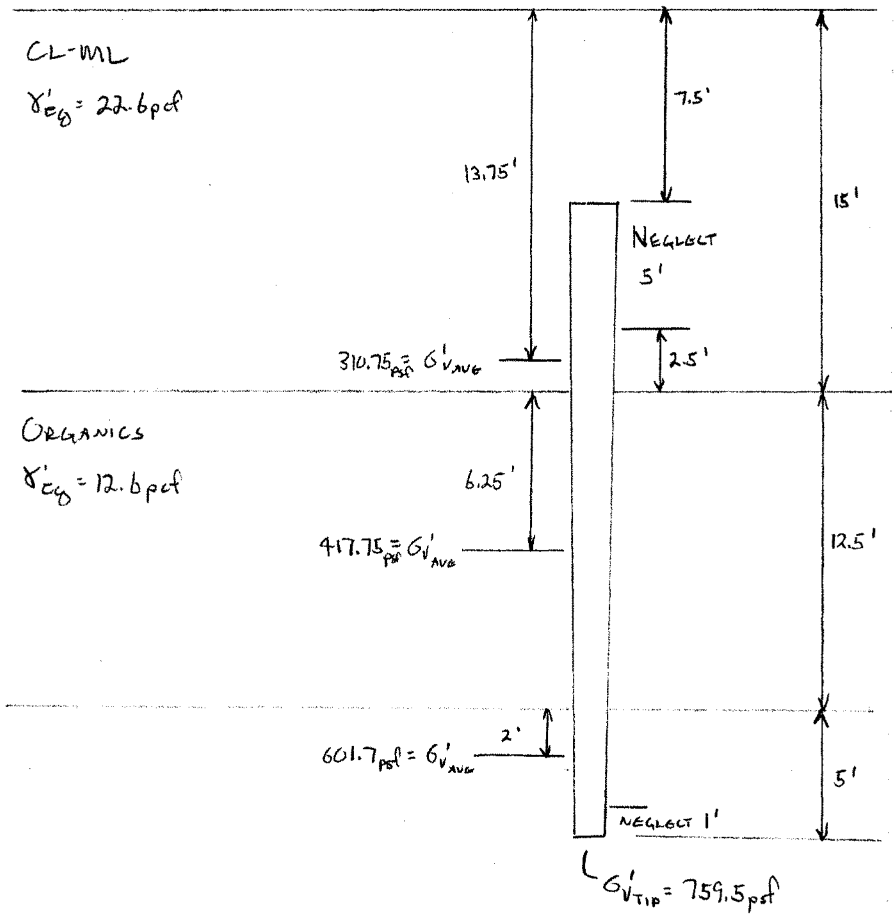
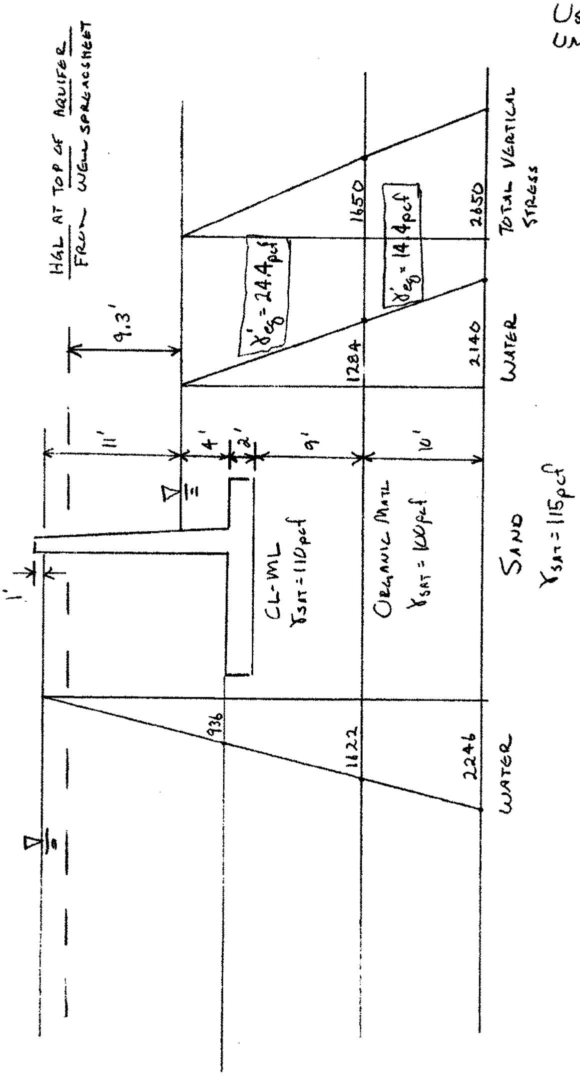
HIGH COV ORGANIC THICKNESS - WATER TO TOP OF WALL



South Topeka Floodwall - Sta 84+50 — 20 Oct 2007, RSK

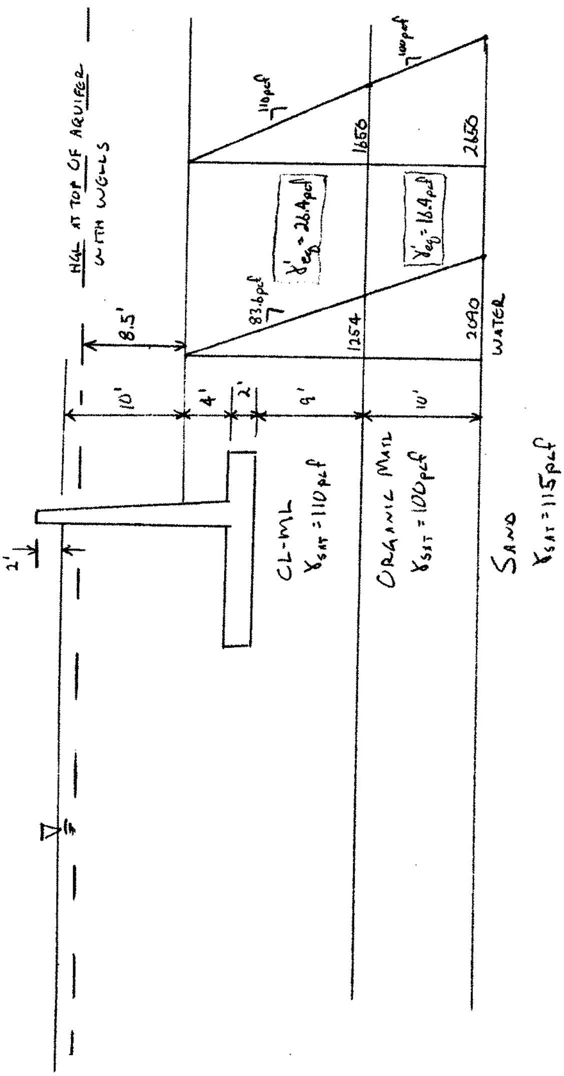
- Use computed HGL with wells case to determine effective unit weights of soils
- Water 1 ft below top of wall

Use the landside equivalent unit weights for a pile



South Topeka Floodwall Sta 84+50 — 20 Oct 2007 — 10/

- Use computed HGL with wells case to determine effective unit weights of soils
- Water 2' below top of wall



SOUTH TOPEKA FLOODWALL STA 84+50 20 OCT 2007

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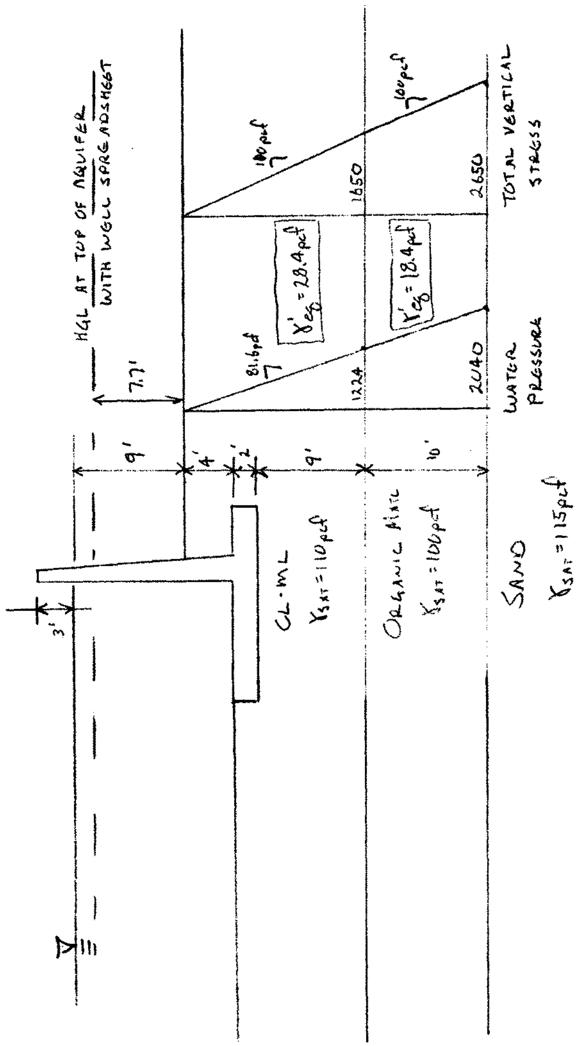
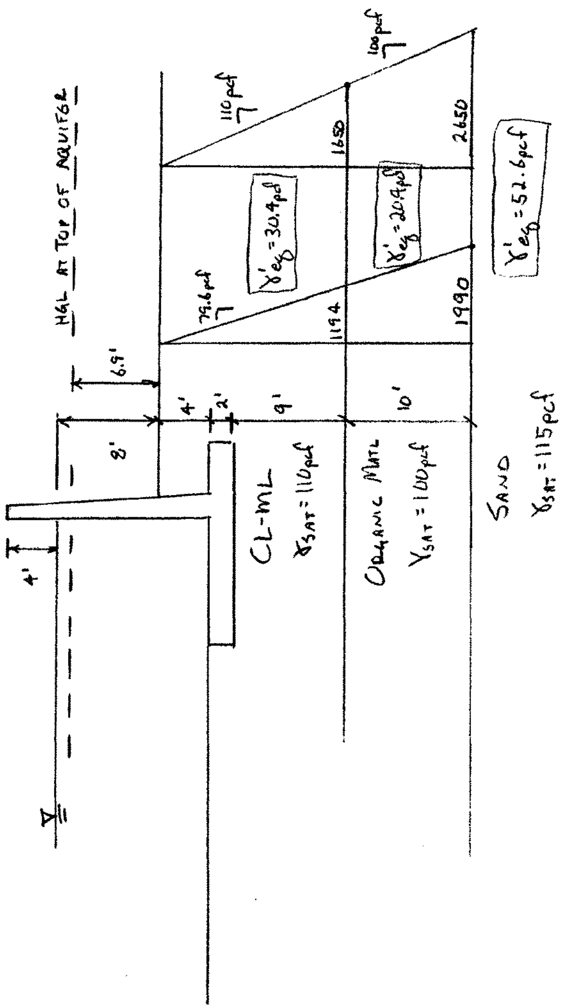
- USE COMPUTED HGL WITH WELLS CASE TO DETERMINE EFFECTIVE UNIT WEIGHT OF SOILS
- WATER 3' BELOW TOP OF WALL

FOR INPUT INTO APILE



SOUTH TOPEKA FLOODWALL 84+50 20 OCT 2007 RSK 14/

- USE COMPUTED HGL WITH WELLS CASE TO DETERMINE EFFECTIVE UNIT WEIGHT OF SOILS
- WATER 4' BELOW TOP OF WALL

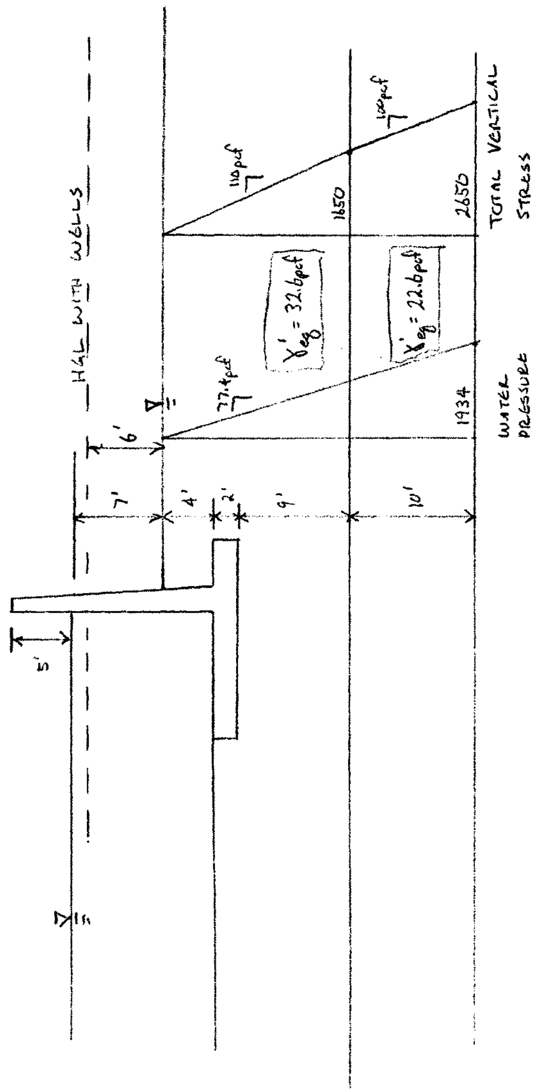


SOUTH TOPEKA FLOODWALL 84+50 21 OCT 2007

- USE COMPUTED HGL WITH WELLS TO DETERMINE RSK 13/

EFFECTIVE UNIT WEIGHT OF SOILS

- WATER 5' BELOW TOP OF WALL:

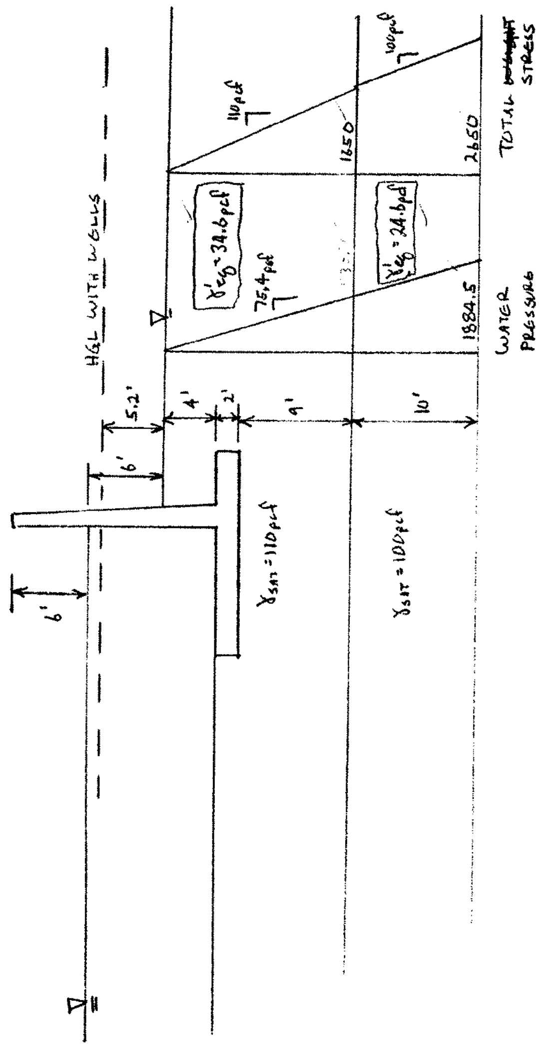


South Topeka Floodwall 84+50

- Use computed HGL with wells to determine effective unit weight of soils
- Water 6' below top of walls

6 Dec 2007
RSK

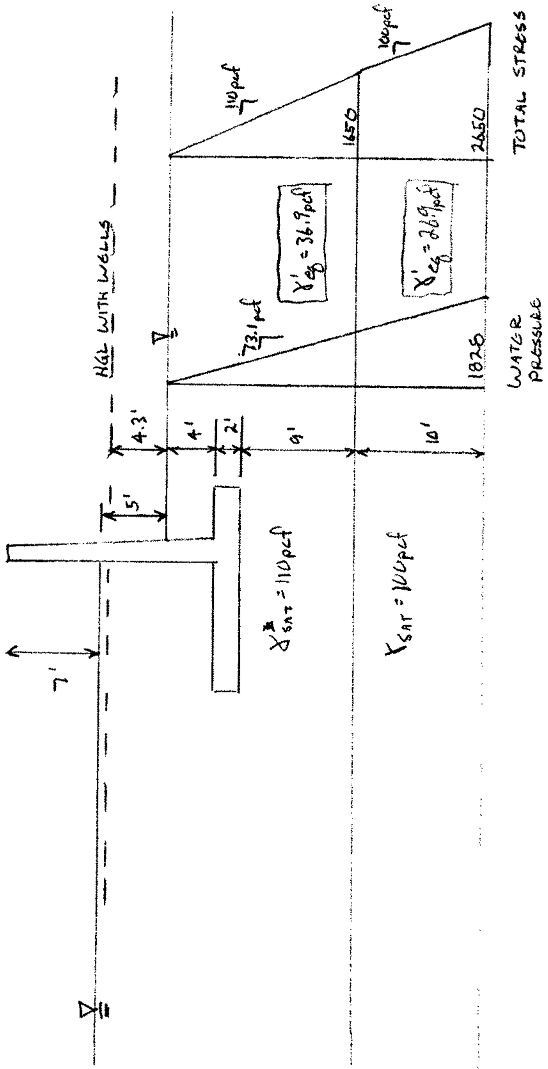
Review: GMB
12/20/07



SOUTH TOPEKA FLOODWALL 84+50 6 DEC 2007

- USE COMPUTED HGL WITH WELLS TO DETERMINE EFFECTIVE UNIT WEIGHT OF SOILS RSK

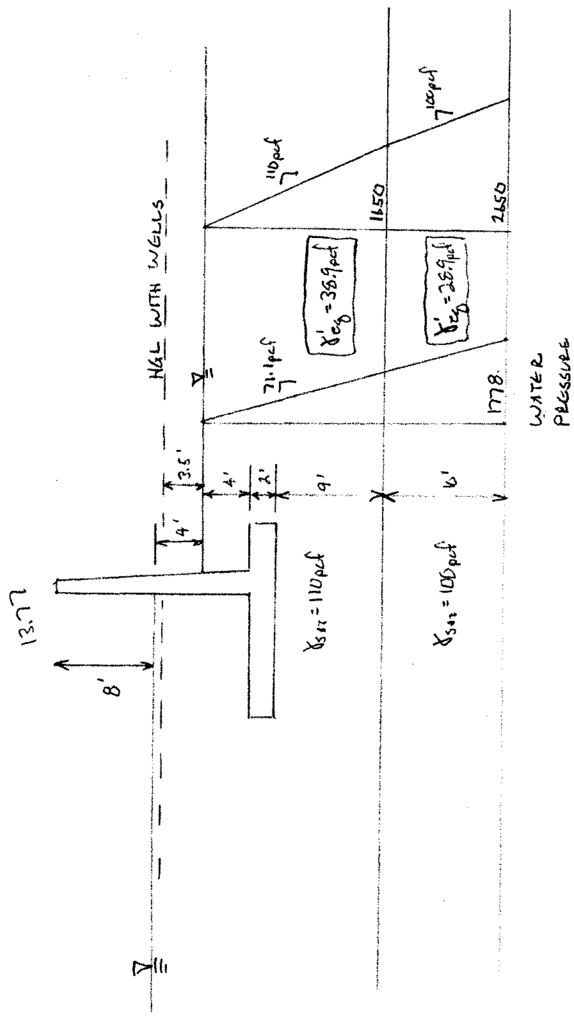
- WATER 7' BELOW TOP OF WALLS



SOUTH TOPEKA FLOODWALL 84+50

6 DEC 2007
RSK

- USE COMPUTED HGL WITH WELLS TO DETERMINE EFFECTIVE UNIT WEIGHT OF SOILS
- WATER 8' BELOW TOP OF WALLS



South Topeka Floodwall Feasibility Study
Calculation of equivalent effective unit weight of the blanket materials

Landside Ground Surface Elevation:	880 ft msl	Coefficient of Variation of CL-ML Thickness:	25%
Unit Weight of Water:	62.4 pcf	Coefficient of Variation of Organics Thickness:	25%
Saturated Unit Weight of CL-ML:	110 pcf		
Saturated Unit Weight of Organics:	100 pcf		

	River Level	River Elevation (ft msl)	Height of Water on Wall (ft)	HGL Above Ground (feet)	HGL Elevation* (ft msl)	Water Pressure at Ground Surface (psf)	CL-ML Thickness (ft)	Organic Thickness (ft)	Total Blanket Thickness (ft)	Water Pressure at Bottom of Blanket (psf)	Change in Water Pressure Through Blanket (psf/ft)	Equivalent Effective Unit Weight CL-ML (pcf)	Equivalent Effective Unit Weight Organics (pcf)
Expected Value	Top of Wall	892	12	10	890	748.8	15	10	25	2184	87.36	22.6	12.6
[EV] - COV							11.25	7.50	18.75	1794	95.68	14.3	4.3
[EV] + COV							18.75	12.50	31.25	2574	82.37	27.6	17.6
Expected Value	TOW - 1	891	11	9.3	889.3	686.4	15	10	25	2140.32	85.61	24.4	14.4
[EV] - COV							11.25	7.50	18.75	1750.32	93.35	16.6	6.6
[EV] + COV							18.75	12.50	31.25	2530.32	80.97	29.0	19.0
Expected Value	TOW - 2	890	10	8.5	888.5	624	15	10	25	2090.4	83.62	26.4	16.4
[EV] - COV							11.25	7.50	18.75	1700.4	90.69	19.3	9.3
[EV] + COV							18.75	12.50	31.25	2480.4	79.37	30.6	20.6
Expected Value	TOW - 3	889	9	7.7	887.7	561.6	15	10	25	2040.48	81.62	28.4	18.4
[EV] - COV							11.25	7.50	18.75	1650.48	88.03	22.0	12.0
[EV] + COV							18.75	12.50	31.25	2430.48	77.78	32.2	22.2
Expected Value	TOW - 4	888	8	6.9	886.9	499.2	15	10	25	1990.56	79.62	30.4	20.4
[EV] - COV							11.25	7.50	18.75	1600.56	85.36	24.6	14.6
[EV] + COV							18.75	12.50	31.25	2380.56	76.18	33.8	23.8
Expected Value	TOW - 5	887	7	6	886	436.8	15	10	25	1934.4	77.38	32.6	22.6
[EV] - COV							11.25	7.50	18.75	1544.4	82.37	27.6	17.6
[EV] + COV							18.75	12.50	31.25	2324.4	74.38	35.6	25.6
Expected Value	TOW - 6	886	6	5.2	885.2	374.4	15	10	25	1884.48	75.38	34.6	24.6
[EV] - COV							11.25	7.50	18.75	1494.48	79.71	30.3	20.3
[EV] + COV							18.75	12.50	31.25	2274.48	72.78	37.2	27.2
Expected Value	TOW - 7	885	5	4.3	884.3	312	15	10	25	1828.32	73.13	36.9	26.9
[EV] - COV							11.25	7.50	18.75	1438.32	76.71	33.3	23.3
[EV] + COV							18.75	12.50	31.25	2218.32	70.99	39.0	29.0
Expected Value	TOW - 8	884	4	3.5	883.5	249.6	15	10	25	1778.4	71.14	38.9	28.9
[EV] - COV							11.25	7.50	18.75	1388.4	74.05	36.0	26.0
[EV] + COV							18.75	12.50	31.25	2168.4	69.39	40.6	30.6

*HGL computed using effect of the relief wells

Exhibit 10

Pile Axial Capacity Reliability Analysis
Excel Files to Determine Probability of Failure

South Topeka Floodwall
Wall Data from Construction Drawings Dated March 1938 showing plan, profile and sections of all wall types
Landside Ground Surface Data From Record Drawings Dated November 1969
Compression load on landward most pile at different water levels
Station 80+42 to 83+78 (Wall station 6+72 to 10+08) Type B Wall Type

Distance to Water Surface from Top of Wall (ft)	Axial Load in Compression (kips)
0	23
1	20
2	17
3	14
4	12
5	10
6	9
7	8
8	6

South Topeka Axial Pile Capacity Reliability Analysis - November 2007
Reference: Corps of Engineers EM 1110-2-2906 dated 15 January 1991

Analysis: **Water to the top of the wall** Elevation. 892.00
Maximum Axial Load on Pile: **23 kips**

Top of Pile Below Ground Surface. 27 7.5 feet Bearing Capacity Factor in Sand (Nq): 40
Friction between soil and timber pile (δ): 0.9

Neglect skin friction on upper part of pile: 5 feet
Neglect skin friction on lower part of pile 1 feet
Earth Pressure Coefficients
CL-ML: 1.0
Organics: 1.0
Sand: 1.5
Expected Length of Pile 25 feet
Average Diameter of Pile
CL-ML: 0.95 feet (11.5 inches)
Organics: 0.875 feet (10.5 inches)
Sand: 0.8 feet (9.5 inches)
Pile Tip: 0.75 feet (9 inches)

	CL-ML Blanket Material Shaft Capacity							Organic Blanket Material Shaft Capacity					
Analysis	Coefficient of Variance (%)	Effective Unit Weight (pcf)	Thickness of Layer (ft)	Length of Pile in Layer (ft)	φ' (deg)	Average Effective Vertical Stress (psf)	Pile Surface Area (sq ft)	Ultimate Shaft Capacity (kips)	Effective Unit Weight (pcf)	Thickness of Layer (ft)	φ' (deg)	Average Effective Vertical Stress (psf)	Pile Surface Area (sq ft)
Expected Value	N/A	22.6	15	7.5	24	310.75	7.46	0.92	12.6	10	17	402.00	27.49
Lower COV Strength CL-ML	30%	22.6	15	7.5	16.8	310.75	7.46	0.63	12.6	10	17	402.00	27.49
Upper COV Strength CL-ML	30%	22.6	15	7.5	31.2	310.75	7.46	1.24	12.6	10	17	402.00	27.49
Lower COV Strength Organics	30%	22.6	15	7.5	24	310.75	7.46	0.92	12.6	10	11.9	402.00	27.49
Upper COV Strength Organics	30%	22.6	15	7.5	24	310.75	7.46	0.92	12.6	10	22.1	402.00	27.49
Lower COV Strength Sand	15%	22.6	15	7.5	24	310.75	7.46	0.92	12.6	10	17	402.00	27.49
Upper COV Strength Sand	15%	22.6	15	7.5	24	310.75	7.46	0.92	12.6	10	17	402.00	27.49
Lower COV Blanket Thickness CL-ML	25%	22.6	11.25	3.75	24	0	0.00	0.00	12.6	10	17	325.13	24.05
Upper COV Blanket Thickness CL-ML	25%	22.6	18.75	11.25	24	353.125	18.65	2.61	12.6	10	17	486.75	27.49
Lower COV Blanket Thickness Organic	25%	22.6	15	7.5	24	310.75	7.46	0.92	12.6	7.5	17	386.25	20.62
Upper COV Blanket Thickness Organic	25%	22.6	15	7.5	24	310.75	7.46	0.92	12.6	12.5	17	417.75	34.36
Lower COV Pile Length	20%	22.6	15	7.5	24	310.75	7.46	0.92	12.6	10	17	402.00	27.49
Upper COV Pile Length	20%	22.6	15	7.5	24	310.75	7.46	0.92	12.6	10	17	402.00	27.49

	Aquifer Shaft Capacity						Aquifer Tip Capacity				Total Capacity			
Analysis	Ultimate Shaft Capacity (kips)	Effective Unit Weight (pcf)	Length of Pile in Sand (ft)	φ' (deg)	Average Effective Vertical Stress (psf)	Pile Surface Area (sq ft)	Ultimate Shaft Capacity (kips)	Effective Vertical Stress at Tip (psf)	Area of Pile Tip (psf)	Ultimate Tip Capacity (kips)	Total Ultimate Pile Capacity (kips)	Factor of Safety	Variance Component	Percent of Variance
Expected Value	3.02	52.6	7.5	33	635.95	16.34	8.89	859.5	0.44	15.19	28.02	1.22		
Lower COV Strength CL-ML	3.02	52.6	7.5	33	635.95	16.34	8.89	859.5	0.44	15.19	27.73	1.21		
Upper COV Strength CL-ML	3.02	52.6	7.5	33	635.95	16.34	8.89	859.5	0.44	15.19	28.34	1.23	0.000176	0.040237%
Lower COV Strength Organics	2.09	52.6	7.5	33	635.95	16.34	8.89	859.5	0.44	15.19	27.09	1.18		
Upper COV Strength Organics	4.00	52.6	7.5	33	635.95	16.34	8.89	859.5	0.44	15.19	28.99	1.26	0.001721	0.393038%
Lower COV Strength Sand	3.02	52.6	7.5	28.05	635.95	16.34	7.35	859.5	0.44	15.19	26.48	1.15		
Upper COV Strength Sand	3.02	52.6	7.5	37.95	635.95	16.34	10.57	859.5	0.44	15.19	29.70	1.29	0.004914	1.122611%
Lower COV Blanket Thickness CL-ML	2.14	52.6	11.25	33	649.825	25.76	14.32	972	0.44	17.18	33.64	1.46		
Upper COV Blanket Thickness CL-ML	3.86	52.6	3.75	33	622.075	6.91	3.68	747	0.44	13.20	23.15	1.01	0.052015	11.882365%
Lower COV Blanket Thickness Organic	2.18	52.6	10	33	670.2	22.62	12.97	959.5	0.44	16.96	33.02	1.44		
Upper COV Blanket Thickness Organic	3.93	52.6	5	33	601.7	10.05	5.18	759.5	0.44	13.42	23.44	1.02	0.043380	9.909828%
Lower COV Pile Length	3.02	52.6	2.5	33	504.45	3.77	1.63	596.5	0.44	10.54	16.11	0.70		
Upper COV Pile Length	3.02	52.6	12.5	33	767.45	28.90	18.98	1122.5	0.44	19.84	42.76	1.86	0.335546	76.652123%

SUM: 0.437752 100.000000%

Variance $Var[\beta_{FS}]$ = 0.437752

Standard of Deviation σ_{FS} = 0.661628

Coefficient of Variation COV_{FS} = 0.543123

Reliability Index β_{FS} = 0.133981

Probability of Failure P_f = **44.67%**

Notes:

1. The average pile diameters were not changed with the varying stratigraphy. This simplification is not exactly correct, however variations in pile diameter would be very minor

South Topeka Axial Pile Capacity Reliability Analysis - November 2007
Reference: Corps of Engineers EM 1110-2-2906 dated 15 January 1991

Analysis: **Water 1 Foot below the top of the wall** Elevation: 891.00
Maximum Axial Load on Pile: **20 kips**

Top of Pile Below Ground Surface: 7.5 feet
Friction between soil and timber pile (δ): 0.9

Bearing Capacity Factor in Sand (Nq): 40

Neglect skin friction on upper part of pile: 5 feet
Neglect skin friction on lower part of pile 1 feet
Earth Pressure Coefficients
CL-ML: 1.0
Organics: 1.0
Sand: 1.5
Expected Length of Pile 25 feet
Average Diameter of Pile
CL-ML: 0.95 feet (11.5 inches)
Organics: 0.875 feet (10.5 inches)
Sand: 0.8 feet (9.5 inches)
Pile Tip: 0.75 feet (9 inches)

		CL-ML Blanket Material Shaft Capacity						Organic Blanket Material Shaft Capacity						Aquifer Shaft Capacity						Aquifer Tip Capacity				Total Capacity			
Analysis	Coefficient of Variance (%)	Effective Unit Weight (pcf)	Thickness of Layer (ft)	Length of Pile in Layer (ft)	φ' (deg)	Average Effective Vertical Stress (psf)	Pile Surface Area (sq ft)	Ultimate Shaft Capacity (kips)	Effective Unit Weight (pcf)	Thickness of Layer (ft)	φ' (deg)	Average Effective Vertical Stress (psf)	Pile Surface Area (sq ft)	Ultimate Shaft Capacity (kips)	Effective Unit Weight (pcf)	Length of Pile in Sand (ft)	φ' (deg)	Average Effective Vertical Stress (psf)	Pile Surface Area (sq ft)	Ultimate Shaft Capacity (kips)	Effective Vertical Stress at Tip (psf)	Area of Pile Tip (psf)	Ultimate Tip Capacity (kips)	Total Ultimate Pile Capacity (kips)	Factor of Safety	Variance Component	Percent of Variance
Expected Value	N/A	24.4	15	7.5	24	335.5	7.46	0.99	14.4	10	17	438.00	27.49	3.29	52.6	7.5	33	680.95	16.34	9.52	904.5	0.44	15.98	29.79	1.49		
Lower COV Strength CL-ML	30%	24.4	15	7.5	16.8	335.5	7.46	0.68	14.4	10	17	438.00	27.49	3.29	52.6	7.5	33	680.95	16.34	9.52	904.5	0.44	15.98	29.47	1.47		
Upper COV Strength CL-ML	30%	24.4	15	7.5	31.2	335.5	7.46	1.34	14.4	10	17	438.00	27.49	3.29	52.6	7.5	33	680.95	16.34	9.52	904.5	0.44	15.98	30.13	1.51	0.000272	0.044287%
Lower COV Strength Organics	30%	24.4	15	7.5	24	335.5	7.46	0.99	14.4	10	11.9	438.00	27.49	2.28	52.6	7.5	33	680.95	16.34	9.52	904.5	0.44	15.98	28.77	1.44		
Upper COV Strength Organics	30%	24.4	15	7.5	24	335.5	7.46	0.99	14.4	10	22.1	438.00	27.49	4.36	52.6	7.5	33	680.95	16.34	9.52	904.5	0.44	15.98	30.85	1.54	0.002701	0.440567%
Lower COV Strength Sand	15%	24.4	15	7.5	24	335.5	7.46	0.99	14.4	10	17	438.00	27.49	3.29	52.6	7.5	28.05	680.95	16.34	7.87	904.5	0.44	15.98	28.14	1.41		
Upper COV Strength Sand	15%	24.4	15	7.5	24	335.5	7.46	0.99	14.4	10	17	438.00	27.49	3.29	52.6	7.5	37.95	680.95	16.34	11.32	904.5	0.44	15.98	31.59	1.58	0.007451	1.215339%
Lower COV Blanket Thickness CL-ML	25%	24.4	11.25	3.75	24	0	0.00	0.00	14.4	10	17	355.50	24.05	2.34	52.6	11.25	33	688.075	25.76	15.17	1010.25	0.44	17.85	35.38	1.77		
Upper COV Blanket Thickness CL-ML	25%	24.4	18.75	11.25	24	381.25	18.65	2.82	14.4	10	17	529.50	27.49	3.98	52.6	3.75	33	673.825	6.91	3.98	798.75	0.44	14.12	24.90	1.24	0.068386	11.153957%
Lower COV Blanket Thickness Organic	25%	24.4	15	7.5	24	335.5	7.46	0.99	14.4	7.5	17	420.00	20.62	2.37	52.6	10	33	710.7	22.62	13.75	1000	0.44	17.67	34.79	1.74		
Upper COV Blanket Thickness Organic	25%	24.4	15	7.5	24	335.5	7.46	0.99	14.4	12.5	17	456.00	34.36	4.29	52.6	5	33	651.2	10.05	5.60	809	0.44	14.30	25.17	1.26	0.057727	9.415365%
Lower COV Pile Length	20%	24.4	15	7.5	24	335.5	7.46	0.99	14.4	10	17	438.00	27.49	3.29	52.6	2.5	33	549.45	3.77	1.77	641.5	0.44	11.34	17.39	0.87		
Upper COV Pile Length	20%	24.4	15	7.5	24	335.5	7.46	0.99	14.4	10	17	438.00	27.49	3.29	52.6	12.5	33	812.45	28.90	20.09	1167.5	0.44	20.63	45.01	2.25	0.476575	77.730485%

SUM: 0.613112 100.000000%

Variance $Var[_{FS}]$ = 0.613112

Standard of Deviation σ_{FS} = 0.783015

Coefficient of Variation COV_{FS} = 0.525752

Reliability Index β_{FS} = 0.559276

Probability of Failure P_f = **28.80%**

Notes:

1. The average pile diameters were not changed with the varying stratigraphy. This simplification is not exactly correct, however variations in pile diameter would be very minor.

South Topeka Axial Pile Capacity Reliability Analysis - November 2007
Reference: Corps of Engineers EM 1110-2-2906 dated 15 January 1991

Analysis: **Water 2 Feet below the top of the wall** Elevation: 890.00
Maximum Axial Load on Pile: **17 kips**

Top of Pile Below Ground Surface: 7.5 feet
Friction between soil and timber pile (δ): 0.9

Neglect skin friction on upper part of pile: 5 feet
Neglect skin friction on lower part of pile: 1 feet
Earth Pressure Coefficients
CL-ML: 1.0
Organics: 1.0
Sand: 1.5
Expected Length of Pile: 25 feet
Average Diameter of Pile
CL-ML: 0.95 feet (11.5 inches)
Organics: 0.875 feet (10.5 inches)
Sand: 0.8 feet (9.5 inches)
Pile Tip: 0.75 feet (9 inches)

Bearing Capacity Factor in Sand (Nq): 40

	CL-ML Blanket Material Shaft Capacity							Organic Blanket Material Shaft Capacity						Aquifer Shaft Capacity						Aquifer Tip Capacity				Total Capacity			
Analysis	Coefficient of Variance (%)	Effective Unit Weight (pcf)	Thickness of Layer (ft)	Length of Pile in Layer (ft)	φ' (deg)	Average Effective Vertical Stress (psf)	Pile Surface Area (sq ft)	Ultimate Shaft Capacity (kips)	Effective Unit Weight (pcf)	Thickness of Layer (ft)	φ' (deg)	Average Effective Vertical Stress (psf)	Pile Surface Area (sq ft)	Ultimate Shaft Capacity (kips)	Effective Unit Weight (pcf)	Length of Pile in Sand (ft)	φ' (deg)	Average Effective Vertical Stress (psf)	Pile Surface Area (sq ft)	Ultimate Shaft Capacity (kips)	Effective Vertical Stress at Tip (psf)	Area of Pile Tip (psf)	Ultimate Tip Capacity (kips)	Total Ultimate Pile Capacity (kips)	Factor of Safety	Variance Component	Percent of Variance
Expected Value	N/A	26.4	15	7.5	24	363	7.46	**1.07**	16.4	10	17	478.00	27.49	**3.59**	52.6	7.5	33	730.95	16.34	**10.22**	954.5	0.44	**16.87**	**31.75**	1.87		
Lower COV Strength CL-ML	30%	26.4	15	7.5	**16.8**	363	7.46	**0.73**	16.4	10	17	478.00	27.49	**3.59**	52.6	7.5	33	730.95	16.34	**10.22**	954.5	0.44	**16.87**	**31.41**	1.85		
Upper COV Strength CL-ML	30%	26.4	15	7.5	**31.2**	363	7.46	**1.44**	16.4	10	17	478.00	27.49	**3.59**	52.6	7.5	33	730.95	16.34	**10.22**	954.5	0.44	**16.87**	**32.12**	1.89	0.000440	0.048708%
Lower COV Strength Organics	30%	26.4	15	7.5	24	363	7.46	**1.07**	16.4	10	**11.9**	478.00	27.49	**2.49**	52.6	7.5	33	730.95	16.34	**10.22**	954.5	0.44	**16.87**	**30.84**	1.80		
Upper COV Strength Organics	30%	26.4	15	7.5	24	363	7.46	**1.07**	16.4	10	**22.1**	478.00	27.49	**4.75**	52.6	7.5	33	730.95	16.34	**10.22**	954.5	0.44	**16.87**	**32.91**	1.94	0.004453	0.492966%
Lower COV Strength Sand	15%	26.4	15	7.5	24	363	7.46	**1.07**	16.4	10	17	478.00	27.49	**3.59**	52.6	7.5	**28.05**	730.95	16.34	**8.45**	954.5	0.44	**16.87**	**29.98**	1.76		
Upper COV Strength Sand	15%	26.4	15	7.5	24	363	7.46	**1.07**	16.4	10	17	478.00	27.49	**3.59**	52.6	7.5	**37.95**	730.95	16.34	**12.15**	954.5	0.44	**16.87**	**33.69**	1.98	0.011883	1.315848%
Lower COV Blanket Thickness CL-ML	25%	26.4	**11.25**	3.75	24	0	0.00	**0.00**	16.4	10	17	389.25	24.05	**2.56**	52.6	11.25	33	730.575	25.76	**16.10**	1052.75	0.44	**18.60**	**37.27**	2.10		
Upper COV Blanket Thickness CL-ML	25%	26.4	**18.75**	11.25	24	412.5	18.65	**3.05**	16.4	10	17	577.00	27.49	**4.34**	52.6	3.75	33	731.325	6.91	**4.32**	856.25	0.44	**15.13**	**26.84**	1.58	0.094033	10.410586%
Lower COV Blanket Thickness Organic	25%	26.4	15	7.5	24	363	7.46	**1.07**	16.4	**7.5**	17	457.50	20.62	**2.58**	52.6	10	33	755.7	22.62	**14.62**	1045	0.44	**18.47**	**36.74**	2.16		
Upper COV Blanket Thickness Organic	25%	26.4	15	7.5	24	363	7.46	**1.07**	16.4	**12.5**	17	498.50	34.36	**4.69**	52.6	5	33	706.2	10.05	**6.07**	864	0.44	**15.27**	**27.10**	1.59	0.080450	8.906763%
Lower COV Pile Length	20%	26.4	15	7.5	24	363	7.46	**1.07**	16.4	10	17	478.00	27.49	**3.59**	52.6	**2.5**	33	599.45	3.77	**1.93**	691.5	0.44	**12.22**	**18.82**	1.11		
Upper COV Pile Length	20%	26.4	15	7.5	24	363	7.46	**1.07**	16.4	10	17	478.00	27.49	**3.59**	52.6	**12.5**	33	862.45	28.90	**21.33**	1217.5	0.44	**21.52**	**47.51**	2.79	0.711984	78.825330%

SUM: 0.903243 100.000000%

Variance $Var_{[FS]}$ = 0.903243

Standard of Deviation σ_{FS} = 0.950391

Coefficient of Variation COV_{FS} = 0.508858

Reliability Index β_{FS} = 1.061925

Probability of Failure P_f = **14.41%**

Notes:

1. The average pile diameters were not changed with the varying stratigraphy. This simplification is not exactly correct, however variations in pile diameter would be very minor.

South Topeka Axial Pile Capacity Reliability Analysis - November 2007
Reference: Corps of Engineers EM 1110-2-2906 dated 15 January 1991

Analysis: **Water 3 Feet below the top of the wall** Elevation: 889.00
Maximum Axial Load on Pile: **14 kips**

Top of Pile Below Ground Surface: 7.5 feet
Friction between soil and timber pile (δ): 0.9

Bearing Capacity Factor in Sand (Nq): 40

Neglect skin friction on upper part of pile: 5 feet
Neglect skin friction on lower part of pile: 1 feet
Earth Pressure Coefficients
CL-ML: 1.0
Organics: 1.0
Sand: 1.5
Expected Length of Pile: 25 feet
Average Diameter of Pile
CL-ML: 0.95 feet (11.5 inches)
Organics: 0.875 feet (10.5 inches)
Sand: 0.8 feet (9.5 inches)
Pile Tip: 0.75 feet (9 inches)

Analysis	Coefficient of Variance (%)	CL-ML Blanket Material Shaft Capacity: Effective Unit Weight (pcf)	Thickness of Layer (ft)	Length of Pile in Layer (ft)	φ' (deg)	Average Effective Vertical Stress (psf)	Pile Surface Area (sq ft)	Ultimate Shaft Capacity (kips)	Organic Blanket Material Shaft Capacity: Effective Unit Weight (pcf)	Thickness of Layer (ft)	φ' (deg)	Average Effective Vertical Stress (psf)	Pile Surface Area (sq ft)	Ultimate Shaft Capacity (kips)
Expected Value	N/A	28.4	15	7.5	24	390.5	7.46	1.15	18.4	10	17	518.00	27.49	3.90
Lower COV Strength CL-ML	30%	28.4	15	7.5	16.8	390.5	7.46	0.79	18.4	10	17	518.00	27.49	3.90
Upper COV Strength CL-ML	30%	28.4	15	7.5	31.2	390.5	7.46	1.55	18.4	10	17	518.00	27.49	3.90
Lower COV Strength Organics	30%	28.4	15	7.5	24	390.5	7.46	1.15	18.4	10	11.9	518.00	27.49	2.69
Upper COV Strength Organics	30%	28.4	15	7.5	24	390.5	7.46	1.15	18.4	10	22.1	518.00	27.49	5.15
Lower COV Strength Sand	15%	28.4	15	7.5	24	390.5	7.46	1.15	18.4	10	17	518.00	27.49	3.90
Upper COV Strength Sand	15%	28.4	15	7.5	24	390.5	7.46	1.15	18.4	10	17	518.00	27.49	3.90
Lower COV Blanket Thickness CL-ML	25%	28.4	11.25	3.75	24	0	0.00	0.00	18.4	10	17	423.00	24.05	2.78
Upper COV Blanket Thickness CL-ML	25%	28.4	18.75	11.25	24	443.75	18.65	3.29	18.4	10	17	624.50	27.49	4.70
Lower COV Blanket Thickness Organic	25%	28.4	15	7.5	24	390.5	7.46	1.15	18.4	7.5	17	495.00	20.62	2.79
Upper COV Blanket Thickness Organic	25%	28.4	15	7.5	24	390.5	7.46	1.15	18.4	12.5	17	541.00	34.36	5.00
Lower COV Pile Length	20%	28.4	15	7.5	24	390.5	7.46	1.15	18.4	10	17	518.00	27.49	3.90
Upper COV Pile Length	20%	28.4	15	7.5	24	390.5	7.46	1.15	18.4	10	17	518.00	27.49	3.90

Analysis	Aquifer Shaft Capacity: Effective Unit Weight (pcf)	Length of Pile in Sand (ft)	φ' (deg)	Average Effective Vertical Stress (psf)	Pile Surface Area (sq ft)	Ultimate Shaft Capacity (kips)	Aquifer Tip Capacity: Effective Vertical Stress at Tip (psf)	Area of Pile Tip (psf)	Ultimate Tip Capacity (kips)	Total Capacity: Total Ultimate Pile Capacity (kips)	Factor of Safety	Variance Component	Percent of Variance
Expected Value	52.6	7.5	33	780.95	16.34	10.92	1004.5	0.44	17.75	33.72	2.41		
Lower COV Strength CL-ML	52.6	7.5	33	780.95	16.34	10.92	1004.5	0.44	17.75	33.35	2.38		
Upper COV Strength CL-ML	52.6	7.5	33	780.95	16.34	10.92	1004.5	0.44	17.75	34.12	2.44	0.000751	0.053031%
Lower COV Strength Organics	52.6	7.5	33	780.95	16.34	10.92	1004.5	0.44	17.75	32.51	2.32		
Upper COV Strength Organics	52.6	7.5	33	780.95	16.34	10.92	1004.5	0.44	17.75	34.97	2.50	0.007710	0.544655%
Lower COV Strength Sand	52.6	7.5	28.05	780.95	16.34	9.02	1004.5	0.44	17.75	31.82	2.27		
Upper COV Strength Sand	52.6	7.5	37.95	780.95	16.34	12.98	1004.5	0.44	17.75	35.78	2.56	0.020001	1.412902%
Lower COV Blanket Thickness CL-ML	52.6	11.25	33	773.075	25.76	17.04	1095.25	0.44	19.35	39.18	2.80		
Upper COV Blanket Thickness CL-ML	52.6	3.75	33	788.825	6.91	4.66	913.75	0.44	16.15	28.79	2.06	0.137740	9.730073%
Lower COV Blanket Thickness Organic	52.6	10	33	800.7	22.62	15.50	1090	0.44	19.26	38.70	2.76		
Upper COV Blanket Thickness Organic	52.6	5	33	761.2	10.05	6.55	919	0.44	16.24	29.03	2.07	0.119438	8.437165%
Lower COV Pile Length	52.6	2.5	33	649.45	3.77	2.09	741.5	0.44	13.10	20.25	1.45		
Upper COV Pile Length	52.6	12.5	33	912.45	28.90	22.56	1267.5	0.44	22.40	50.01	3.57	1.129975	79.822174%

SUM: 1.415815 100.000000%

Variance $Var_{[FS]}$ = 1.415815

Standard of Deviation σ_{FS} = 1.189796

Coefficient of Variation COV_{FS} = 0.494052

Reliability Index β_{FS} = 1.646990

Probability of Failure P_f = **4.98%**

Notes:

1. The average pile diameters were not changed with the varying stratigraphy. This simplification is not exactly correct, however variations in pile diameter would be very minor.

South Topeka Axial Pile Capacity Reliability Analysis - November 2007
Reference: Corps of Engineers EM 1110-2-2906 dated 15 January 1991

Analysis: **Water 4 Feet below the top of the wall** Elevation: 888.00
Maximum Axial Load on Pile: **12 kips**

Top of Pile Below Ground Surface: 7.5 feet
Friction between soil and timber pile (δ): 0.9

Bearing Capacity Factor in Sand (Nq): 40

Neglect skin friction on upper part of pile: 5 feet
Neglect skin friction on lower part of pile: 1 feet
Earth Pressure Coefficients
CL-ML: 1.0
Organics: 1.0
Sand: 1.5
Expected Length of Pile: 25 feet
Average Diameter of Pile
CL-ML: 0.95 feet (11.5 inches)
Organics: 0.875 feet (10.5 inches)
Sand: 0.8 feet (9.5 inches)
Pile Tip: 0.75 feet (9 inches)

	CL-ML Blanket Material Shaft Capacity							Organic Blanket Material Shaft Capacity						Aquifer Shaft Capacity						Aquifer Tip Capacity				Total Capacity			
Analysis	Coefficient of Variance (%)	Effective Unit Weight (pcf)	Thickness of Layer (ft)	Length of Pile in Layer (ft)	φ' (deg)	Average Effective Vertical Stress (psf)	Pile Surface Area (sq ft)	Ultimate Shaft Capacity (kips)	Effective Unit Weight (pcf)	Thickness of Layer (ft)	φ' (deg)	Average Effective Vertical Stress (psf)	Pile Surface Area (sq ft)	Ultimate Shaft Capacity (kips)	Effective Unit Weight (pcf)	Length of Pile in Sand (ft)	φ' (deg)	Average Effective Vertical Stress (psf)	Pile Surface Area (sq ft)	Ultimate Shaft Capacity (kips)	Effective Vertical Stress at Tip (psf)	Area of Pile Tip (psf)	Ultimate Tip Capacity (kips)	Total Ultimate Pile Capacity (kips)	Factor of Safety	Variance Component	Percent of Variance
Expected Value	N/A	30.4	15	7.5	24	418	7.46	**1.23**	20.4	10	17	558.00	27.49	**4.20**	52.6	7.5	33	830.95	16.34	**11.61**	1054.5	0.44	**18.63**	**35.68**	2.97		
Lower COV Strength CL-ML	30%	30.4	15	7.5	**16.8**	418	7.46	**0.84**	20.4	10	17	558.00	27.49	**4.20**	52.6	7.5	33	830.95	16.34	**11.61**	1054.5	0.44	**18.63**	**35.29**	2.94		
Upper COV Strength CL-ML	30%	30.4	15	7.5	**31.2**	418	7.46	**1.66**	20.4	10	17	558.00	27.49	**4.20**	52.6	7.5	33	830.95	16.34	**11.61**	1054.5	0.44	**18.63**	**36.11**	3.01	0.001171	0.057245%
Lower COV Strength Organics	30%	30.4	15	7.5	24	418	7.46	**1.23**	20.4	10	**11.9**	558.00	27.49	**2.90**	52.6	7.5	33	830.95	16.34	**11.61**	1054.5	0.44	**18.63**	**34.38**	2.87		
Upper COV Strength Organics	30%	30.4	15	7.5	24	418	7.46	**1.23**	20.4	10	**22.1**	558.00	27.49	**5.55**	52.6	7.5	33	830.95	16.34	**11.61**	1054.5	0.44	**18.63**	**37.03**	3.09	0.012178	0.595422%
Lower COV Strength Sand	15%	30.4	15	7.5	24	418	7.46	**1.23**	20.4	10	17	558.00	27.49	**4.20**	52.6	7.5	**28.05**	830.95	16.34	**9.60**	1054.5	0.44	**18.63**	**33.67**	2.81		
Upper COV Strength Sand	15%	30.4	15	7.5	24	418	7.46	**1.23**	20.4	10	17	558.00	27.49	**4.20**	52.6	7.5	**37.95**	830.95	16.34	**13.81**	1054.5	0.44	**18.63**	**37.88**	3.16	0.030822	1.506988%
Lower COV Blanket Thickness CL-ML	25%	30.4	**11.25**	3.75	24	0	0.00	**0.00**	20.4	10	17	456.75	24.05	**3.01**	52.6	11.25	33	815.575	25.76	**17.98**	1137.75	0.44	**20.11**	**41.09**	3.42		
Upper COV Blanket Thickness CL-ML	25%	30.4	**18.75**	11.25	24	475	18.65	**3.51**	20.4	10	17	672.00	27.49	**5.05**	52.6	3.75	33	846.325	6.91	**5.00**	971.25	0.44	**17.16**	**30.73**	2.56	0.186245	9.106275%
Lower COV Blanket Thickness Organic	25%	30.4	15	7.5	24	418	7.46	**1.23**	20.4	**7.5**	17	532.50	20.62	**3.00**	52.6	10	33	845.7	22.62	**16.37**	1135	0.44	**20.06**	**40.66**	3.39		
Upper COV Blanket Thickness Organic	25%	30.4	15	7.5	24	418	7.46	**1.23**	20.4	**12.5**	17	583.50	34.36	**5.48**	52.6	5	33	816.2	10.05	**7.02**	974	0.44	**17.21**	**30.95**	2.58	0.163682	8.003062%
Lower COV Pile Length	20%	30.4	15	7.5	24	418	7.46	**1.23**	20.4	10	17	558.00	27.49	**4.20**	52.6	**2.5**	33	699.45	3.77	**2.26**	791.5	0.44	**13.99**	**21.67**	1.81		
Upper COV Pile Length	20%	30.4	15	7.5	24	418	7.46	**1.23**	20.4	10	17	558.00	27.49	**4.20**	52.6	**12.5**	33	962.45	28.90	**23.80**	1317.5	0.44	**23.28**	**52.51**	4.38	1.851143	80.731008%

SUM: 2.045241 100.000000%

Variance $Var_{[FS]}$ = 2.045241

Standard of Deviation σ_{FS} = 1.430119

Coefficient of Variation COV_{FS} = 0.480984

Reliability Index β_{FS} = 2.160571

Probability of Failure P_f = **1.54%**

Notes:

1. The average pile diameters were not changed with the varying stratigraphy. This simplification is not exactly correct, however variations in pile diameter would be very minor.

South Topeka Axial Pile Capacity Reliability Analysis - November 2007
Reference: Corps of Engineers EM 1110-2-2906 dated 15 January 1991

Analysis: **Water 5 Feet below the top of the wall** Elevation: 887.00
Maximum Axial Load on Pile: **10 kips**

Top of Pile Below Ground Surface: 7.5 feet
Friction between soil and timber pile (δ): 0.9

Bearing Capacity Factor in Sand (Nq): 40

Neglect skin friction on upper part of pile: 5 feet
Neglect skin friction on lower part of pile: 1 feet
Earth Pressure Coefficients
CL-ML: 1.0
Organics: 1.0
Sand: 1.5
Expected Length of Pile: 25 feet
Average Diameter of Pile
CL-ML: 0.95 feet (11.5 inches)
Organics: 0.875 feet (10.5 inches)
Sand: 0.8 feet (9.5 inches)
Pile Tip: 0.75 feet (9 inches)

	CL-ML Blanket Material Shaft Capacity								Organic Blanket Material Shaft Capacity						Aquifer Shaft Capacity						Aquifer Tip Capacity			Total Capacity			
Analysis	Coefficient of Variance (%)	Effective Unit Weight (pcf)	Thickness of Layer (ft)	Length of Pile in Layer (ft)	φ' (deg)	Average Effective Vertical Stress (psf)	Pile Surface Area (sq ft)	Ultimate Shaft Capacity (kips)	Effective Unit Weight (pcf)	Thickness of Layer (ft)	φ' (deg)	Average Effective Vertical Stress (psf)	Pile Surface Area (sq ft)	Ultimate Shaft Capacity (kips)	Effective Unit Weight (pcf)	Length of Pile in Sand (ft)	φ' (deg)	Average Effective Vertical Stress (psf)	Pile Surface Area (sq ft)	Ultimate Shaft Capacity (kips)	Effective Vertical Stress at Tip (psf)	Area of Pile Tip (psf)	Ultimate Tip Capacity (kips)	Total Ultimate Pile Capacity (kips)	Factor of Safety	Variance Component	Percent of Variance
Expected Value	N/A	32.6	15	7.5	24	448.25	7.46	**1.32**	22.6	10	17	602.00	27.49	**4.53**	52.6	7.5	33	885.95	16.34	**12.38**	1109.5	0.44	**19.61**	**37.84**	3.78		
Lower COV Strength CL-ML	30%	32.6	15	7.5	**16.8**	448.25	7.46	**0.90**	22.6	10	17	602.00	27.49	**4.53**	52.6	7.5	33	885.95	16.34	**12.38**	1109.5	0.44	**19.61**	**37.42**	3.74		
Upper COV Strength CL-ML	30%	32.6	15	7.5	**31.2**	448.25	7.46	**1.78**	22.6	10	17	602.00	27.49	**4.53**	52.6	7.5	33	885.95	16.34	**12.38**	1109.5	0.44	**19.61**	**38.30**	3.83	0.001939	0.061744%
Lower COV Strength Organics	30%	32.6	15	7.5	24	448.25	7.46	**1.32**	22.6	10	**11.9**	602.00	27.49	**3.13**	52.6	7.5	33	885.95	16.34	**12.38**	1109.5	0.44	**19.61**	**36.44**	3.64		
Upper COV Strength Organics	30%	32.6	15	7.5	24	448.25	7.46	**1.32**	22.6	10	**22.1**	602.00	27.49	**5.99**	52.6	7.5	33	885.95	16.34	**12.38**	1109.5	0.44	**19.61**	**39.30**	3.93	0.020411	0.650015%
Lower COV Strength Sand	15%	32.6	15	7.5	24	448.25	7.46	**1.32**	22.6	10	17	602.00	27.49	**4.53**	52.6	7.5	**28.05**	885.95	16.34	**10.24**	1109.5	0.44	**19.61**	**35.69**	3.57		
Upper COV Strength Sand	15%	32.6	15	7.5	24	448.25	7.46	**1.32**	22.6	10	17	602.00	27.49	**4.53**	52.6	7.5	**37.95**	885.95	16.34	**14.73**	1109.5	0.44	**19.61**	**40.10**	4.02	0.050453	1.606763%
Lower COV Blanket Thickness CL-ML	25%	32.6	**11.25**	3.75	24	0	0.00	**0.00**	22.6	10	17	493.88	24.05	**3.25**	52.6	11.25	33	862.325	25.76	**19.01**	1184.5	0.44	**20.93**	**43.19**	4.32		
Upper COV Blanket Thickness CL-ML	25%	32.6	**18.75**	11.25	24	509.375	18.65	**3.76**	22.6	10	17	724.25	27.49	**5.45**	52.6	3.75	33	909.575	6.91	**5.38**	1034.5	0.44	**18.28**	**32.87**	3.29	0.266244	8.479041%
Lower COV Blanket Thickness Organic	25%	32.6	15	7.5	24	448.25	7.46	**1.32**	22.6	**7.5**	17	573.75	20.62	**3.24**	52.6	10	33	895.2	22.62	**17.32**	1184.5	0.44	**20.93**	**42.82**	4.28		
Upper COV Blanket Thickness Organic	25%	32.6	15	7.5	24	448.25	7.46	**1.32**	22.6	**12.5**	17	630.25	34.36	**5.92**	52.6	5	33	876.7	10.05	**7.54**	1034.5	0.44	**18.28**	**33.07**	3.31	0.237472	7.562753%
Lower COV Pile Length	20%	32.6	15	7.5	24	448.25	7.46	**1.32**	22.6	10	17	602.00	27.49	**4.53**	52.6	**2.5**	33	754.45	3.77	**2.43**	846.5	0.44	**14.98**	**23.24**	2.32		
Upper COV Pile Length	20%	32.6	15	7.5	24	448.25	7.46	**1.32**	22.6	10	17	602.00	27.49	**4.53**	52.6	**12.5**	33	1017.45	28.90	**25.16**	1372.5	0.44	**24.25**	**55.27**	5.53	2.583507	81.639683%

SUM 3.140026 100.000000%

Variance Var[$_{FS}$] = 3.140026

Standard of Deviation σ_{FS} = 1.772012

Coefficient of Variation COV_{FS} = 0.468281

Reliability Index β_{FS} = 2.766110

Probability of Failure P_f = **0.28%**

Notes:

1. The average pile diameters were not changed with the varying stratigraphy. This simplification is not exactly correct, however variations in pile diameter would be very minor.

South Topeka Axial Pile Capacity Reliability Analysis - November 2007
Reference: Corps of Engineers EM 1110-2-2906 dated 15 January 1991

Analysis: **Water 6 Feet below the top of the wall** Elevation: 886.00
Maximum Axial Load on Pile: **9 kips**

Top of Pile Below Ground Surface: 7.5 feet
Friction between soil and timber pile (δ): 0.9

Bearing Capacity Factor in Sand (Nq): 40

Neglect skin friction on upper part of pile: 5 feet
Neglect skin friction on lower part of pile: 1 feet
Earth Pressure Coefficients
CL-ML: 1.0
Organics: 1.0
Sand: 1.5

Expected Length of Pile: 25 feet
Average Diameter of Pile
CL-ML: 0.95 feet (11.5 inches)
Organics: 0.875 feet (10.5 inches)
Sand: 0.8 feet (9.5 inches)
Pile Tip: 0.75 feet (9 inches)

	CL-ML Blanket Material Shaft Capacity							Organic Blanket Material Shaft Capacity						Aquifer Shaft Capacity						Aquifer Tip Capacity				Total Capacity			
Analysis	Coefficient of Variance (%)	Effective Unit Weight (pcf)	Thickness of Layer (ft)	Length of Pile in Layer (ft)	ϕ' (deg)	Average Effective Vertical Stress (psf)	Pile Surface Area (sq ft)	Ultimate Shaft Capacity (kips)	Effective Unit Weight (pcf)	Thickness of Layer (ft)	ϕ' (deg)	Average Effective Vertical Stress (psf)	Pile Surface Area (sq ft)	Ultimate Shaft Capacity (kips)	Effective Unit Weight (pcf)	Length of Pile in Sand (ft)	ϕ' (deg)	Average Effective Vertical Stress (psf)	Pile Surface Area (sq ft)	Ultimate Shaft Capacity (kips)	Effective Vertical Stress at Tip (psf)	Area of Pile Tip (psf)	Ultimate Tip Capacity (kips)	Total Ultimate Pile Capacity (kips)	Factor of Safety	Variance Component	Percent of Variance
Expected Value	N/A	34.6	15	7.5	24	475.75	7.46	1.41	24.6	10	17	642.00	27.49	4.83	52.6	7.5	33	935.95	16.34	13.08	1159.5	0.44	20.49	39.81	4.42		
Lower COV Strength CL-ML	30%	34.6	15	7.5	16.8	475.75	7.46	0.96	24.6	10	17	642.00	27.49	4.83	52.6	7.5	33	935.95	16.34	13.08	1159.5	0.44	20.49	39.36	4.37		
Upper COV Strength CL-ML	30%	34.6	15	7.5	31.2	475.75	7.46	1.89	24.6	10	17	642.00	27.49	4.83	52.6	7.5	33	935.95	16.34	13.08	1159.5	0.44	20.49	40.29	4.48	0.002696	0.065707%
Lower COV Strength Organics	30%	34.6	15	7.5	24	475.75	7.46	1.41	24.6	10	11.9	642.00	27.49	3.34	52.6	7.5	33	935.95	16.34	13.08	1159.5	0.44	20.49	38.32	4.26		
Upper COV Strength Organics	30%	34.6	15	7.5	24	475.75	7.46	1.41	24.6	10	22.1	642.00	27.49	6.38	52.6	7.5	33	935.95	16.34	13.08	1159.5	0.44	20.49	41.36	4.60	0.028658	0.698389%
Lower COV Strength Sand	15%	34.6	15	7.5	24	475.75	7.46	1.41	24.6	10	17	642.00	27.49	4.83	52.6	7.5	28.05	935.95	16.34	10.81	1159.5	0.44	20.49	37.54	4.17		
Upper COV Strength Sand	15%	34.6	15	7.5	24	475.75	7.46	1.41	24.6	10	17	642.00	27.49	4.83	52.6	7.5	37.95	935.95	16.34	15.56	1159.5	0.44	20.49	42.28	4.70	0.069516	1.694087%
Lower COV Blanket Thickness CL-ML	25%	34.6	11.25	3.75	24	0	0.00	0.00	24.6	10	17	527.63	24.05	3.47	52.6	11.25	33	904.825	25.76	19.94	1227	0.44	21.68	45.10	5.01		
Upper COV Blanket Thickness CL-ML	25%	34.6	18.75	11.25	24	540.625	18.65	3.99	24.6	10	17	771.75	27.49	5.80	52.6	3.75	33	967.075	6.91	5.72	1092	0.44	19.30	34.81	3.87	0.326516	7.957080%
Lower COV Blanket Thickness Organic	25%	34.6	15	7.5	24	475.75	7.46	1.41	24.6	7.5	17	611.25	20.62	3.45	52.6	10	33	940.2	22.62	18.20	1229.5	0.44	21.73	44.78	4.98		
Upper COV Blanket Thickness Organic	25%	34.6	15	7.5	24	475.75	7.46	1.41	24.6	12.5	17	672.75	34.36	6.32	52.6	5	33	931.7	10.05	8.01	1089.5	0.44	19.25	35.00	3.89	0.295170	7.193179%
Lower COV Pile Length	20%	34.6	15	7.5	24	475.75	7.46	1.41	24.6	10	17	642.00	27.49	4.83	52.6	2.5	33	804.45	3.77	2.59	896.5	0.44	15.84	24.67	2.74		
Upper COV Pile Length	20%	34.6	15	7.5	24	475.75	7.46	1.41	24.6	10	17	642.00	27.49	4.83	52.6	12.5	33	1087.45	28.90	26.40	1422.5	0.44	25.14	57.77	6.42	3.380914	82.391559%

SUM: 4.103472 100.000000%

Variance $Var_{[FS]}$ = 4.103472

Standard of Deviation σ_{FS} = 2.025703

Coefficient of Variation COV_{FS} = 0.458013

Reliability Index β_{FS} = 3.188800

Probability of Failure P_f = **0.07%**

Notes:

1. The average pile diameters were not changed with the varying stratigraphy. This simplification is not exactly correct, however variations in pile diameter would be very minor.

South Topeka Axial Pile Capacity Reliability Analysis - November 2007
Reference: Corps of Engineers EM 1110-2-2906 dated 15 January 1991

Analysis:	**Water 7 Feet below the top of the wall**	Elevation:	885.00
Maximum Axial Load on Pile:	**8 kips**		
Top of Pile Below Ground Surface:		7.5 feet	
Friction between soil and timber pile (δ):		0.9	
Neglect skin friction on upper part of pile:		5 feet	
Neglect skin friction on lower part of pile		1 feet	
Earth Pressure Coefficients			
	CL-ML:	1.0	
	Organics:	1.0	
	Sand:	1.5	
Expected Length of Pile		25 feet	
Average Diameter of Pile			
	CL-ML:	0.95 feet	(11.5 inches)
	Organics:	0.875 feet	(10.5 inches)
	Sand:	0.8 feet	(9.5 inches)
	Pile Tip:	0.75 feet	(9 inches)

Bearing Capacity Factor in Sand (Nq): 40

Analysis	CL-ML Blanket Material Shaft Capacity: Coefficient of Variance (%)	Effective Unit Weight (pcf)	Thickness of Layer (ft)	Length of Pile in Layer (ft)	φ' (deg)	Average Effective Vertical Stress (psf)	Pile Surface Area (sq ft)
Expected Value	N/A	36.9	15	7.5	24	507.375	7.46
Lower COV Strength CL-ML	30%	36.9	15	7.5	**16.8**	507.375	7.46
Upper COV Strength CL-ML	30%	36.9	15	7.5	**31.2**	507.375	7.46
Lower COV Strength Organics	30%	36.9	15	7.5	24	507.375	7.46
Upper COV Strength Organics	30%	36.9	15	7.5	24	507.375	7.46
Lower COV Strength Sand	15%	36.9	15	7.5	24	507.375	7.46
Upper COV Strength Sand	15%	36.9	15	7.5	24	507.375	7.46
Lower COV Blanket Thickness CL-ML	25%	36.9	**11.25**	3.75	24	0	0.00
Upper COV Blanket Thickness CL-ML	25%	36.9	**18.75**	11.25	24	576.5625	16.65
Lower COV Blanket Thickness Organic	25%	36.9	15	7.5	24	507.375	7.46
Upper COV Blanket Thickness Organic	25%	36.9	15	7.5	24	507.375	7.46
Lower COV Pile Length	20%	36.9	15	7.5	24	507.375	7.46
Upper COV Pile Length	20%	36.9	15	7.5	24	507.375	7.46

Analysis	CL-ML: Ultimate Shaft Capacity (kips)	Organic Blanket Material Shaft Capacity: Effective Unit Weight (pcf)	Thickness of Layer (ft)	φ' (deg)	Average Effective Vertical Stress (psf)	Pile Surface Area (sq ft)	Ultimate Shaft Capacity (kips)
Expected Value	**1.50**	26.9	10	17	688.00	27.49	**5.17**
Lower COV Strength CL-ML	**1.02**	26.9	10	17	688.00	27.49	**5.17**
Upper COV Strength CL-ML	**2.02**	26.9	10	17	688.00	27.49	**5.17**
Lower COV Strength Organics	**1.50**	26.9	10	**11.9**	688.00	27.49	**3.58**
Upper COV Strength Organics	**1.50**	26.9	10	**22.1**	688.00	27.49	**6.84**
Lower COV Strength Sand	**1.50**	26.9	10	17	688.00	27.49	**5.17**
Upper COV Strength Sand	**1.50**	26.9	10	17	688.00	27.49	**5.17**
Lower COV Blanket Thickness CL-ML	**0.00**	26.9	10	17	566.44	24.05	**3.73**
Upper COV Blanket Thickness CL-ML	**4.26**	26.9	10	17	826.38	27.49	**6.21**
Lower COV Blanket Thickness Organic	**1.50**	26.9	**7.5**	17	654.38	20.62	**3.69**
Upper COV Blanket Thickness Organic	**1.50**	26.9	**12.5**	17	721.63	34.36	**6.78**
Lower COV Pile Length	**1.50**	26.9	10	17	688.00	27.49	**5.17**
Upper COV Pile Length	**1.50**	26.9	10	17	688.00	27.49	**5.17**

Analysis	Aquifer Shaft Capacity: Effective Unit Weight (pcf)	Length of Pile in Sand (ft)	φ' (deg)	Average Effective Vertical Stress (psf)	Pile Surface Area (sq ft)	Ultimate Shaft Capacity (kips)
Expected Value	52.6	7.5	33	993.45	16.34	**13.89**
Lower COV Strength CL-ML	52.6	7.5	33	993.45	16.34	**13.89**
Upper COV Strength CL-ML	52.6	7.5	33	993.45	16.34	**13.89**
Lower COV Strength Organics	52.6	7.5	33	993.45	16.34	**13.89**
Upper COV Strength Organics	52.6	7.5	33	993.45	16.34	**13.89**
Lower COV Strength Sand	52.6	7.5	**28.05**	993.45	16.34	**11.48**
Upper COV Strength Sand	52.5	7.5	**37.95**	993.45	16.34	**16.52**
Lower COV Blanket Thickness CL-ML	52.6	**11.25**	33	953.7	25.76	**21.02**
Upper COV Blanket Thickness CL-ML	52.6	3.75	33	1033.2	6.91	**6.11**
Lower COV Blanket Thickness Organic	52.6	10	33	991.95	22.62	**19.20**
Upper COV Blanket Thickness Organic	52.6	5	33	984.95	10.05	**8.56**
Lower COV Pile Length	52.6	**2.5**	33	861.95	3.77	**2.78**
Upper COV Pile Length	52.6	**12.5**	33	1124.95	28.90	**27.82**

Analysis	Aquifer Tip Capacity: Effective Vertical Stress at Tip (psf)	Area of Pile Tip (psf)	Ultimate Tip Capacity (kips)	Total Capacity: Total Ultimate Pile Capacity (kips)	Factor of Safety	Variance Component	Percent of Variance
Expected Value	1217	0.44	**21.51**	**42.06**	5.26		
Lower COV Strength CL-ML	1217	0.44	**21.51**	**41.59**	5.20		
Upper COV Strength CL-ML	1217	0.44	**21.51**	**42.59**	5.32	0.003881	0.070110%
Lower COV Strength Organics	1217	0.44	**21.51**	**40.47**	5.06		
Upper COV Strength Organics	1217	0.44	**21.51**	**43.73**	5.47	0.041654	0.752443%
Lower COV Strength Sand	1217	0.44	**21.51**	**39.66**	4.96		
Upper COV Strength Sand	1217	0.44	**21.51**	**44.70**	5.59	0.099124	1.790573%
Lower COV Blanket Thickness CL-ML	1275.875	0.44	**22.55**	**47.29**	5.91		
Upper COV Blanket Thickness CL-ML	1158.125	0.44	**20.47**	**37.05**	4.63	0.410096	7.407783%
Lower COV Blanket Thickness Organic	1281.25	0.44	**22.64**	**47.03**	5.88		
Upper COV Blanket Thickness Organic	1152.75	0.44	**20.37**	**37.21**	4.65	0.376488	6.800864%
Lower COV Pile Length	954	0.44	**16.86**	**26.31**	3.29		
Upper COV Pile Length	1480	0.44	**26.15**	**60.64**	7.58	4.604647	83.178225%
					SUM:	5.535880	100.000000%

Variance $Var_{[FS]}$ = 5.535880

Standard of Deviation σ_{FS} = 2.352845

Coefficient of Variation COV_{FS} = 0.447475

Reliability Index β_{FS} = 3.671420

Probability of Failure P_f = **0.01%**

Notes:

1. The average pile diameters were not changed with the varying stratigraphy. This simplification is not exactly correct, however variations in pile diameter would be very minor.

South Topeka Axial Pile Capacity Reliability Analysis - November 2007
Reference: Corps of Engineers EM 1110-2-2906 dated 15 January 1991

Analysis: **Water 8 Feet below the top of the wall** Elevation: 884.00
Maximum Axial Load on Pile: **6 kips**

Top of Pile Below Ground Surface: 7.5 feet
Friction between soil and timber pile (δ): 0.9

Bearing Capacity Factor in Sand (Nq): 40

Neglect skin friction on upper part of pile: 5 feet
Neglect skin friction on lower part of pile: 1 feet
Earth Pressure Coefficients
CL-ML: 1.0
Organics: 1.0
Sand: 1.5
Expected Length of Pile: 25 feet
Average Diameter of Pile
CL-ML: 0.95 feet (11.5 inches)
Organics: 0.875 feet (10.5 inches)
Sand: 0.8 feet (9.5 inches)
Pile Tip: 0.75 feet (9 inches)

Analysis	CL-ML Blanket Material Shaft Capacity: Coefficient of Variance (%)	Effective Unit Weight (pcf)	Thickness of Layer (ft)	Length of Pile in Layer (ft)	φ' (deg)	Average Effective Vertical Stress (psf)	Pile Surface Area (sq ft)	Organic Blanket Material Shaft Capacity: Ultimate Shaft Capacity (kips)	Effective Unit Weight (pcf)	Thickness of Layer (ft)	φ' (deg)	Average Effective Vertical Stress (psf)	Pile Surface Area (sq ft)
Expected Value	N/A	38.9	15	7.5	24	534.875	7.46	**1.58**	28.9	10	17	728.00	27.49
Lower COV Strength CL-ML	30%	38.9	15	7.5	**16.8**	534.875	7.46	**1.08**	28.9	10	17	728.00	27.49
Upper COV Strength CL-ML	30%	38.9	15	7.5	**31.2**	534.875	7.46	**2.13**	28.9	10	17	728.00	27.49
Lower COV Strength Organics	30%	38.9	15	7.5	24	534.875	7.46	**1.58**	28.9	10	**11.9**	728.00	27.49
Upper COV Strength Organics	30%	38.9	15	7.5	24	534.875	7.46	**1.58**	28.9	10	**22.1**	728.00	27.49
Lower COV Strength Sand	15%	38.9	15	7.5	24	534.875	7.46	**1.58**	28.9	10	17	728.00	27.49
Upper COV Strength Sand	15%	38.9	15	7.5	24	534.875	7.46	**1.58**	28.9	10	17	728.00	27.49
Lower COV Blanket Thickness CL-ML	25%	38.9	**11.25**	3.75	24	0	0.00	**0.00**	28.9	10	17	600.19	24.05
Upper COV Blanket Thickness CL-ML	25%	38.9	**18.75**	11.25	24	607.8125	18.65	**4.49**	28.9	10	17	873.88	27.49
Lower COV Blanket Thickness Organic	25%	38.9	15	7.5	24	534.875	7.46	**1.58**	28.9	**7.5**	17	691.88	20.62
Upper COV Blanket Thickness Organic	25%	38.9	15	7.5	24	534.875	7.46	**1.58**	28.9	**12.5**	17	784.13	34.36
Lower COV Pile Length	20%	38.9	15	7.5	24	534.875	7.46	**1.58**	28.9	10	17	728.00	27.49
Upper COV Pile Length	20%	38.9	15	7.5	24	534.875	7.46	**1.58**	28.9	10	17	728.00	27.49

Analysis	Aquifer Shaft Capacity: Ultimate Shaft Capacity (kips)	Effective Unit Weight (pcf)	Length of Pile in Sand (ft)	φ' (deg)	Average Effective Vertical Stress (psf)	Pile Surface Area (sq ft)	Aquifer Tip Capacity: Ultimate Shaft Capacity (kips)	Effective Vertical Stress at Tip (psf)	Area of Pile Tip (psf)	Ultimate Tip Capacity (kips)	Total Capacity: Total Ultimate Pile Capacity (kips)	Factor of Safety	Variance Component	Percent of Variance
Expected Value	**5.47**	52.6	7.5	33	1043.45	16.34	**14.58**	1267	0.44	**22.39**	**44.03**	7.34		
Lower COV Strength CL-ML	**5.47**	52.6	7.5	33	1043.45	16.34	**14.58**	1267	0.44	**22.39**	**43.53**	7.25		
Upper COV Strength CL-ML	**5.47**	52.6	7.5	33	1043.45	16.34	**14.58**	1267	0.44	**22.39**	**44.58**	7.43	0.007668	0.073805%
Lower COV Strength Organics	**3.78**	52.6	7.5	33	1043.45	16.34	**14.58**	1267	0.44	**22.39**	**42.34**	7.06		
Upper COV Strength Organics	**7.24**	52.6	7.5	33	1043.45	16.34	**14.58**	1267	0.44	**22.39**	**45.79**	7.63	0.082913	0.798029%
Lower COV Strength Sand	**5.47**	52.6	7.5	**28.05**	1043.45	16.34	**12.00**	1267	0.44	**22.39**	**41.50**	6.92		
Upper COV Strength Sand	**5.47**	52.6	7.5	**37.95**	1043.45	16.34	**17.35**	1267	0.44	**22.39**	**46.79**	7.80	0.194405	1.871123%
Lower COV Blanket Thickness CL-ML	**3.95**	52.6	11.25	33	996.2	25.76	**21.96**	1318.375	0.44	**23.30**	**49.20**	8.20		
Upper COV Blanket Thickness CL-ML	**6.57**	52.6	3.75	33	1090.7	6.91	**6.45**	1215.625	0.44	**21.48**	**38.99**	6.50	0.724172	6.970063%
Lower COV Blanket Thickness Organic	**3.90**	52.6	10	33	1036.95	22.62	**20.07**	1326.25	0.44	**23.44**	**48.99**	8.16		
Upper COV Blanket Thickness Organic	**7.10**	52.6	5	33	1049.95	10.05	**9.03**	1207.75	0.44	**21.34**	**39.14**	6.52	0.673831	6.485537%
Lower COV Pile Length	**5.47**	52.6	**2.5**	33	911.95	3.77	**2.94**	1004	0.44	**17.74**	**27.74**	4.62		
Upper COV Pile Length	**5.47**	52.6	**12.5**	33	1174.95	28.90	**29.05**	1530	0.44	**27.04**	**63.15**	10.52	8.705761	83.801442%

SUM: 10.389751 100.000000%

Variance $Var[_{FS}]$ = 10.389751

Standard of Deviation σ_{FS} = 3.223314

Coefficient of Variation COV_{FS} = 0.439255

Reliability Index β_{FS} = 4.535094

Probability of Failure P_f = **0.00%**

Notes:

1. The average pile diameters were not changed with the varying stratigraphy. This simplification is not exactly correct, however variations in pile diameter would be very minor.

Exhibit 11

Probability of Failure Curve for the Axial Capacity of a Single Pile

Summary

Elevation of Water Surface	Probability of Failure	
892.00	44.67%	Top of Wall
891.00	28.80%	
890.00	14.41%	
889.00	4.98%	
888.00	1.54%	
887.00	0.28%	
886.00	0.07%	
885.00	0.01%	
884.00	0.00%	

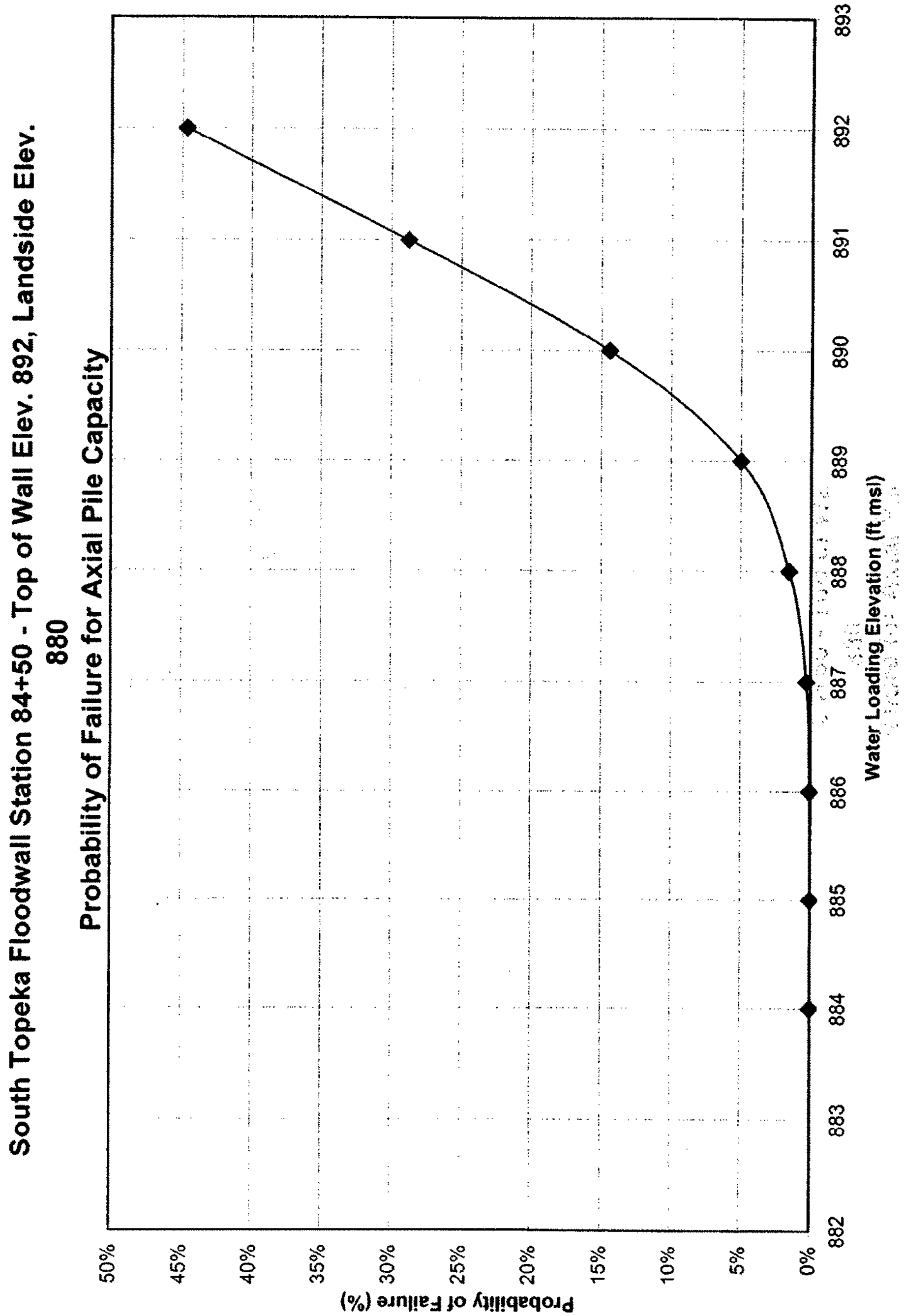

South Topeka Floodwall Station 84+50 - Top of Wall Elev. 892, Landside Elev. 880
Probability of Failure for Axial Pile Capacity
Probability of Failure (%)
0%
5%
10%
15%
20%
25%
30%
35%
40%
45%
50%
882
883
884
885
886
887
888
889
890
891
892
893
Water Loading Elevation (ft msl)

Exhibit 12

Review of Topeka Feasibility Study
Subsurface Investigation and Soils Test Data

6 Nov 2007
RSK 1/5

SOUTH TOPEKA - DRILLING AND SAMPLING

DU-89 ; STA 64+00 ℄ CREST OF LEVEE

LEVEE HEIGHT APPROX 9'

9.5' BLANKS

3.5' SAND

BELOW THAT SAND & SILT LAYERS.

TORVANE

9' ——————— TOP OF GROUND

11' – AVG Su = 0.67 tsf
13.5 – AVG Su = 0.9 tsf
17' – AVG Su = 0.4 tsf

LAB TESTING

ATTERBURG LIMITS: 47 ≤ LL ≤ 22
31 ≤ PI ≤ 5

MOSTLY CLASSIFIED AS CL OR ML TO 30'

ALL Q TESTS FOR TOPEKA FEASIBILITY STUDY, APRIL 2001

- SOLDIER CREEK, STA 190+00 ; 7.5-9.5', CL Su = 910 psf
- OAKLAND, STA 399+00 ; 5.0-7.0', CH (VERY FAT) Su = 540 psf
- OAKLAND ; STA 518+00; 5.0'-7.0' CH Su = 730 psf

6 Nov 2007
RSK 2/5

TOPEKA FEASIBILITY STUDY - CPT DATA OAKLAND UNIT

OAK1CITY THRU OAK7CITY → STA 80+00 TO 95+00
- THESE ARE CLOSEST TO SOUTH TOPEKA UNIT.

- THE APPARENT THICKNESS OF BLANKET CORRELATES PRETTY WELL WITH RECORD DRAWINGS:

5 TO 10' BLANKET, WITH SOME PERCHED SAND LENSES

- PUSHES ARE BETWEEN 15' TO 20'; CANNOT READILY OBTAIN PILE CAPACITY FOR A 25' PILE WITH PILE HEAD 3' TO 5' BELOW GROUND.

HOWEVER; COMPUTING PILE SKIN FRICTION ^FROM CPT TESTS IS^ SIMILAR TO USING UNDRAINED SHEAR STRENGTH FOR UNDRAINED LOADING IN CLAY

a) BASED UPON UNDRAINED SHEAR STRENGTH

$Q_s = f_s A_s$; $f_s = \alpha S_u$ $\quad 1 \leq \alpha \leq 0.5$ DEPENDING UPON S_u; AS S_u DECREASES α INCREASES

b) BASED UPON CPT SLEEVE FRICTION

$Q_s = \alpha' \bar{f}_s A_s$ $\quad \bar{f}_s$ = MEASURED SLEEVE FRICTION

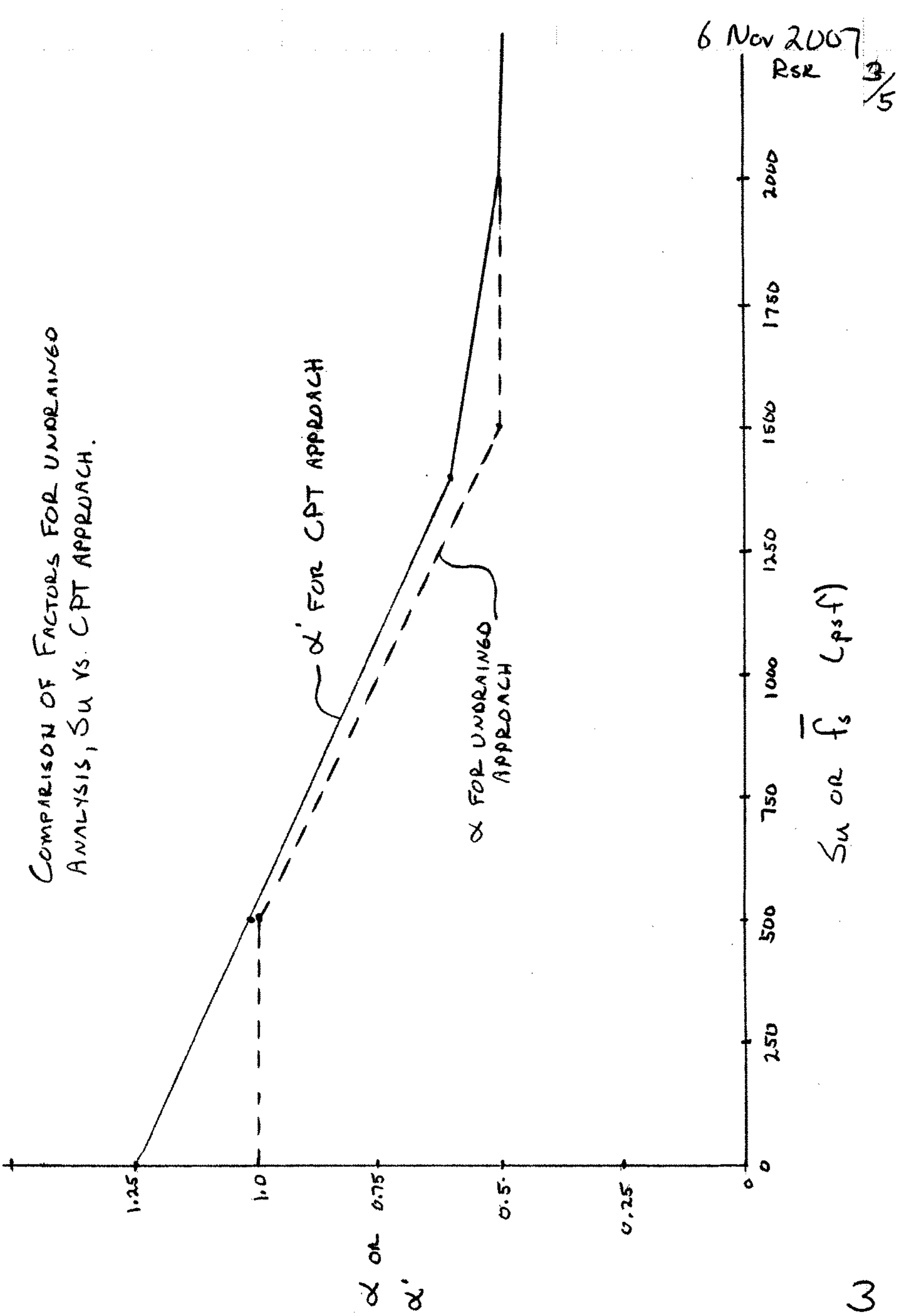
$1.2 \leq \alpha' \leq 0.4$, DEPENDING UPON $\bar{f}_s$; AS $\bar{f}_s$ DECREASES, α' INCREASES

SEE α/α' COMPARISON PLOT PAGE 3

SO:

$$S_u \gtrsim \bar{f}_s$$

COMPARE $\bar{f}_s$ FROM CPT TO EXPECTED VALUE OF S_u USED IN AXIAL CAPACITY CALCULATIONS:


6 Nov 2007
RSR
3/5
COMPARISON OF FACTORS FOR UNDRAINED
ANALYSIS, Su vs. CPT APPROACH.
α' FOR CPT APPROACH
α FOR UNDRAINED
APPROACH
α OR
α'
1.25
1.0
0.75
0.5
0.25
0
0
250
500
750
1000
1250
1500
1750
2000
Su OR $\bar{f}_s$ (psf)
3

6 Nov 2007
RSR 4

EXPECTED VALUE OF S_u = 600psf FOR CL-ML

· IGNORE UPPER 5' OF PILE

	$f_{s\ AVG}$
OAK1 CITY, STA 80+00	700 psf
OAK2CITY; STA 82+00	275 psf
AVG: $\frac{(200psf)(2ft) + 300psf(4ft)}{6ft}$	
OAK3CITY; STA 85+00	600 psf
OAK4 CITY; STA 86+00	300 psf
OAK5 CITY; STA 90+00	500 psf
OAK6 CITY; STA 91+00	730 psf
AVG; $\frac{500psf(2ft) + 800psf(7ft)}{9ft}$	
OAK7CITY; STA 92+00	300 psf
OAK1 HAL; STA 95+00	150 psf
OAK2HAL; STA 96+00	
AVG $\frac{700psf(3ft) + 400psf(6ft)}{9ft}$	500 psf
OAK1ROE; STA 102+00	
AVG $\frac{150psf(4.5ft) + 600psf(3.5ft)}{8ft}$	350 psf
OAK 2ROE; STA 105+00	
AVG = $\frac{260psf(2ft) + 500psf(3ft)}{5ft}$	400 psf
	AVG: 435 psf

4

RSK
6 Nov 2007

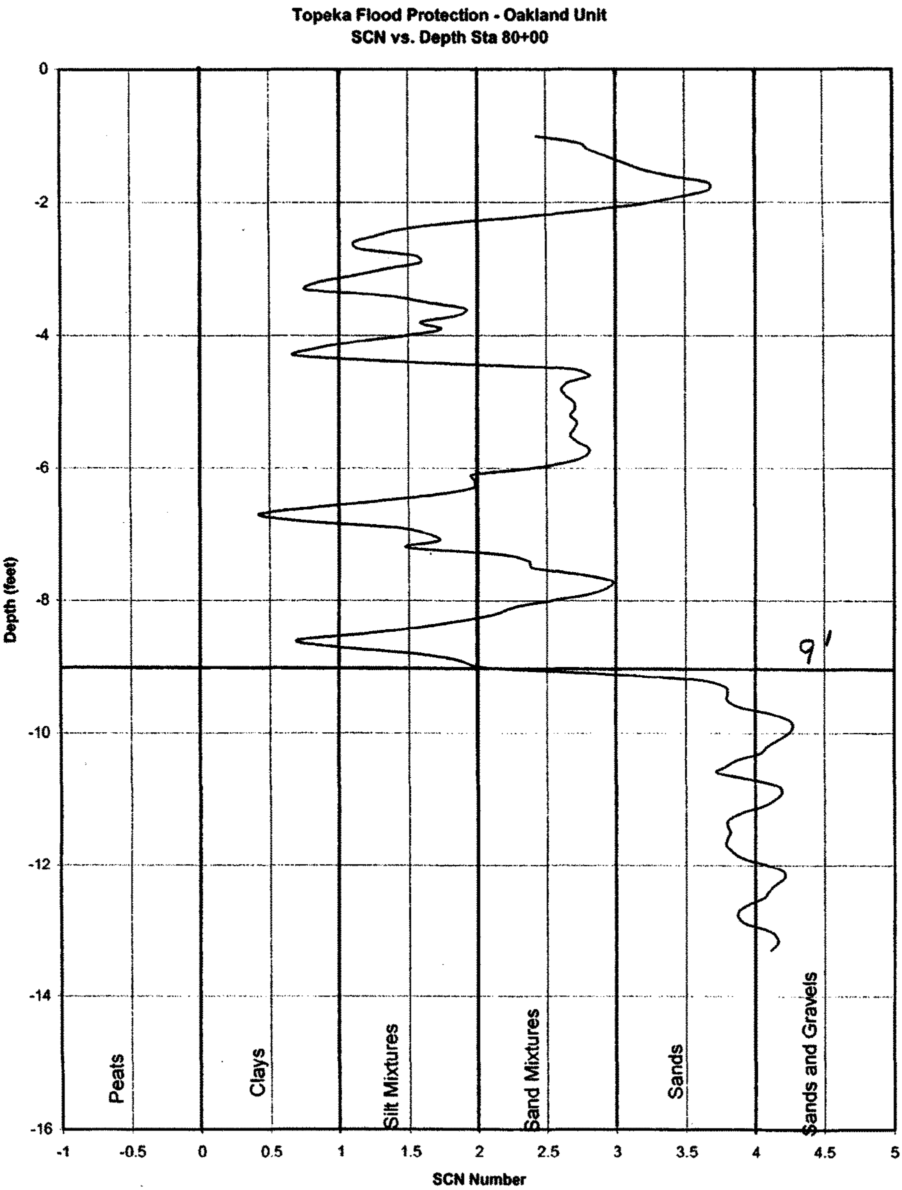
FOR THE BLANKET MATERIALS

Summary

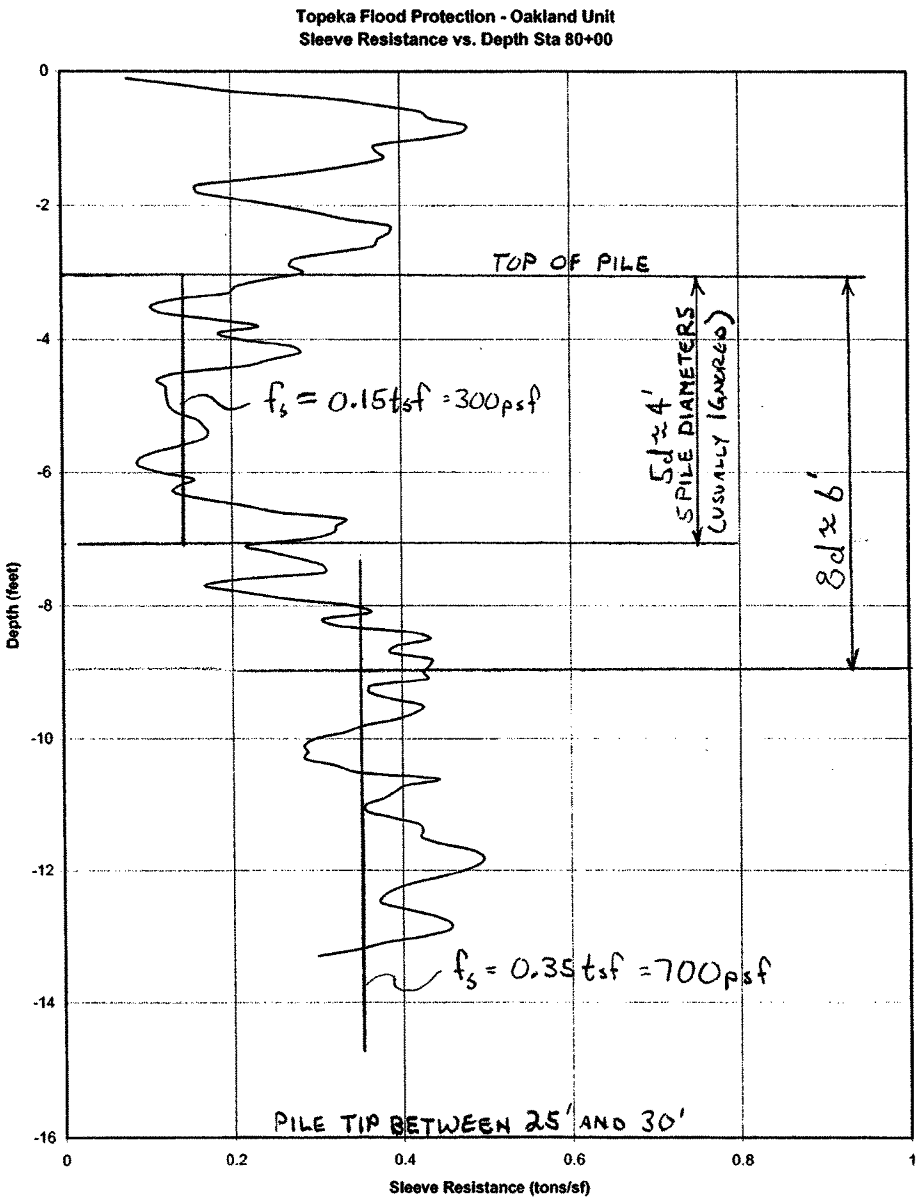
· BASED UPON THE PREVIOUS COMPARISON, IT APPEARS THE UNDRAINED SHEAR STRENGTH USED IN THE CALCULATIONS WAS REASONABLE.

5/5

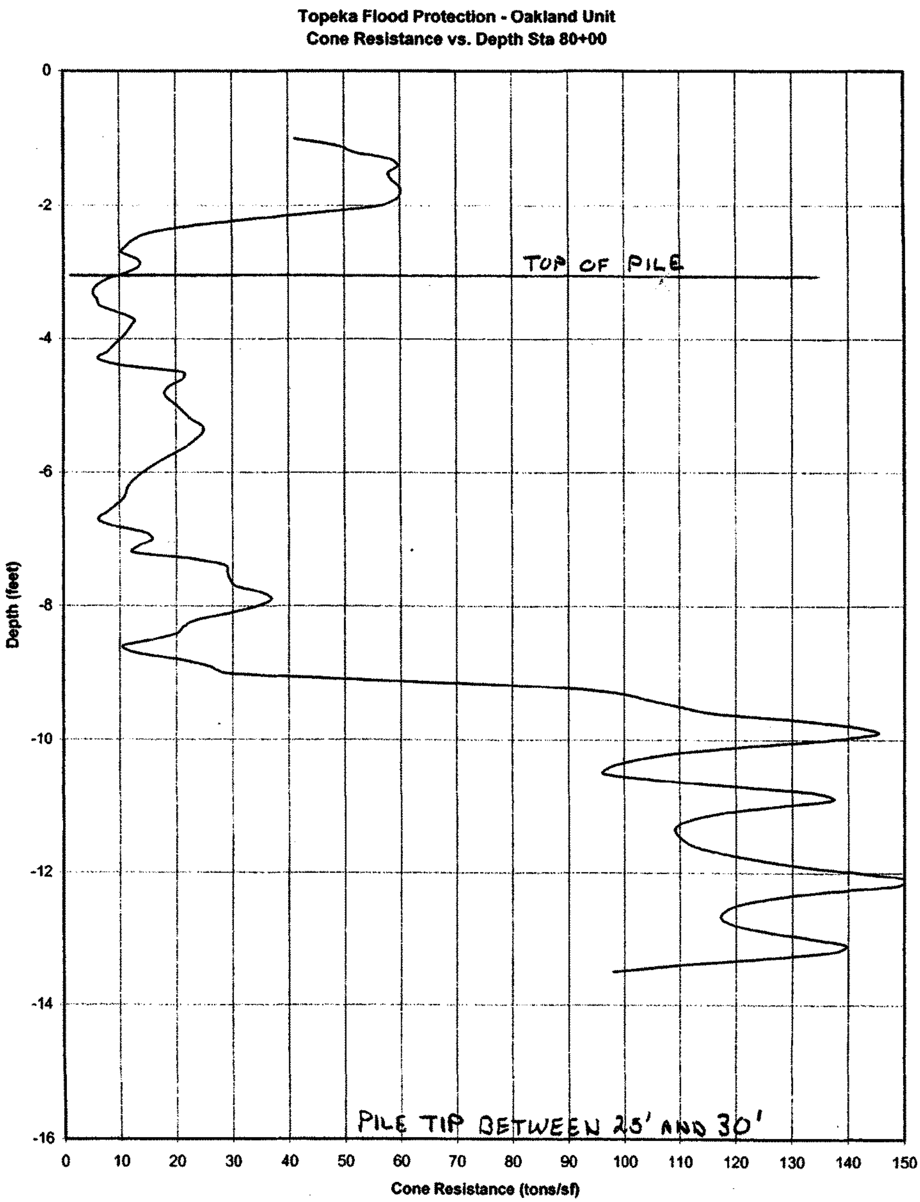
OAK I CITY


Topeka Flood Protection - Oakland Unit
SCN vs. Depth Sta 80+00
Depth (feet)
0
-2
-4
-6
-8
-10
-12
-14
-16
9'
Peats
Clays
Silt Mixtures
Sand Mixtures
Sands
Sands and Gravels
-1
-0.5
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
SCN Number

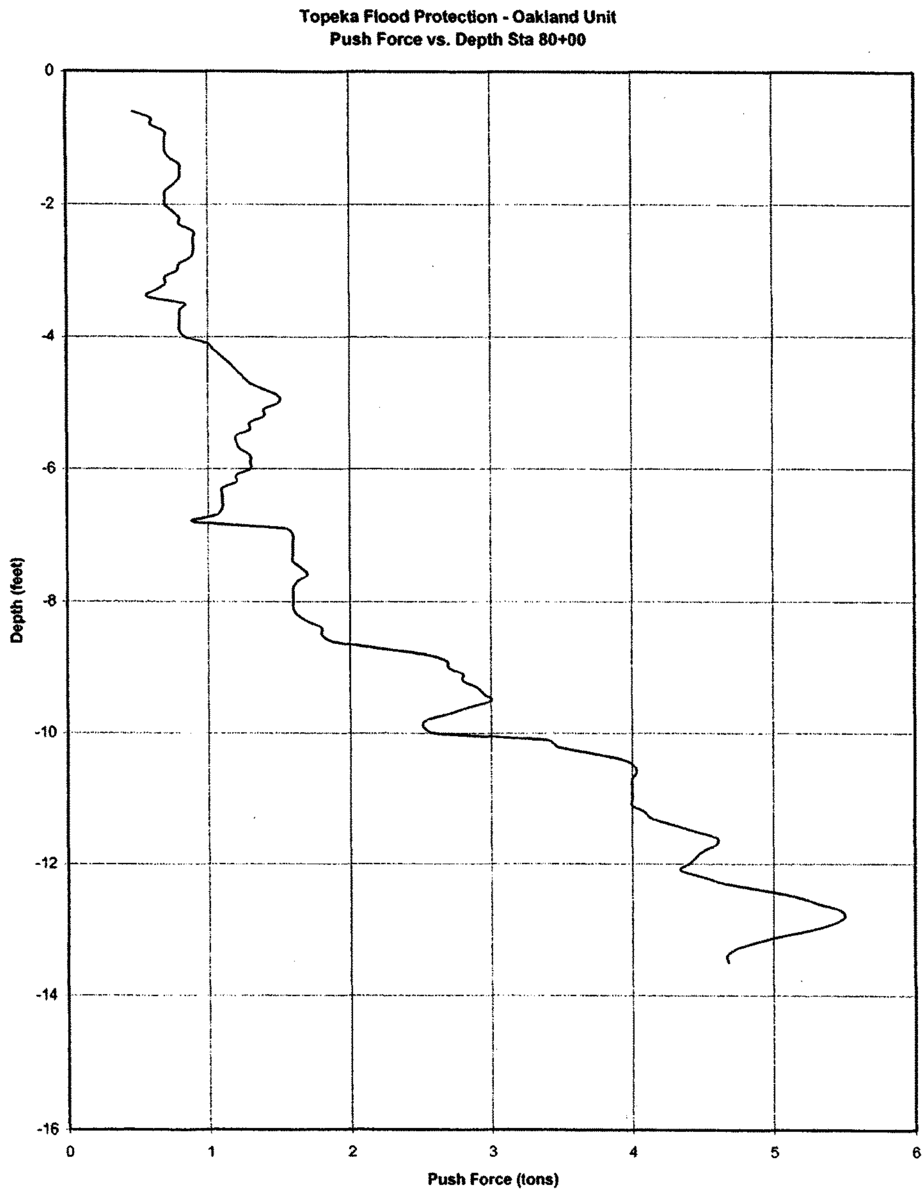
7


Topeka Flood Protection - Oakland Unit
Sleeve Resistance vs. Depth Sta 80+00
Depth (feet)
0
-2
-4
-6
-8
-10
-12
-14
-16
0
0.2
0.4
0.6
0.8
1
Sleeve Resistance (tons/sf)
TOP OF PILE
fs = 0.15tsf = 300psf
5d ≈ 4'
5 PILE DIAMETERS
(USUALLY IGNORED)
8d ≈ 6'
fs = 0.35 tsf = 700psf
PILE TIP BETWEEN 25' AND 30'

8

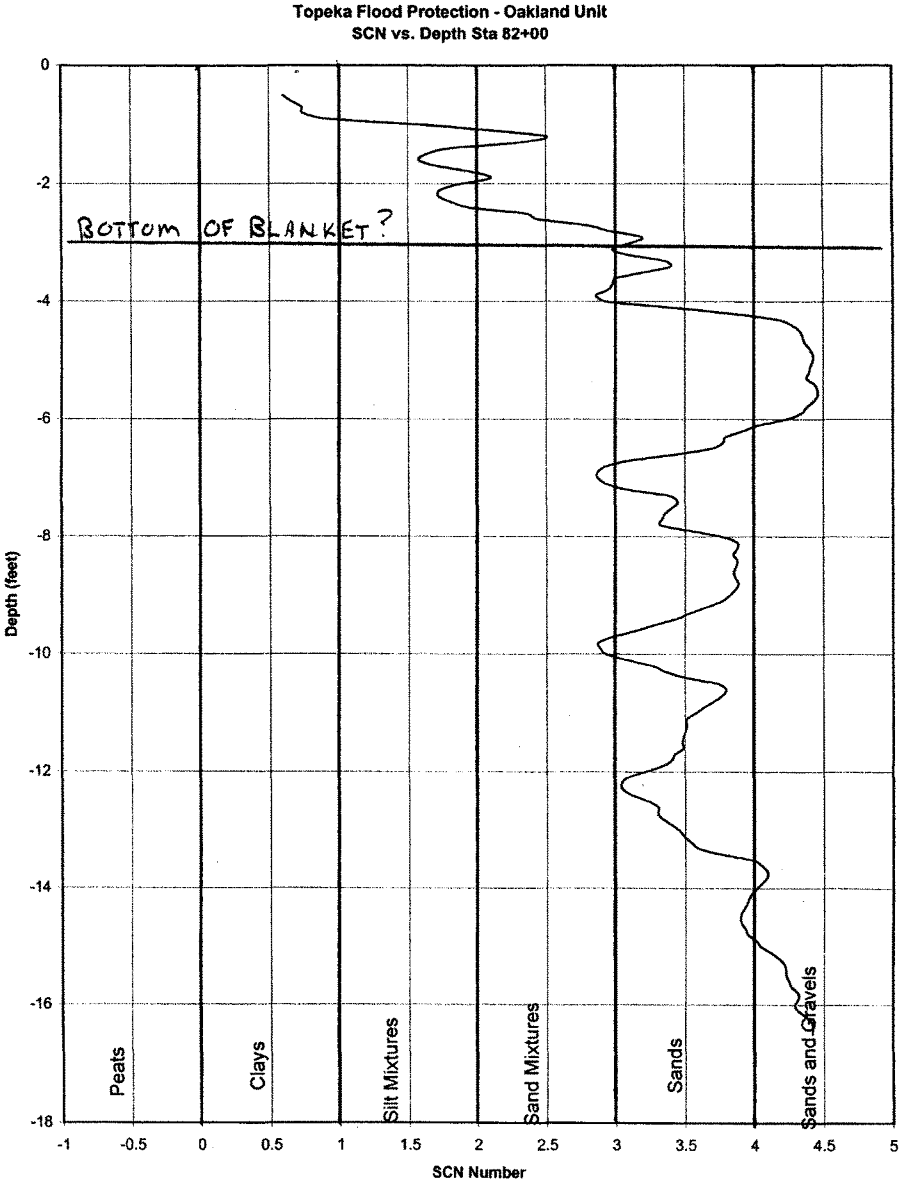

Topeka Flood Protection - Oakland Unit
Cone Resistance vs. Depth Sta 80+00
Depth (feet)
0
-2
-4
-6
-8
-10
-12
-14
-16
TOP OF PILE
PILE TIP BETWEEN 25' AND 30'
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
Cone Resistance (tons/sf)

9

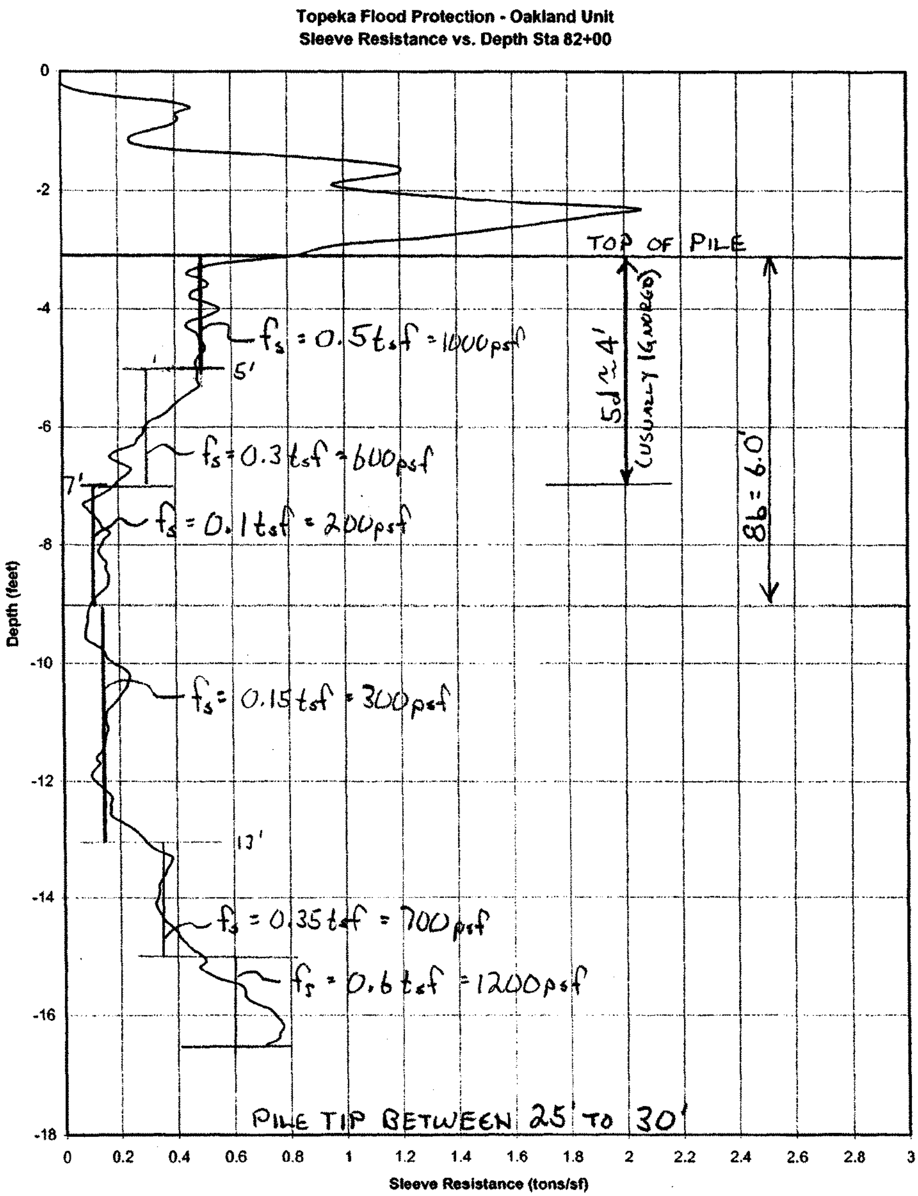

Topeka Flood Protection - Oakland Unit
Push Force vs. Depth Sta 80+00
Depth (feet)
0
-2
-4
-6
-8
-10
-12
-14
-16
0
1
2
3
4
5
6
Push Force (tons)

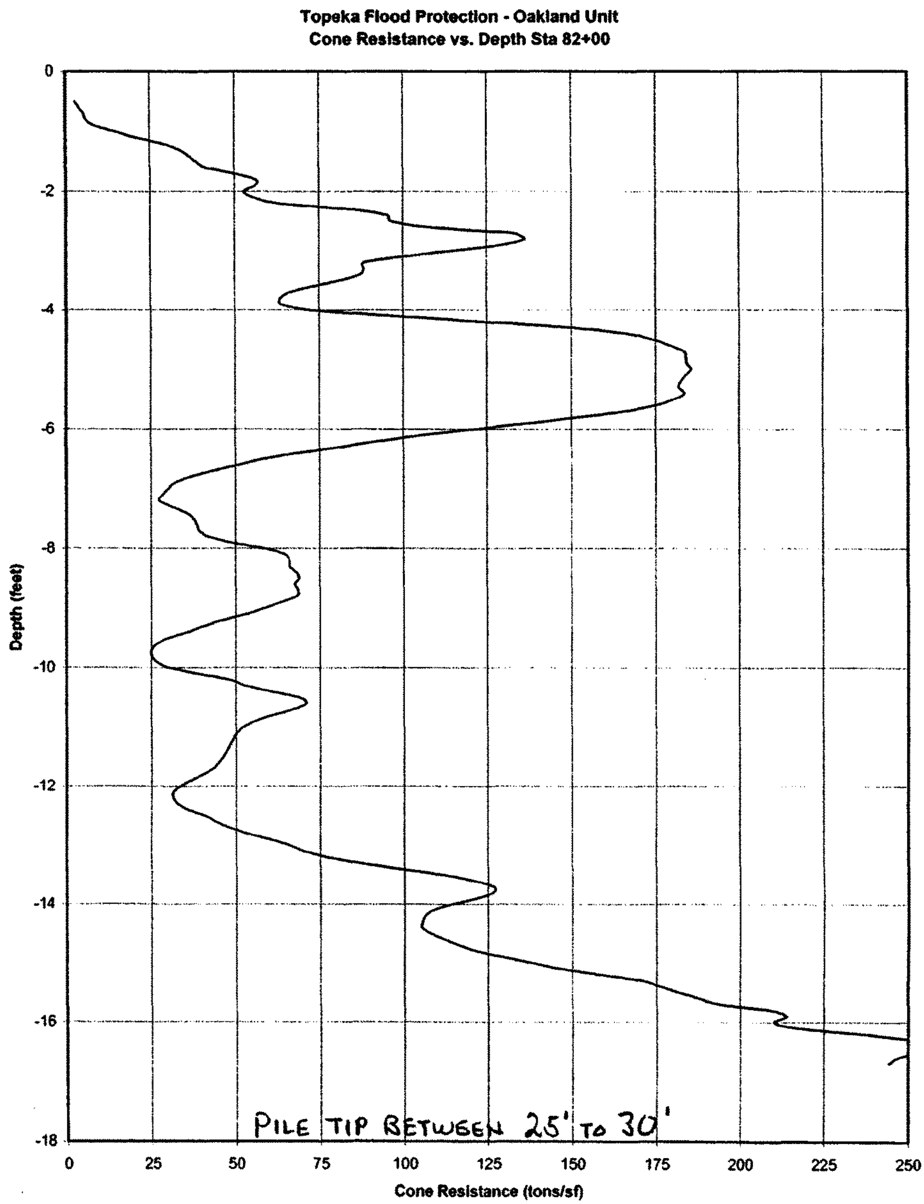
10

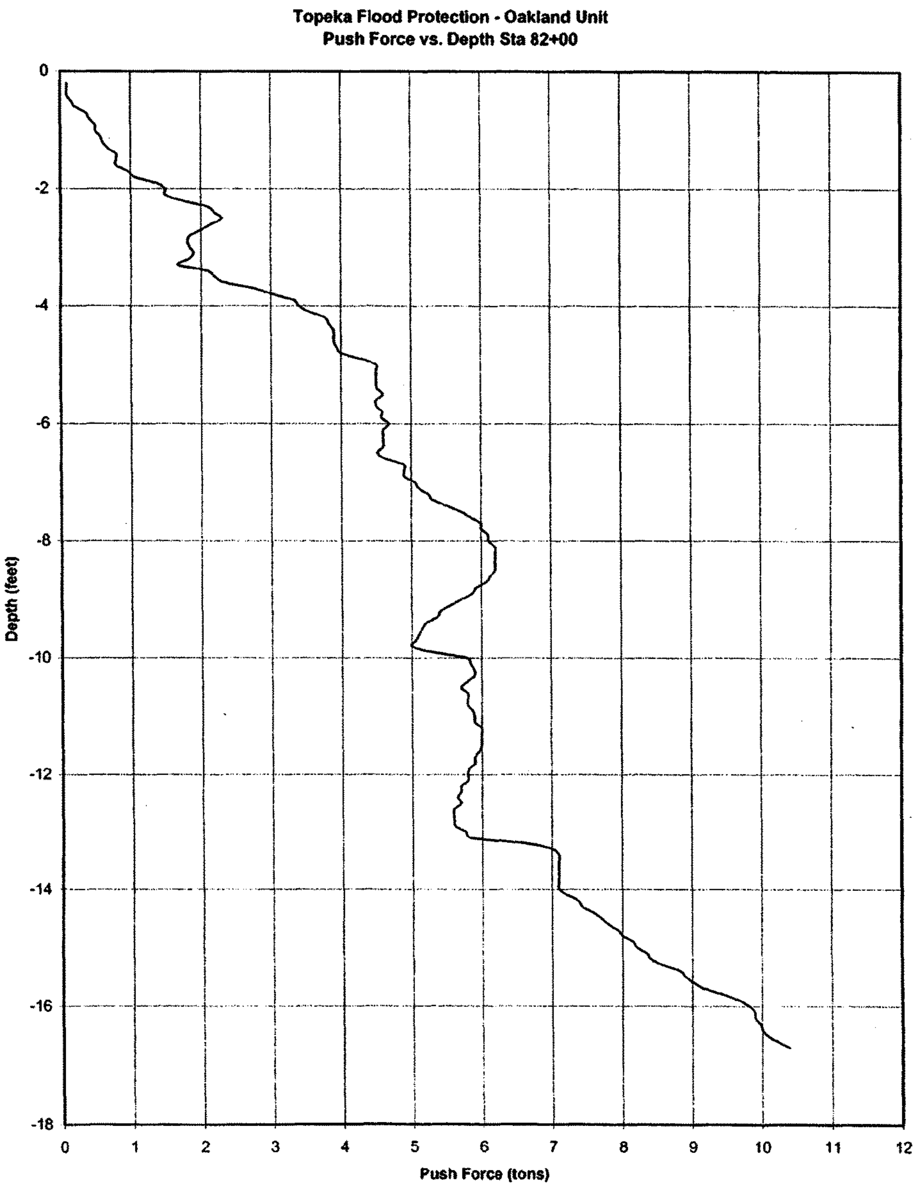
OAK2CITY


Topeka Flood Protection - Oakland Unit
SCN vs. Depth Sta 82+00
Depth (feet)
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
BOTTOM OF BLANKET?
Peats
Clays
Silt Mixtures
Sand Mixtures
Sands
Sands and Gravels
-1
-0.5
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
SCN Number

11

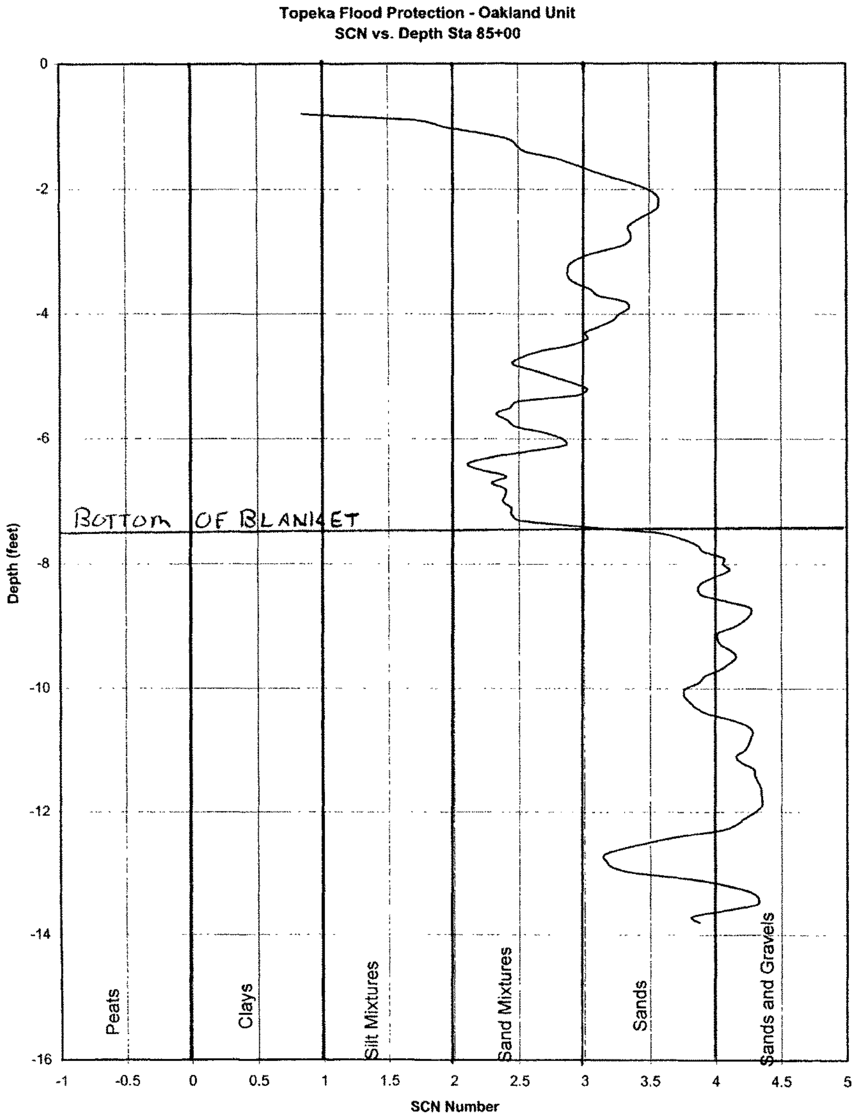

Topeka Flood Protection - Oakland Unit
Sleeve Resistance vs. Depth Sta 82+00
Depth (feet)
Sleeve Resistance (tons/sf)
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
2.2
2.4
2.6
2.8
3
TOP OF PILE
fs = 0.5 tsf = 1000 psf
5'
fs = 0.3 tsf = 600 psf
7'
fs = 0.1 tsf = 200 psf
fs = 0.15 tsf = 300 psf
13'
fs = 0.35 tsf = 700 psf
fs = 0.6 tsf = 1200 psf
5d ≈ 4'
(USUALLY IGNORED)
8b = 6.0'
PILE TIP BETWEEN 25' TO 30'

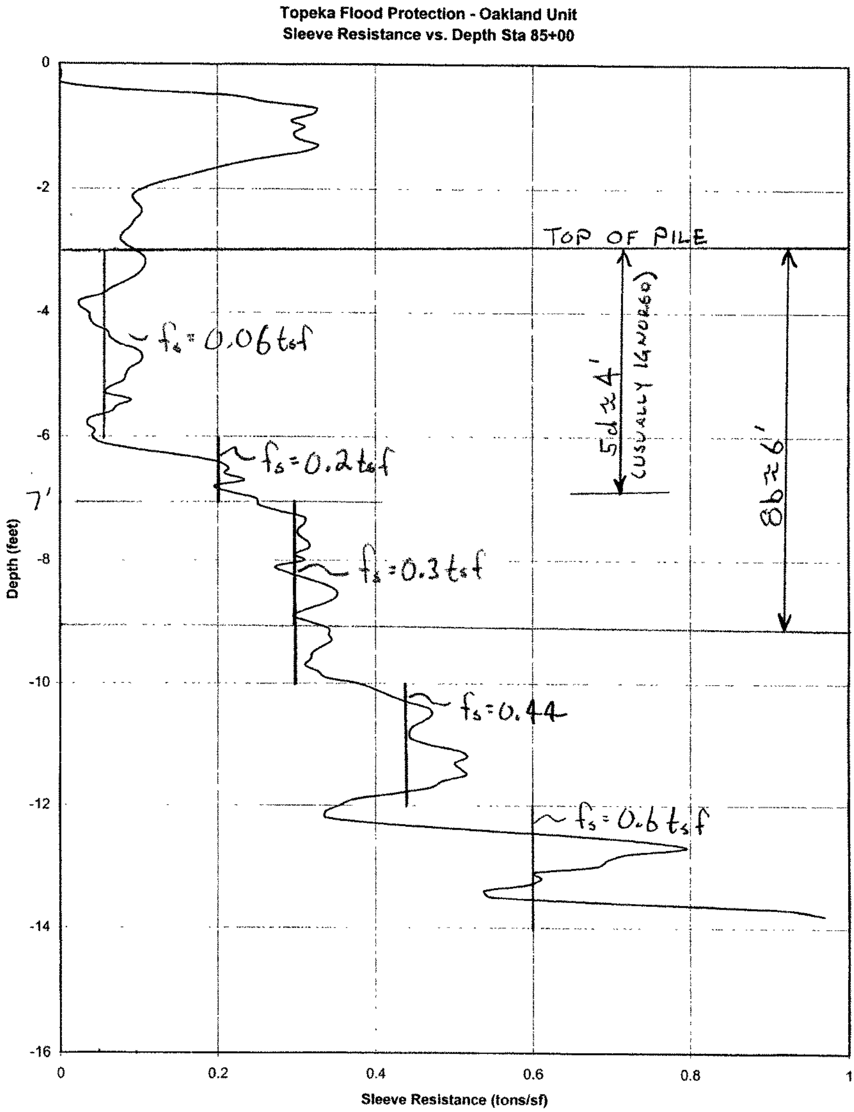

Topeka Flood Protection - Oakland Unit
Cone Resistance vs. Depth Sta 82+00
Depth (feet)
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
0
25
50
75
100
125
150
175
200
225
250
Cone Resistance (tons/sf)
PILE TIP BETWEEN 25' TO 30'


Topeka Flood Protection - Oakland Unit
Push Force vs. Depth Sta 82+00
Depth (feet)
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
0
1
2
3
4
5
6
7
8
9
10
11
12
Push Force (tons)

14

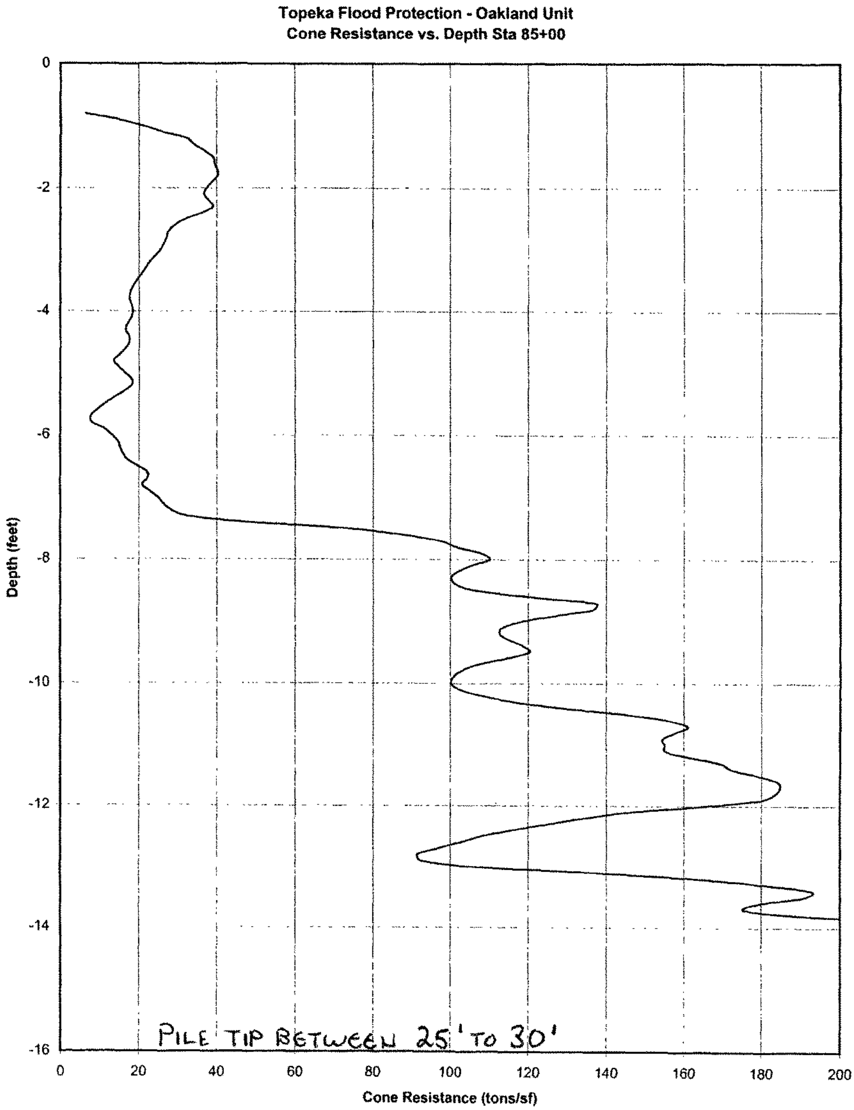
OAK 3 CITY


Topeka Flood Protection - Oakland Unit
SCN vs. Depth Sta 85+00
Depth (feet)
0
-2
-4
-6
-8
-10
-12
-14
-16
BOTTOM OF BLANKET
Peats
Clays
Silt Mixtures
Sand Mixtures
Sands
Sands and Gravels
-1
-0.5
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
SCN Number

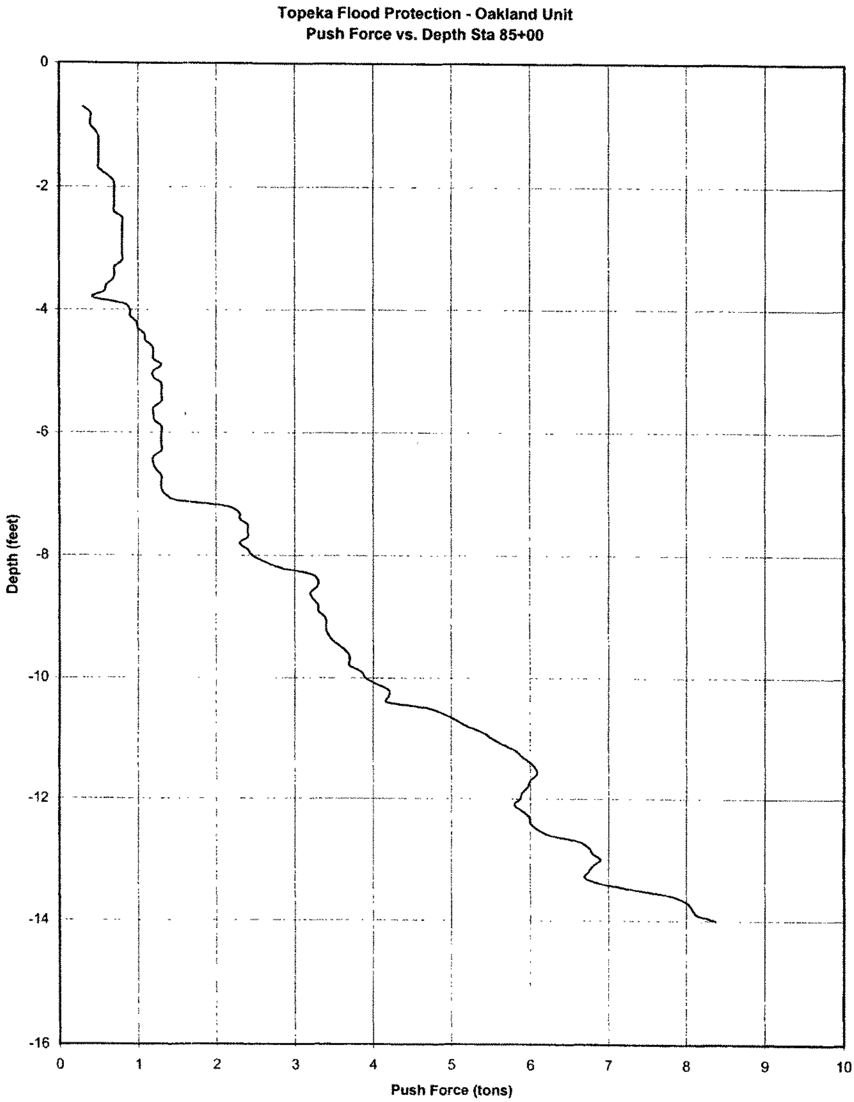


Topeka Flood Protection - Oakland Unit
Sleeve Resistance vs. Depth Sta 85+00
Depth (feet)
0
-2
-4
-6
-8
-10
-12
-14
-16
0
0.2
0.4
0.6
0.8
1
Sleeve Resistance (tons/sf)
TOP OF PILE
fs = 0.06 tsf
fs = 0.2 tsf
fs = 0.3 tsf
fs = 0.44
fs = 0.6 tsf
7'
5d ≈ 4'
(USUALLY IGNORED)
8b ≈ 6'

16

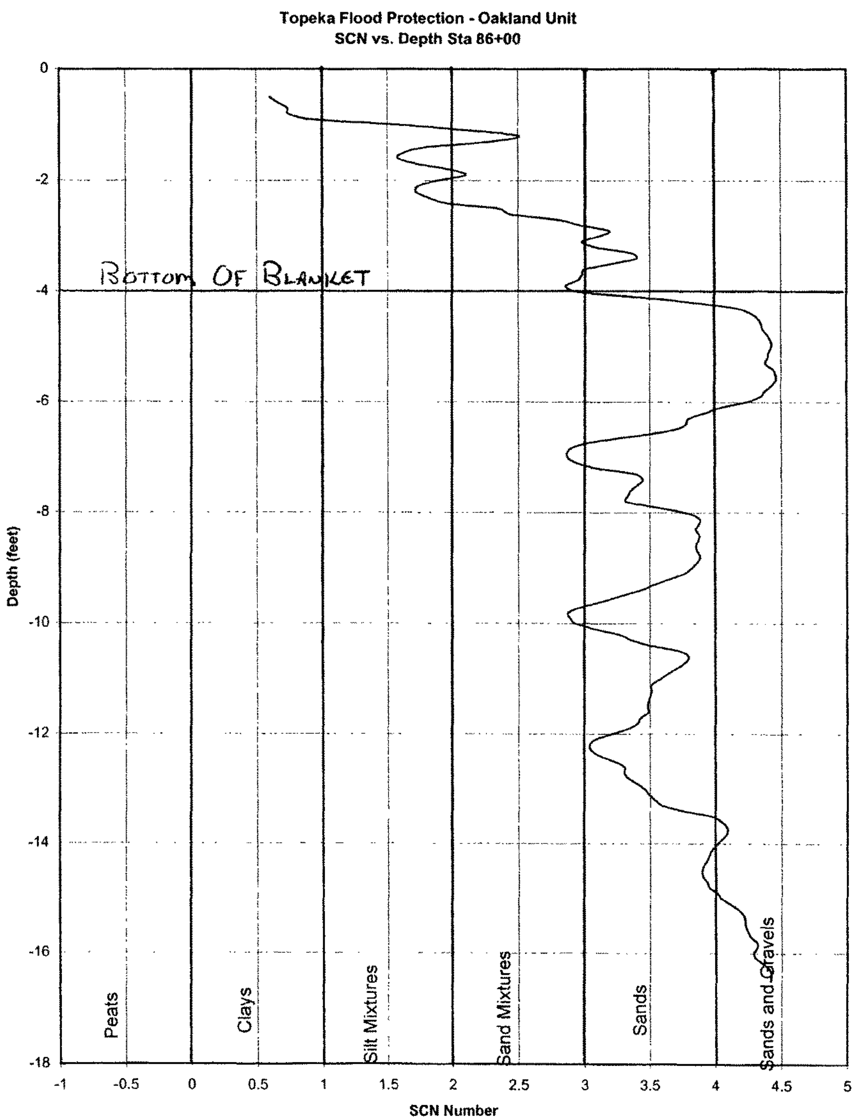

Topeka Flood Protection - Oakland Unit
Cone Resistance vs. Depth Sta 85+00
Depth (feet)
0
-2
-4
-6
-8
-10
-12
-14
-16
0
20
40
60
80
100
120
140
160
180
200
Cone Resistance (tons/sf)
PILE TIP BETWEEN 25' TO 30'

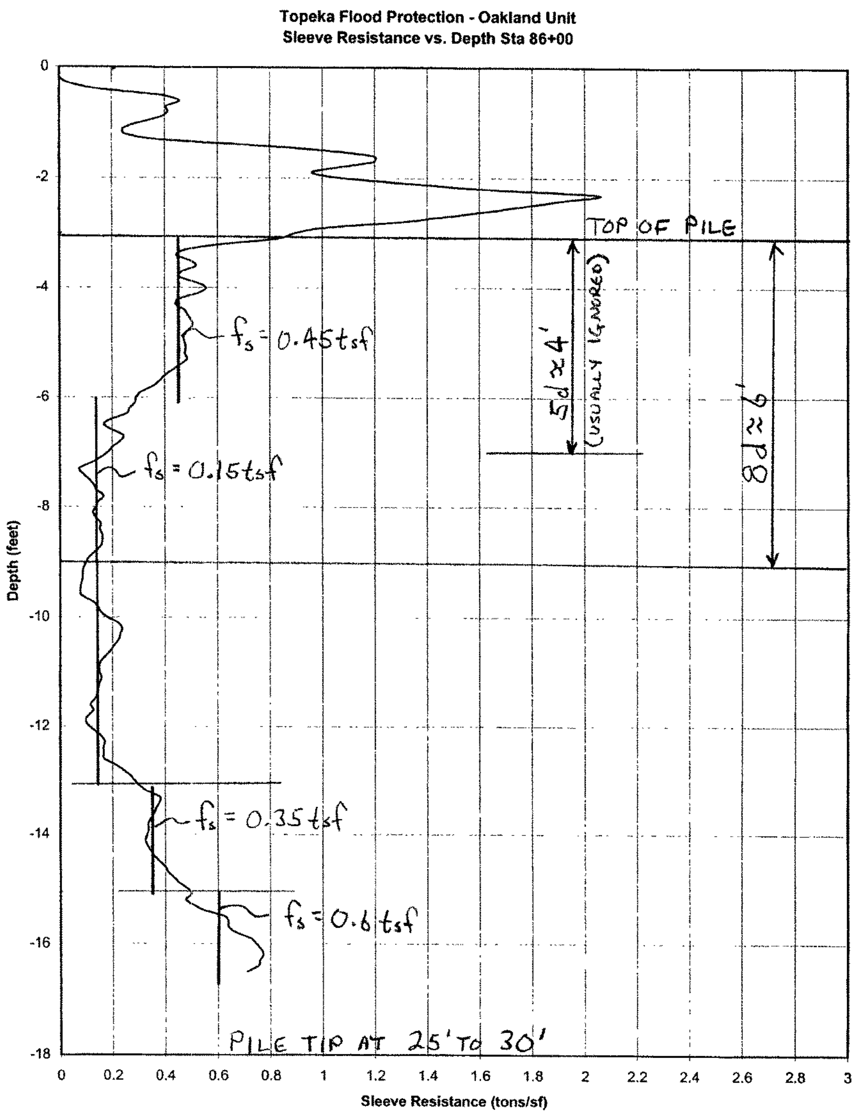
17


Topeka Flood Protection - Oakland Unit
Push Force vs. Depth Sta 85+00
Depth (feet)
0
-2
-4
-6
-8
-10
-12
-14
-16
Push Force (tons)
0
1
2
3
4
5
6
7
8
9
10

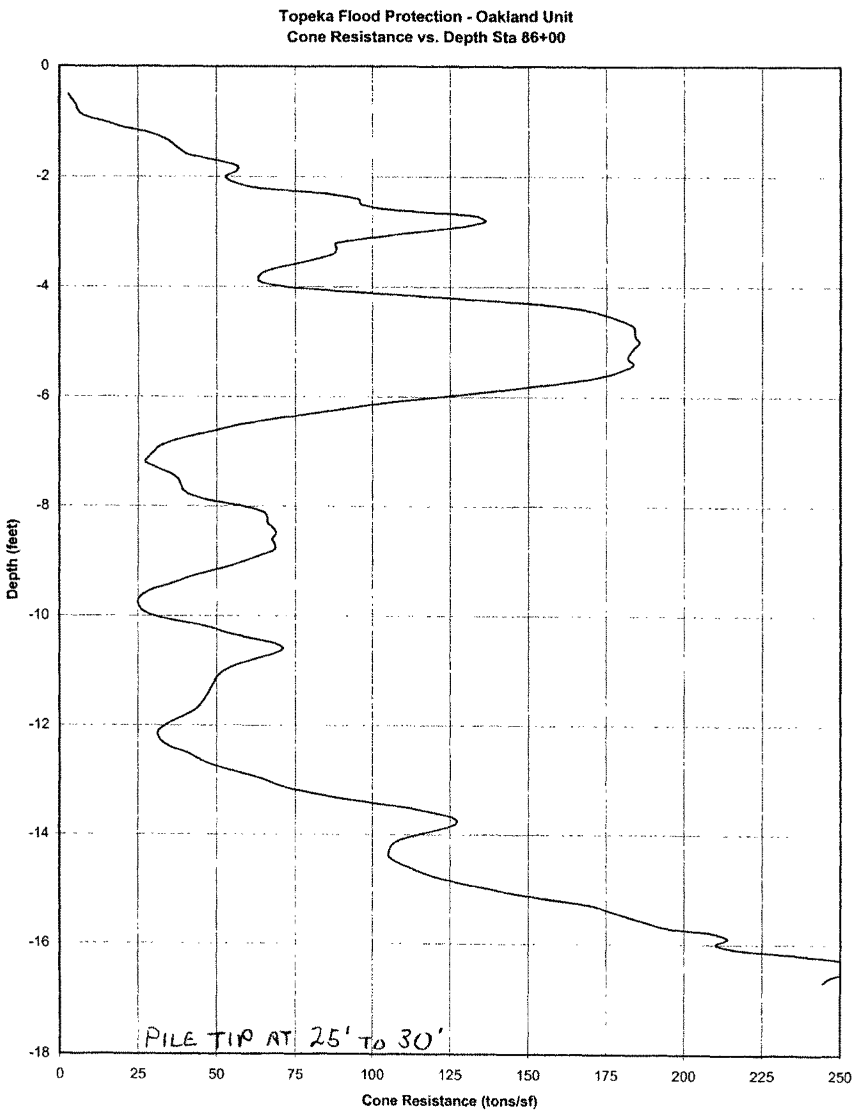
18

OAK4 CITY

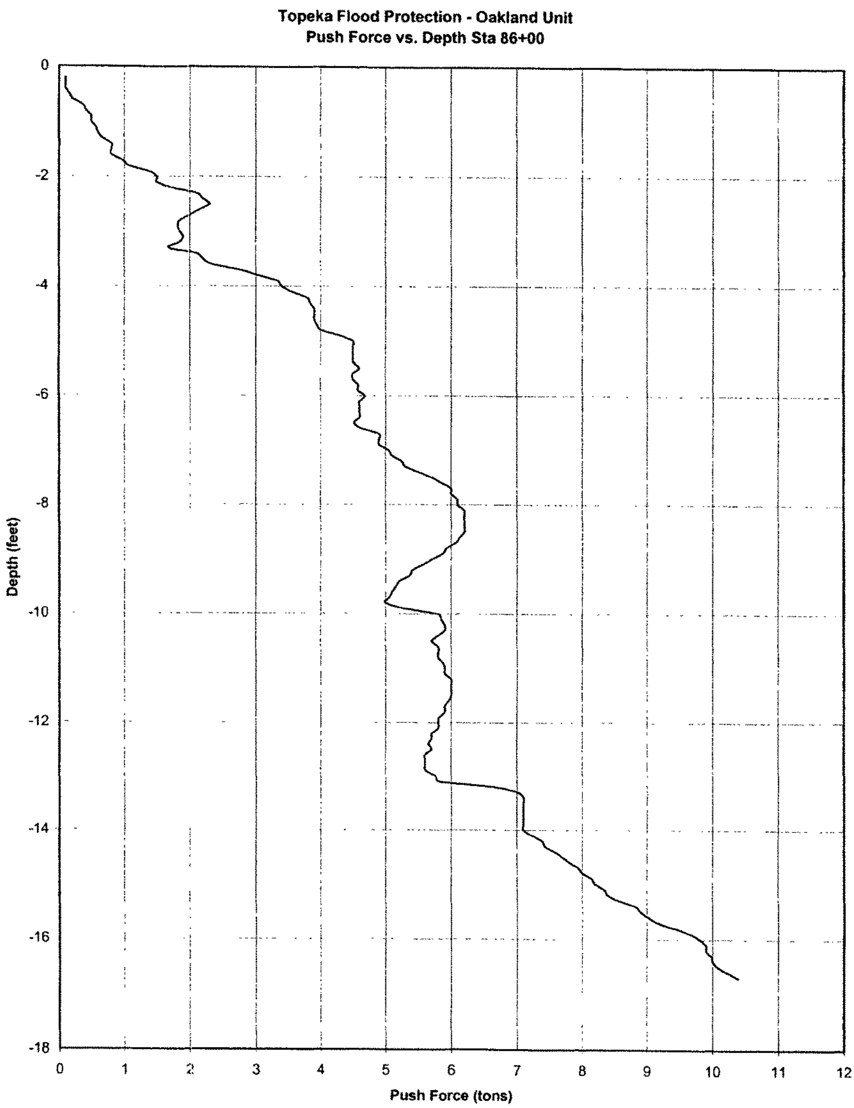

Topeka Flood Protection - Oakland Unit
SCN vs. Depth Sta 86+00
Depth (feet)
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
BOTTOM OF BLANKET
Peats
Clays
Silt Mixtures
Sand Mixtures
Sands
Sands and Gravels
-1
-0.5
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
SCN Number


Topeka Flood Protection - Oakland Unit
Sleeve Resistance vs. Depth Sta 86+00
Depth (feet)
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
Sleeve Resistance (tons/sf)
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
2.2
2.4
2.6
2.8
3
TOP OF PILE
fs = 0.45 tsf
fs = 0.15 tsf
fs = 0.35 tsf
fs = 0.6 tsf
5d ≈ 4'
(USUALLY IGNORED)
8d ≈ 6'
PILE TIP AT 25' TO 30'

2C

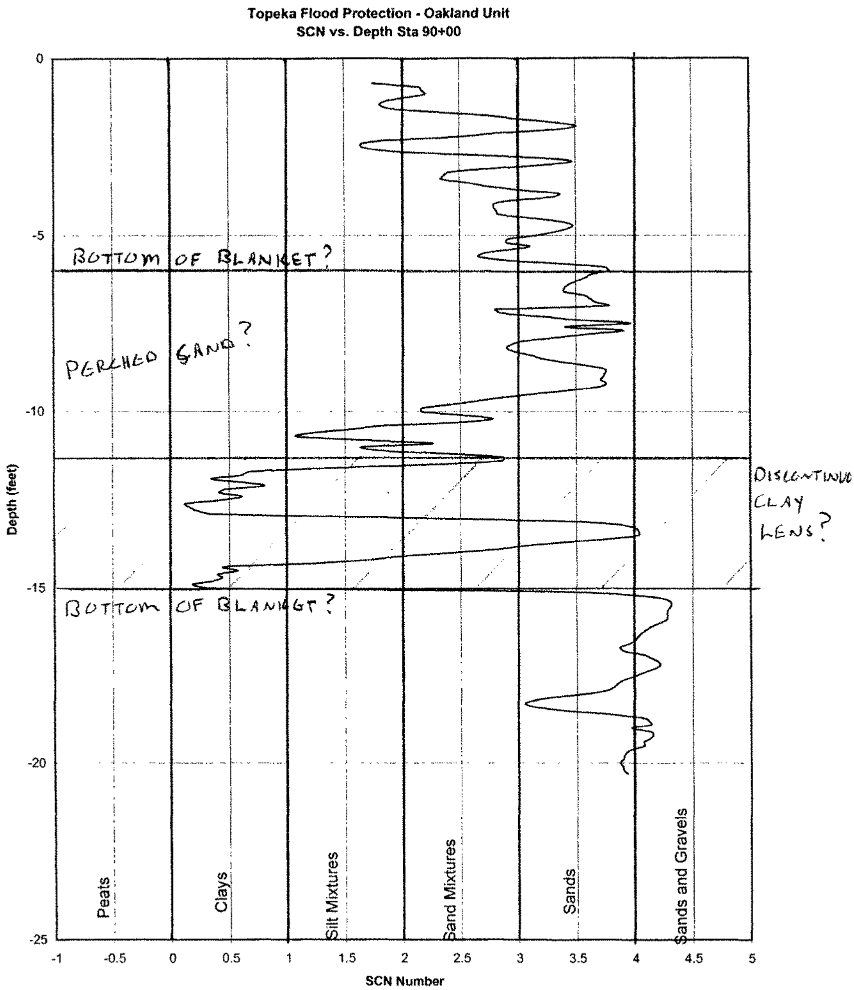

Topeka Flood Protection - Oakland Unit
Cone Resistance vs. Depth Sta 86+00
Depth (feet)
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
0
25
50
75
100
125
150
175
200
225
250
Cone Resistance (tons/sf)
PILE TIP AT 25' TO 30'

21

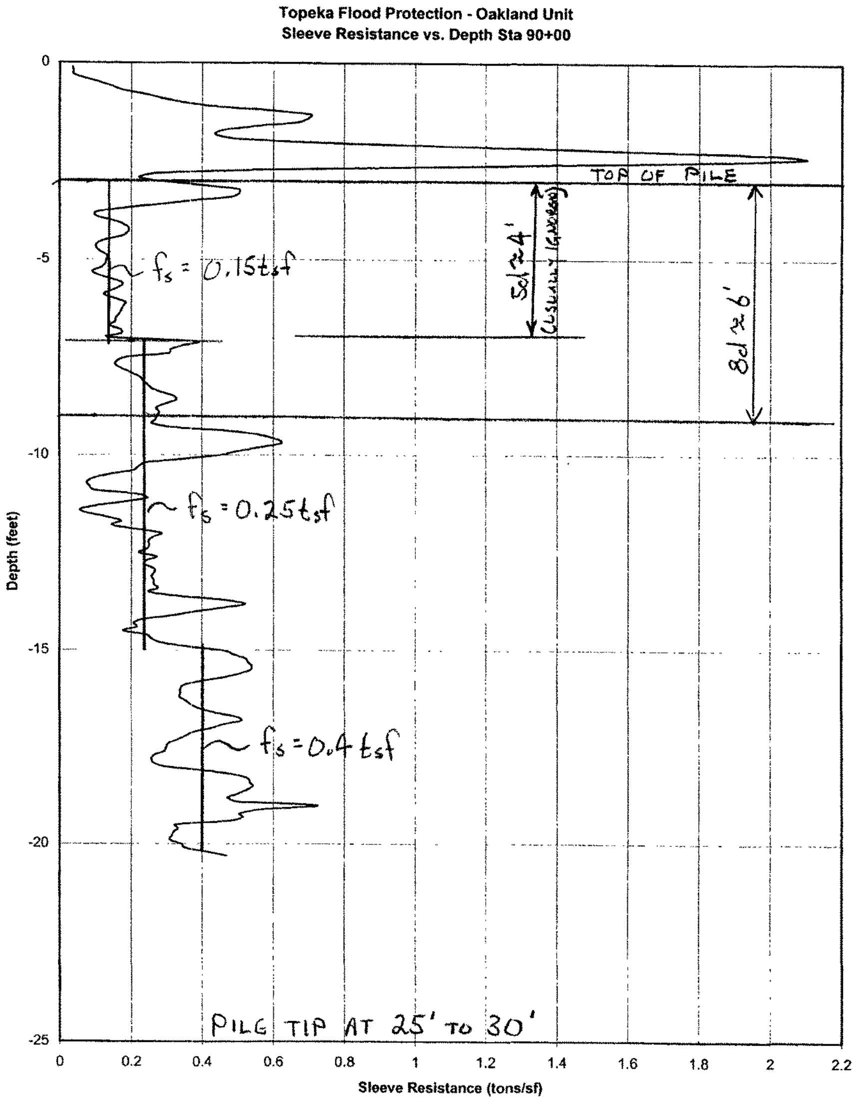

Topeka Flood Protection - Oakland Unit
Push Force vs. Depth Sta 86+00
Depth (feet)
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
0
1
2
3
4
5
6
7
8
9
10
11
12
Push Force (tons)

22

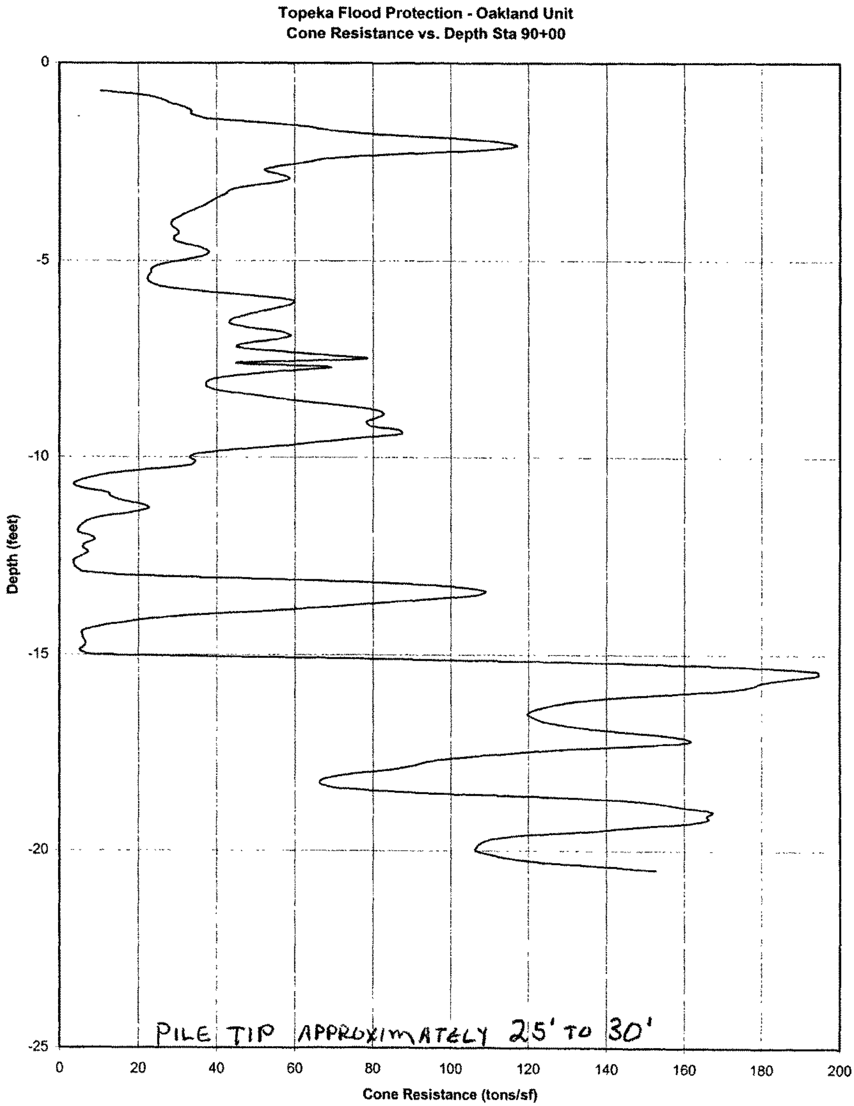
OAKS CITY



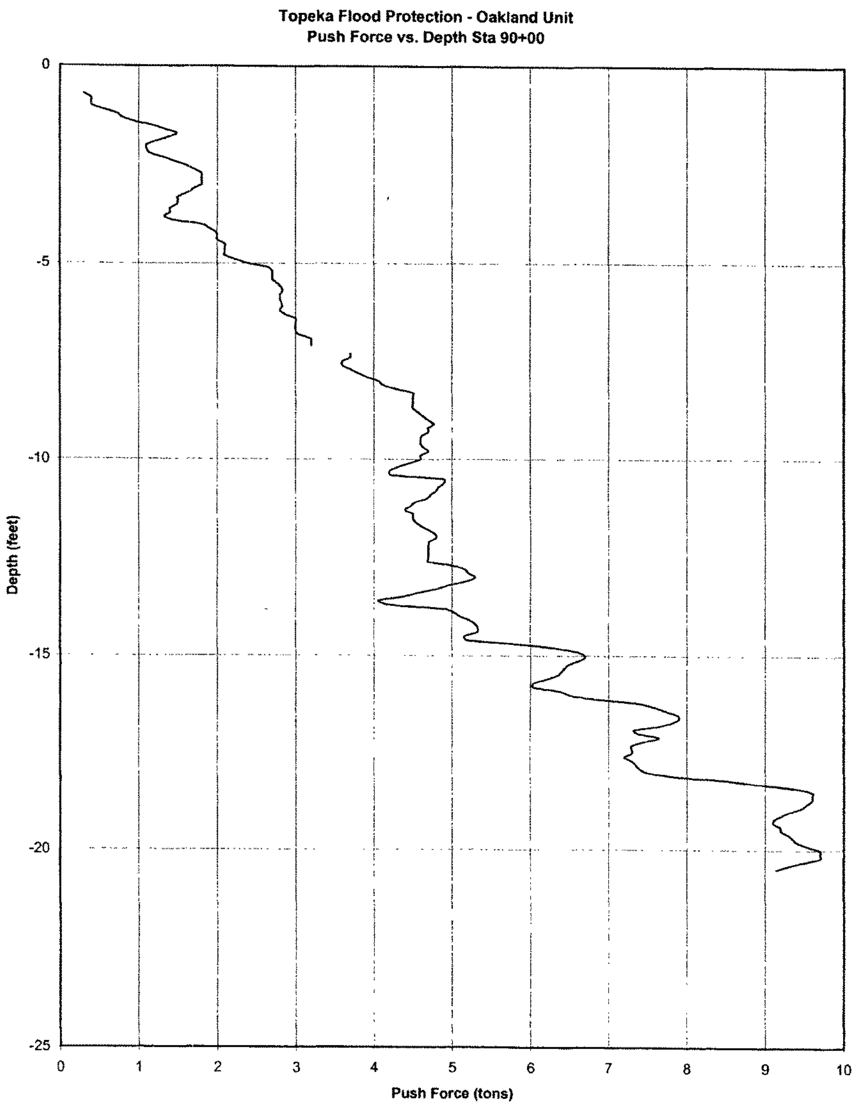
Topeka Flood Protection - Oakland Unit
SCN vs. Depth Sta 90+00
Depth (feet)
SCN Number
0
-5
-10
-15
-20
-25
-1
-0.5
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
Peats
Clays
Silt Mixtures
Sand Mixtures
Sands
Sands and Gravels
BOTTOM OF BLANKET?
PERCHED SAND?
BOTTOM OF BLANKET?
DISCONTINUO CLAY LENS?


Topeka Flood Protection - Oakland Unit
Sleeve Resistance vs. Depth Sta 90+00
Depth (feet)
Sleeve Resistance (tons/sf)
0
-5
-10
-15
-20
-25
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
2.2
TOP OF PILE
f_s = 0.15tsf
f_s = 0.25tsf
f_s = 0.4 tsf
5d ≈ 4'
8d ≈ 6'
PILE TIP AT 25' TO 30'

24

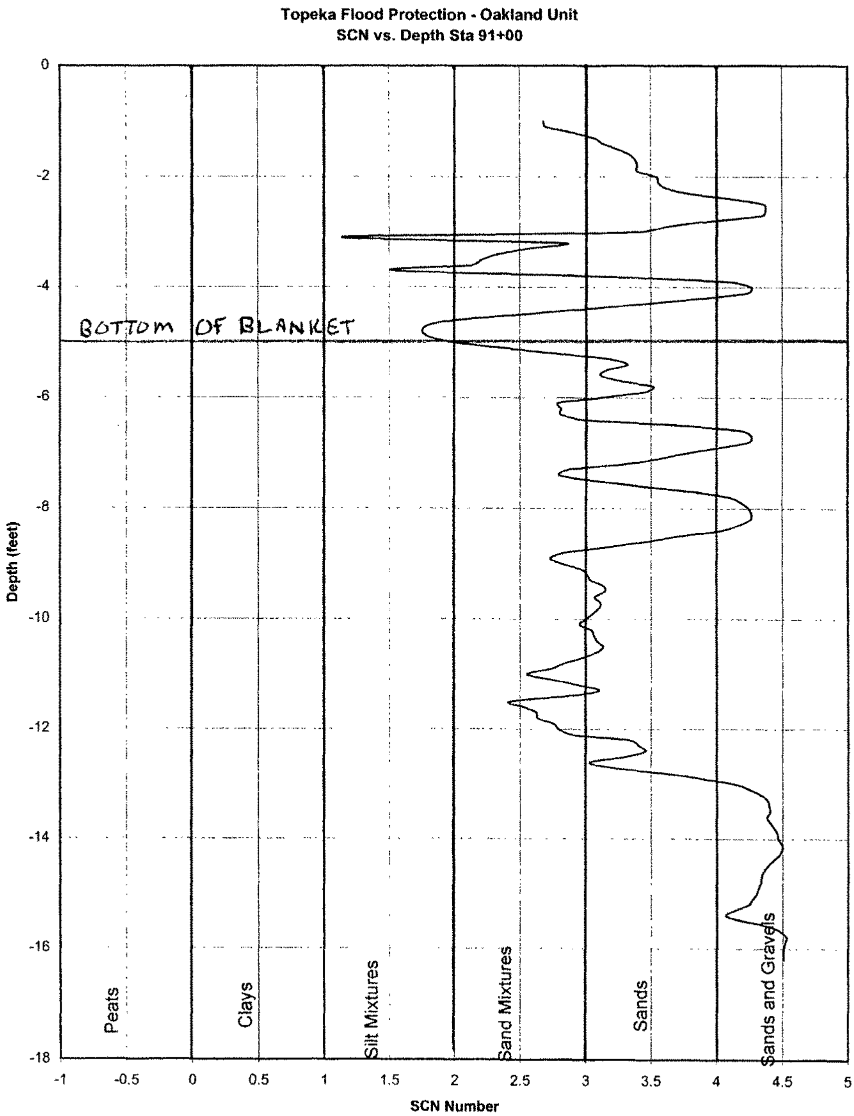

Topeka Flood Protection - Oakland Unit
Cone Resistance vs. Depth Sta 90+00
Depth (feet)
0
-5
-10
-15
-20
-25
PILE TIP APPROXIMATELY 25' TO 30'
0
20
40
60
80
100
120
140
160
180
200
Cone Resistance (tons/sf)

25

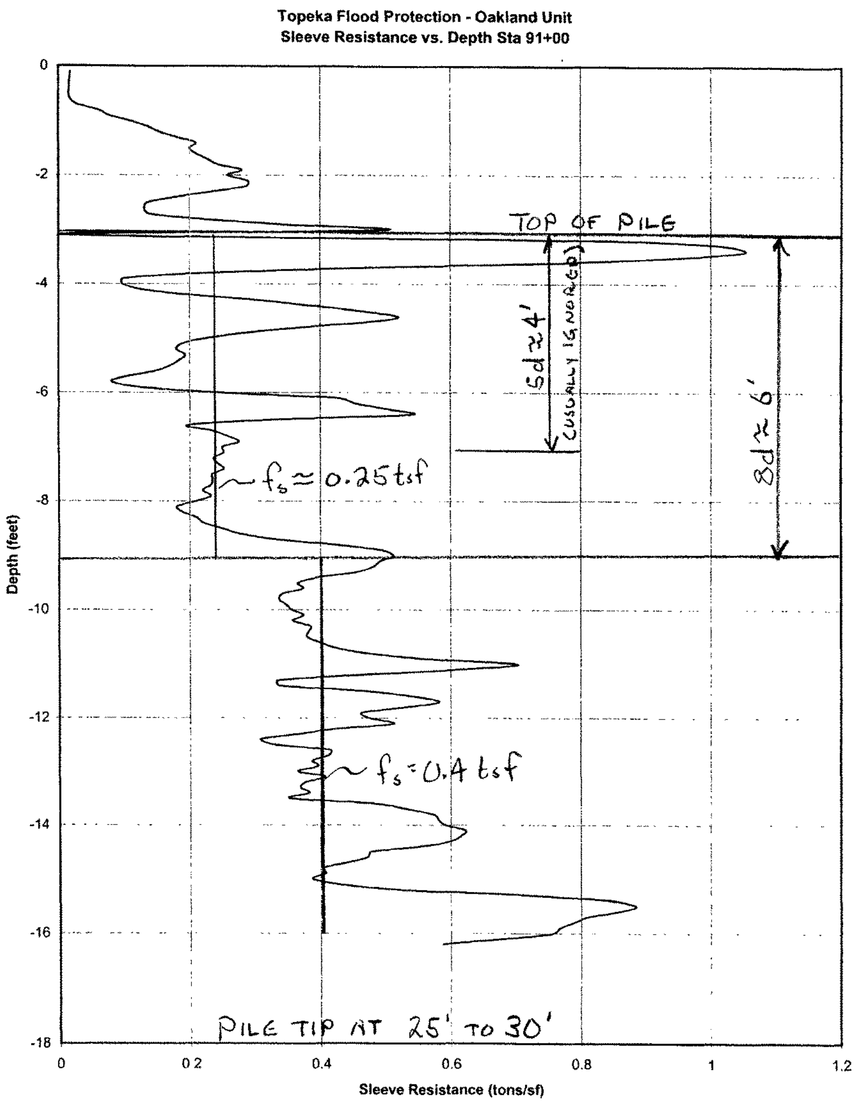

Topeka Flood Protection - Oakland Unit
Push Force vs. Depth Sta 90+00
Depth (feet)
0
-5
-10
-15
-20
-25
0
1
2
3
4
5
6
7
8
9
10
Push Force (tons)

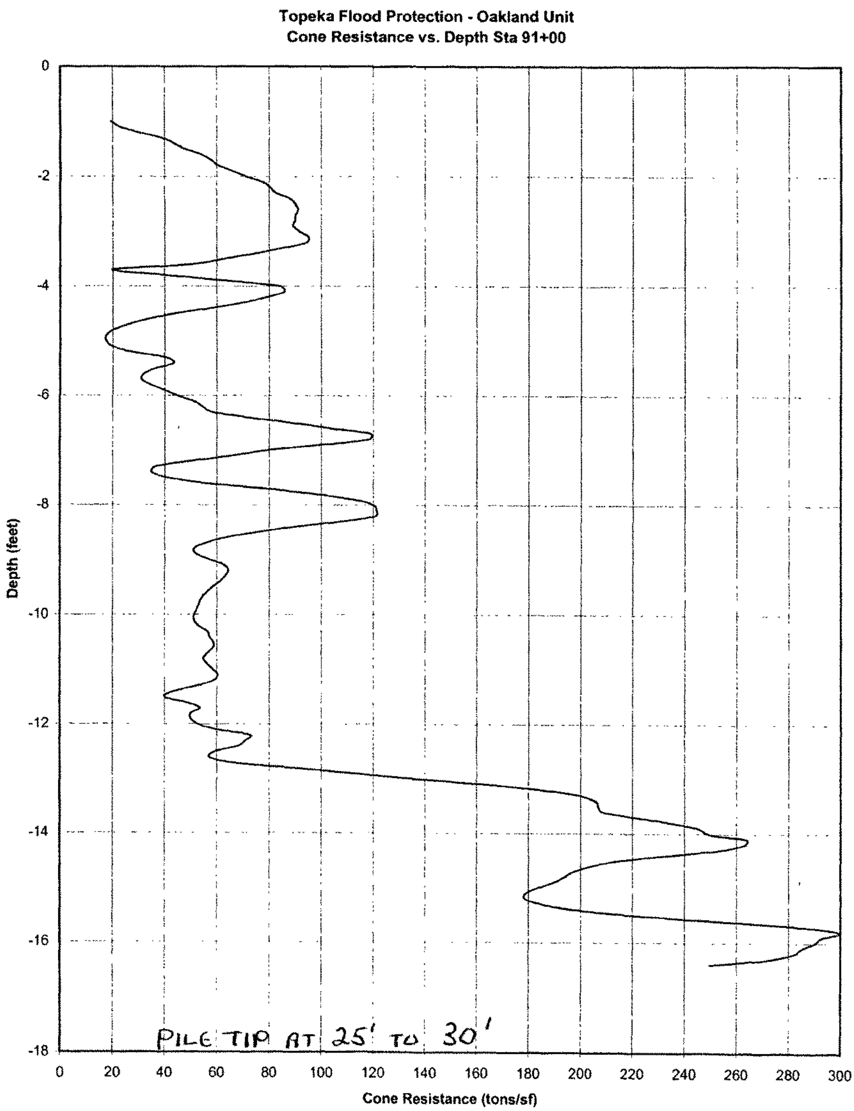
26

OAK6 CITY

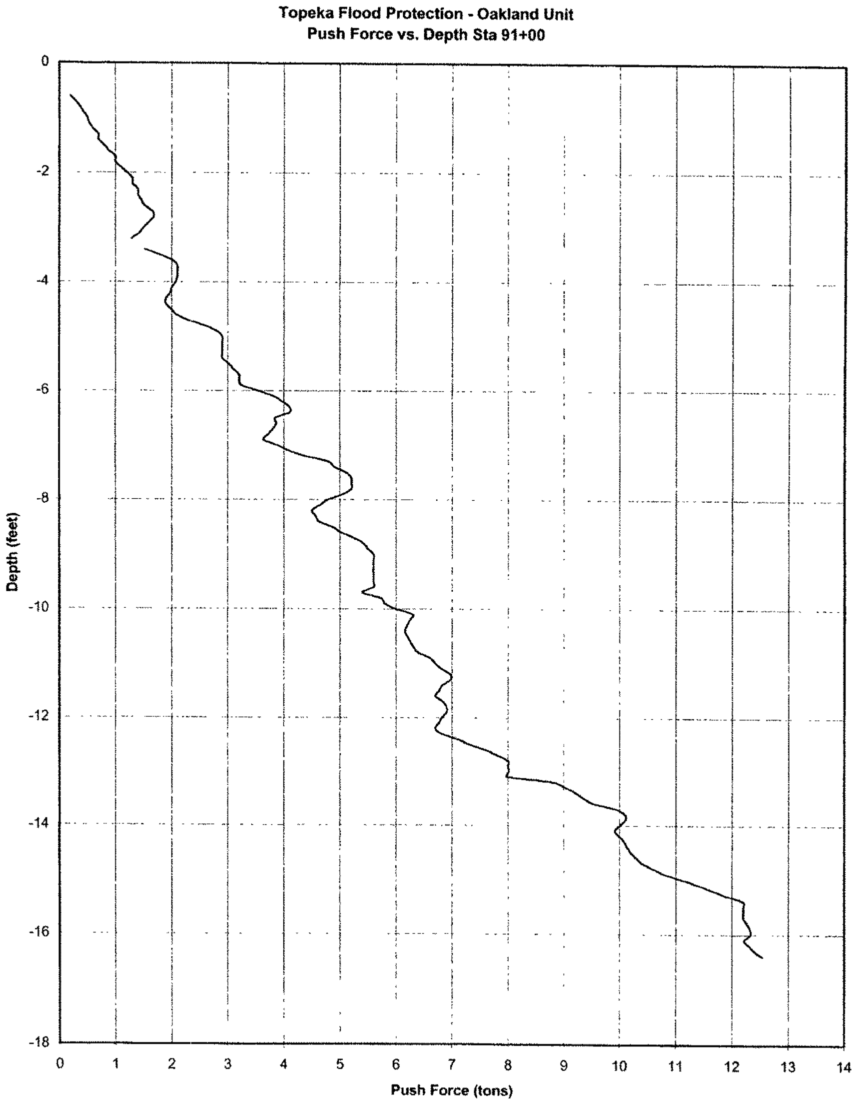

Topeka Flood Protection - Oakland Unit
SCN vs. Depth Sta 91+00
BOTTOM OF BLANKET
Depth (feet)
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
Peats
Clays
Silt Mixtures
Sand Mixtures
Sands
Sands and Gravels
-1
-0.5
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
SCN Number

27


Topeka Flood Protection - Oakland Unit
Sleeve Resistance vs. Depth Sta 91+00
Depth (feet)
Sleeve Resistance (tons/sf)
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
0
0.2
0.4
0.6
0.8
1
1.2
TOP OF PILE
5d ≈ 4'
(USUALLY IGNORED)
8d ≈ 6'
fs ≈ 0.25 tsf
fs = 0.4 tsf
PILE TIP AT 25' TO 30'

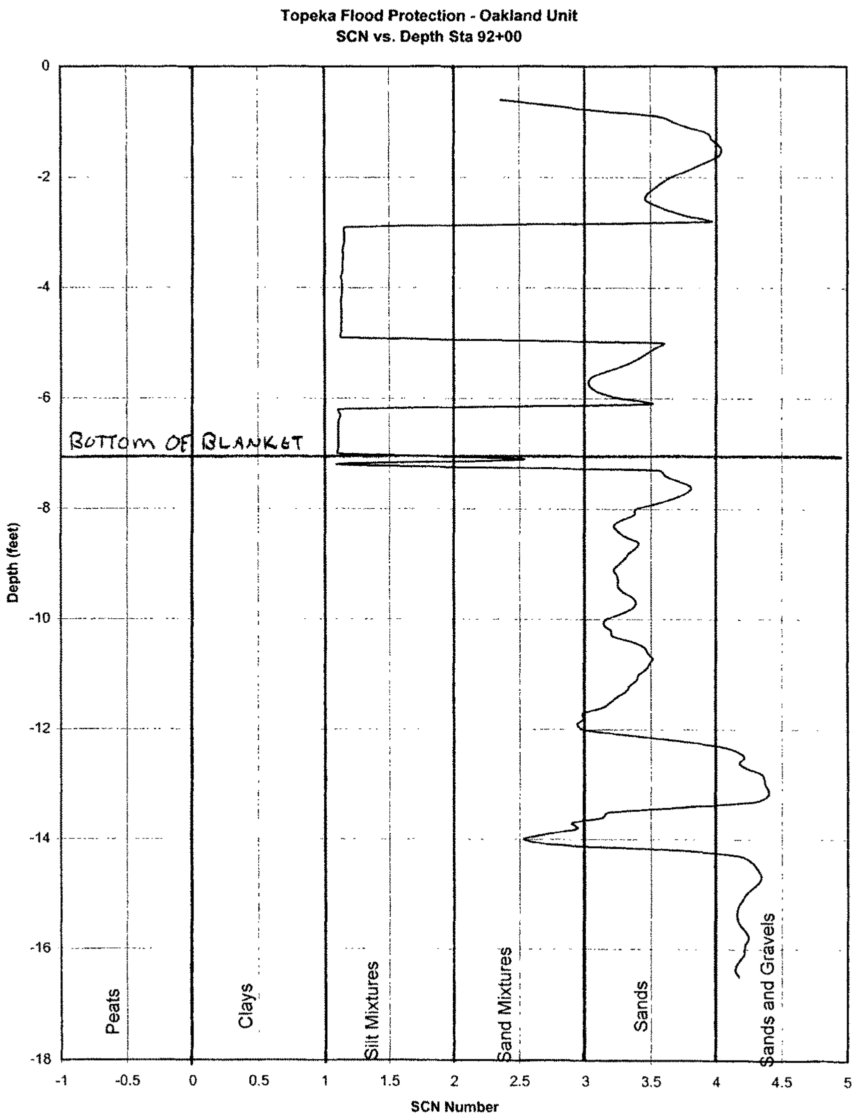

Topeka Flood Protection - Oakland Unit
Cone Resistance vs. Depth Sta 91+00
Depth (feet)
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
Cone Resistance (tons/sf)
PILE TIP AT 25' TO 30'

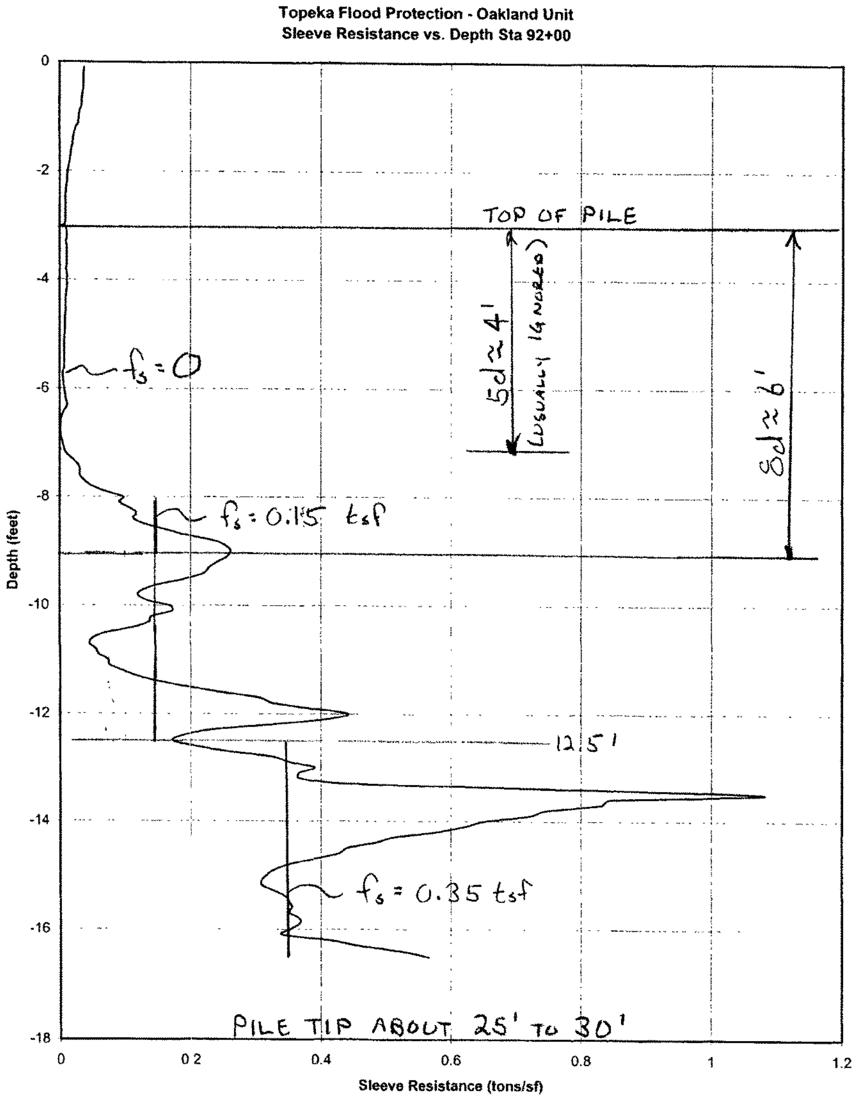
29

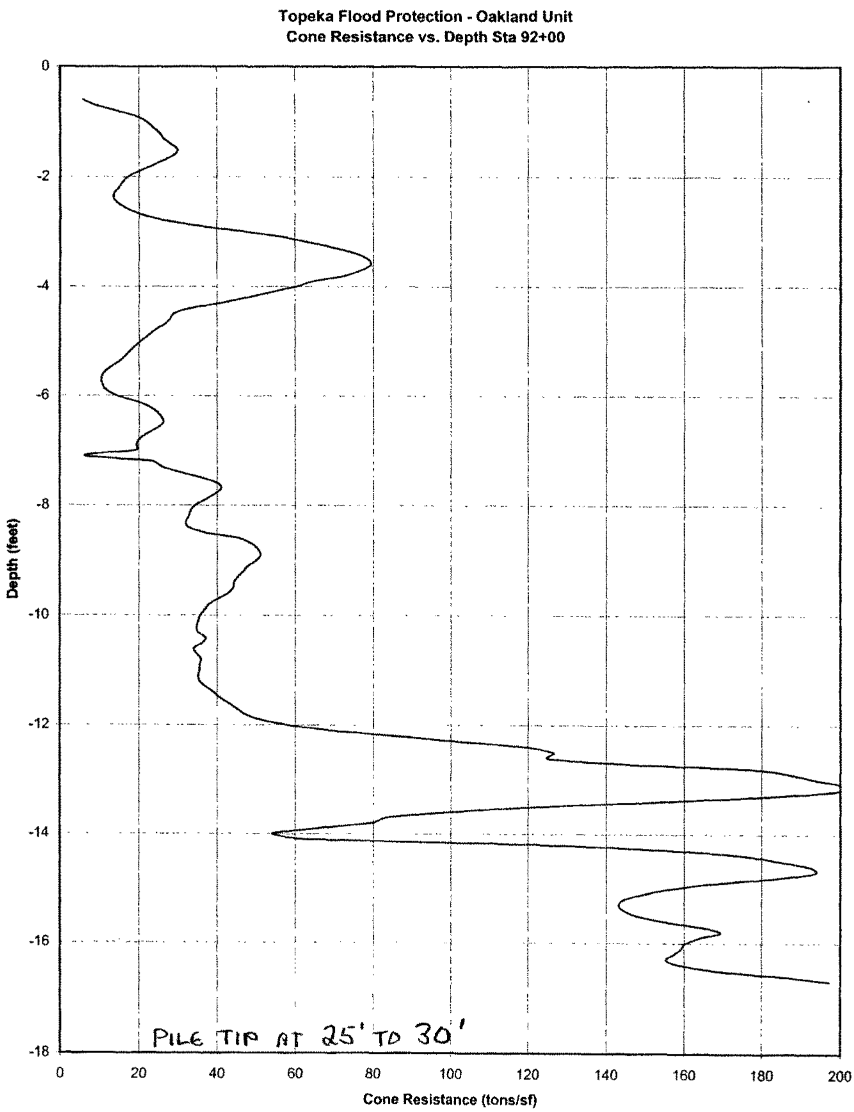

Topeka Flood Protection - Oakland Unit
Push Force vs. Depth Sta 91+00
Depth (feet)
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
Push Force (tons)

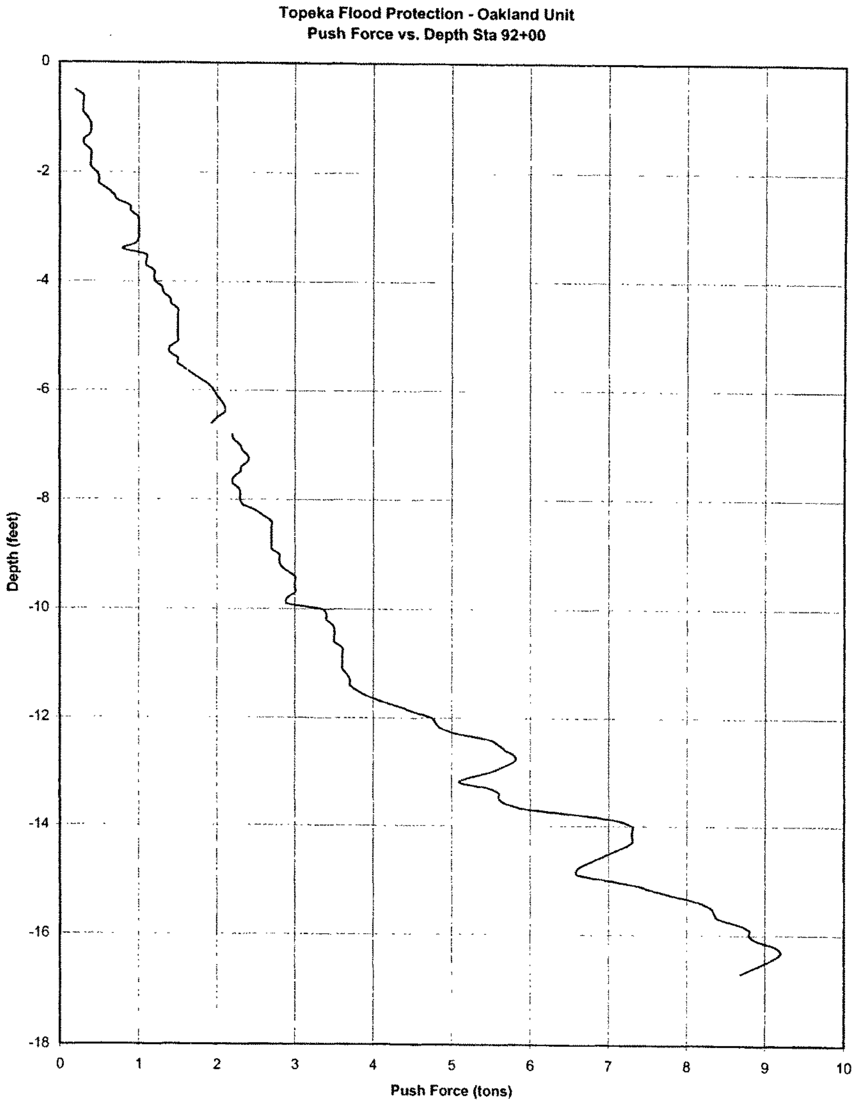
30

OAK 7 CITY


Topeka Flood Protection - Oakland Unit
SCN vs. Depth Sta 92+00
Depth (feet)
SCN Number
BOTTOM OF BLANKET
Peats
Clays
Silt Mixtures
Sand Mixtures
Sands
Sands and Gravels
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
-1
-0.5
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5

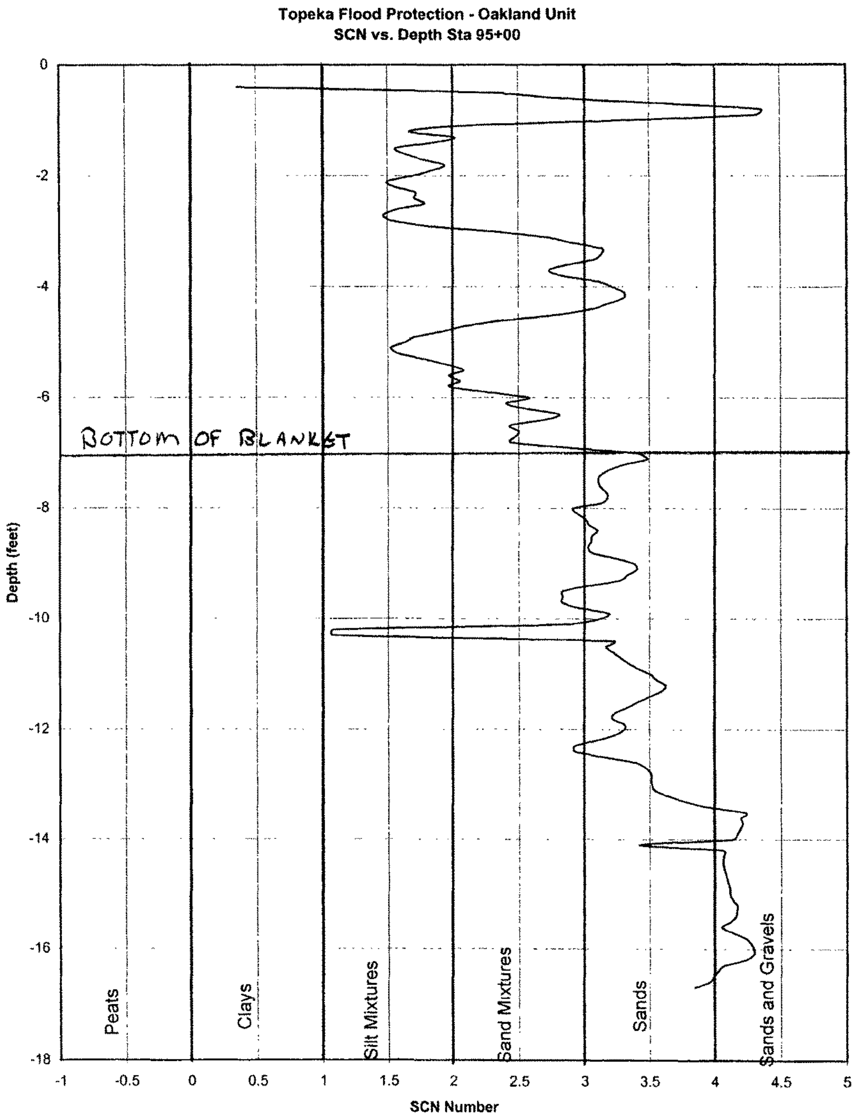

Topeka Flood Protection - Oakland Unit
Sleeve Resistance vs. Depth Sta 92+00
Depth (feet)
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
0
0.2
0.4
0.6
0.8
1
1.2
Sleeve Resistance (tons/sf)
TOP OF PILE
5d ≈ 4'
(USUALLY IGNORED)
8d ≈ 6'
fs = 0
fs = 0.15 tsf
12.5'
fs = 0.35 tsf
PILE TIP ABOUT 25' TO 30'

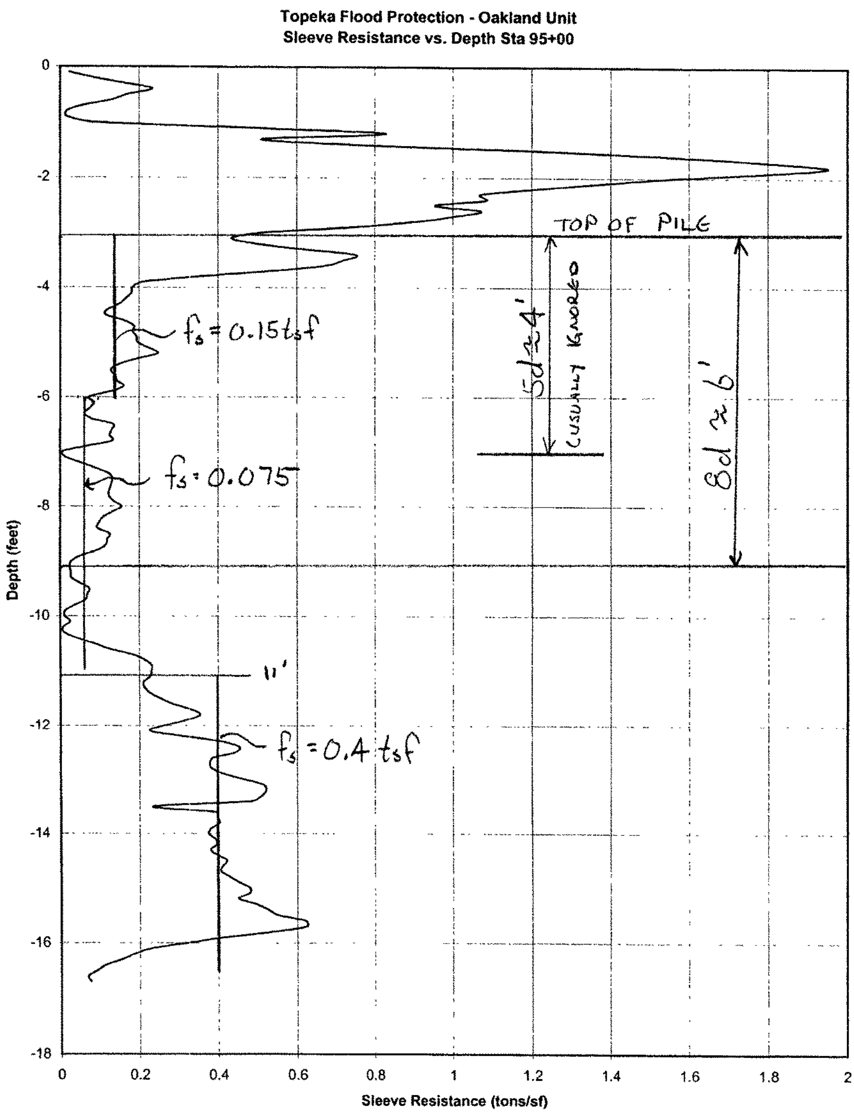

Topeka Flood Protection - Oakland Unit
Cone Resistance vs. Depth Sta 92+00
Depth (feet)
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
0
20
40
60
80
100
120
140
160
180
200
Cone Resistance (tons/sf)
PILE TIP AT 25' TO 30'


Topeka Flood Protection - Oakland Unit
Push Force vs. Depth Sta 92+00
Depth (feet)
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
0
1
2
3
4
5
6
7
8
9
10
Push Force (tons)

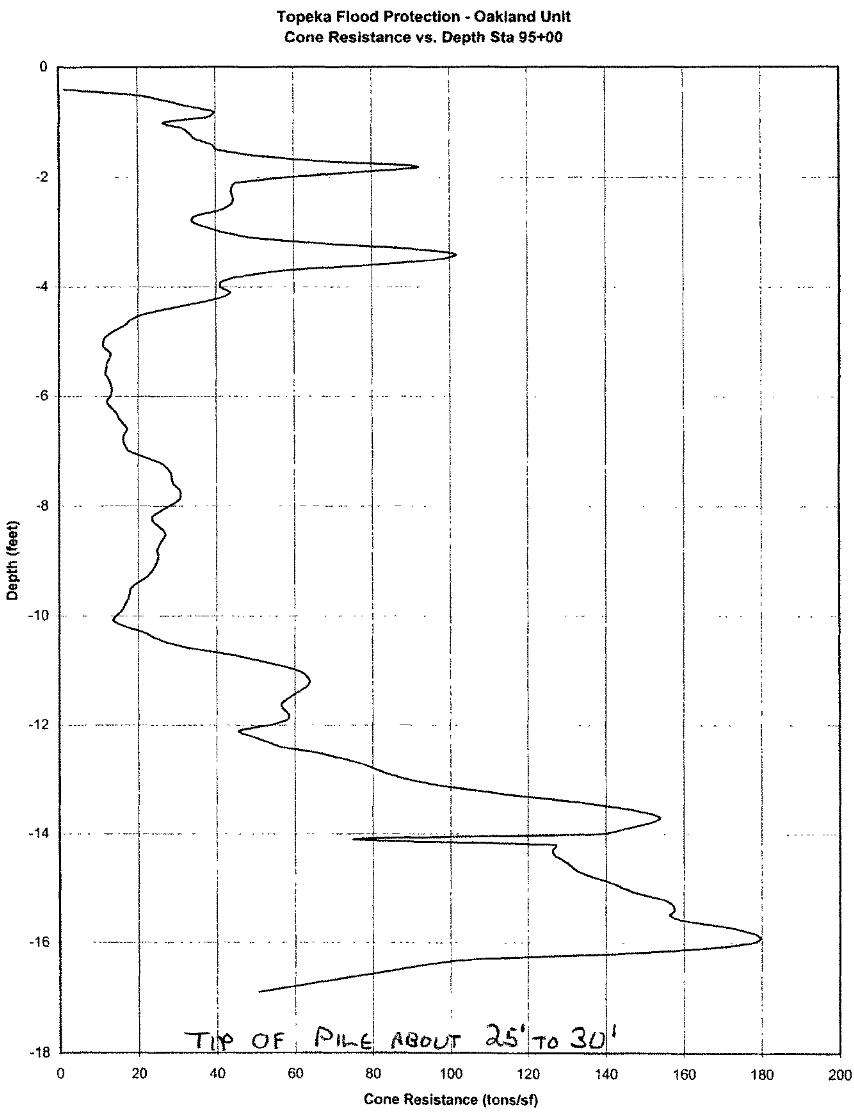
34

OAKIHAL

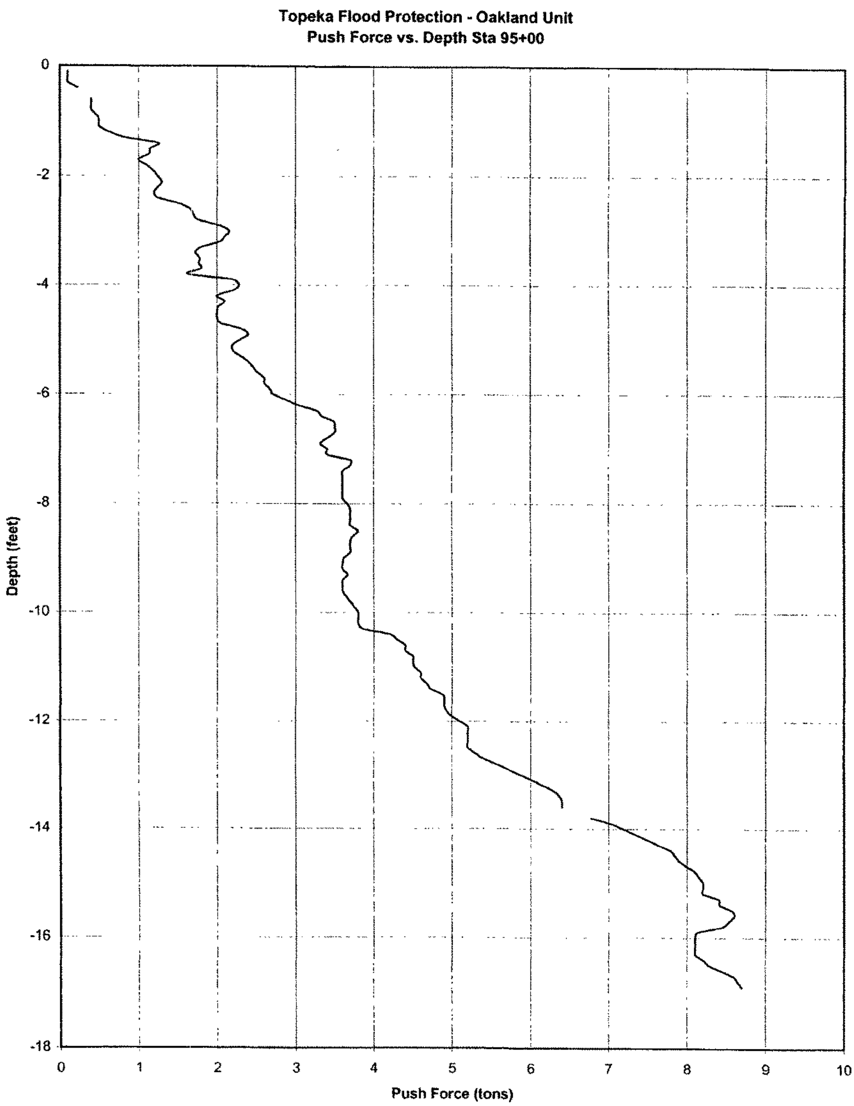

Topeka Flood Protection - Oakland Unit
SCN vs. Depth Sta 95+00
Depth (feet)
SCN Number
BOTTOM OF BLANKET
Peats
Clays
Silt Mixtures
Sand Mixtures
Sands
Sands and Gravels
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
-1
-0.5
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5


Topeka Flood Protection - Oakland Unit
Sleeve Resistance vs. Depth Sta 95+00
Depth (feet)
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
Sleeve Resistance (tons/sf)
TOP OF PILE
5d ≈ 4'
(USUALLY IGNORED
8d ≈ 6'
fs = 0.15 tsf
fs = 0.075
11'
fs = 0.4 tsf

36

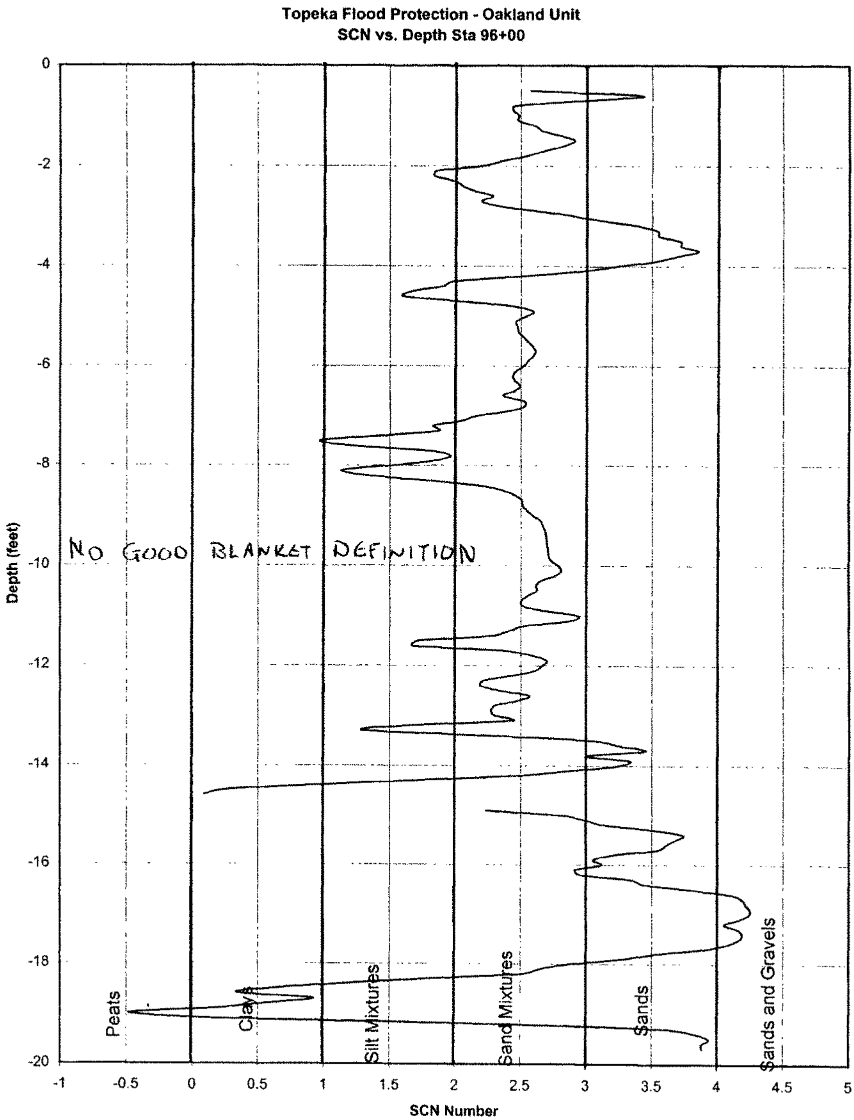

Topeka Flood Protection - Oakland Unit
Cone Resistance vs. Depth Sta 95+00
Depth (feet)
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
0
20
40
60
80
100
120
140
160
180
200
Cone Resistance (tons/sf)
TIP OF PILE ABOUT 25' TO 30'

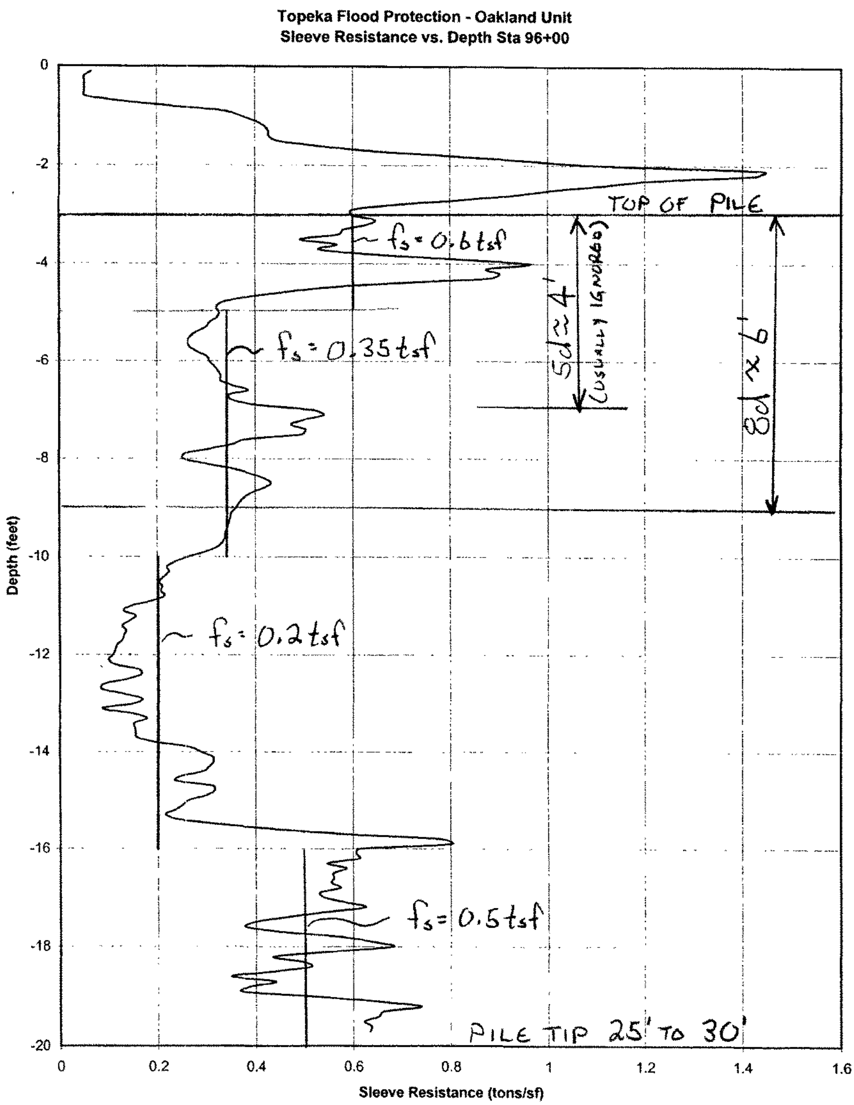
37

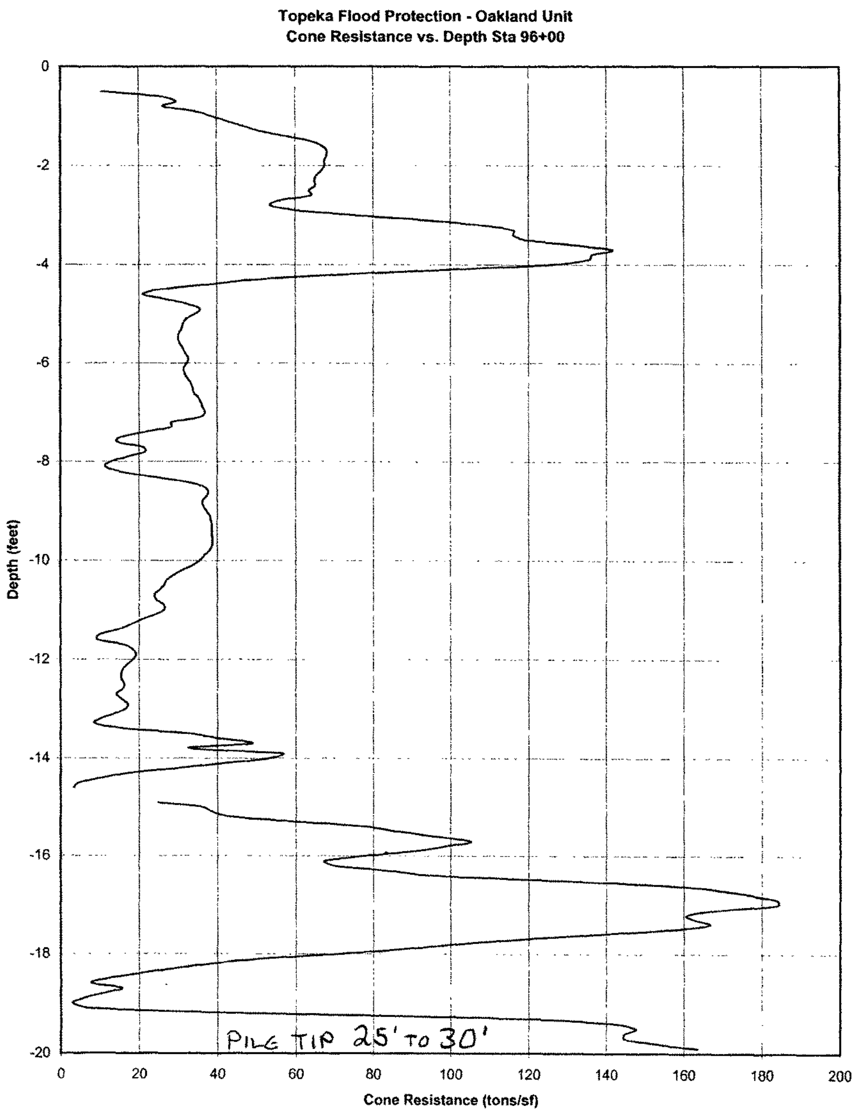

Topeka Flood Protection - Oakland Unit
Push Force vs. Depth Sta 95+00
Depth (feet)
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
0
1
2
3
4
5
6
7
8
9
10
Push Force (tons)

38

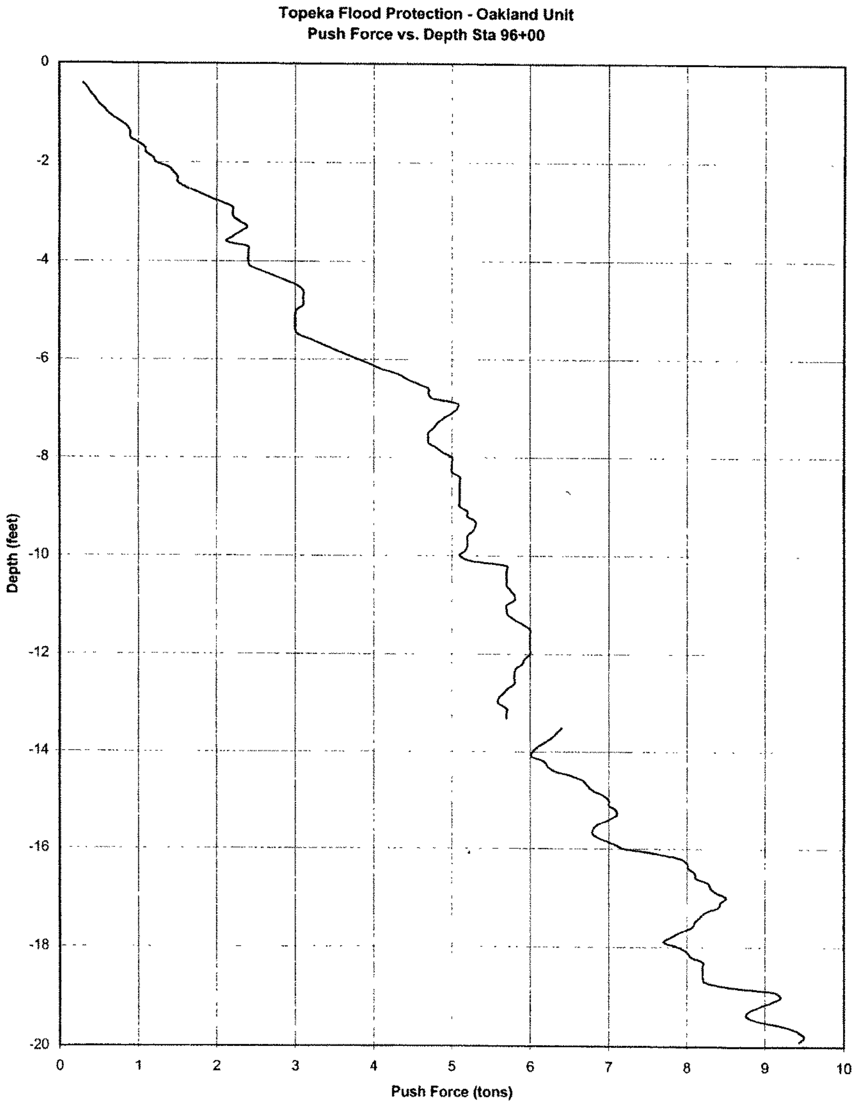
OAK 2 HAL


Topeka Flood Protection - Oakland Unit
SCN vs. Depth Sta 96+00
Depth (feet)
SCN Number
NO GOOD BLANKET DEFINITION
Peats
Clays
Silt Mixtures
Sand Mixtures
Sands
Sands and Gravels
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
-20
-1
-0.5
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5


Topeka Flood Protection - Oakland Unit
Sleeve Resistance vs. Depth Sta 96+00
Depth (feet)
Sleeve Resistance (tons/sf)
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
-20
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
TOP OF PILE
fs = 0.6 tsf
fs = 0.35 tsf
fs = 0.2 tsf
fs = 0.5 tsf
5d ≈ 4'
(USUALLY IGNORED)
8d ≈ 6'
PILE TIP 25' TO 30'

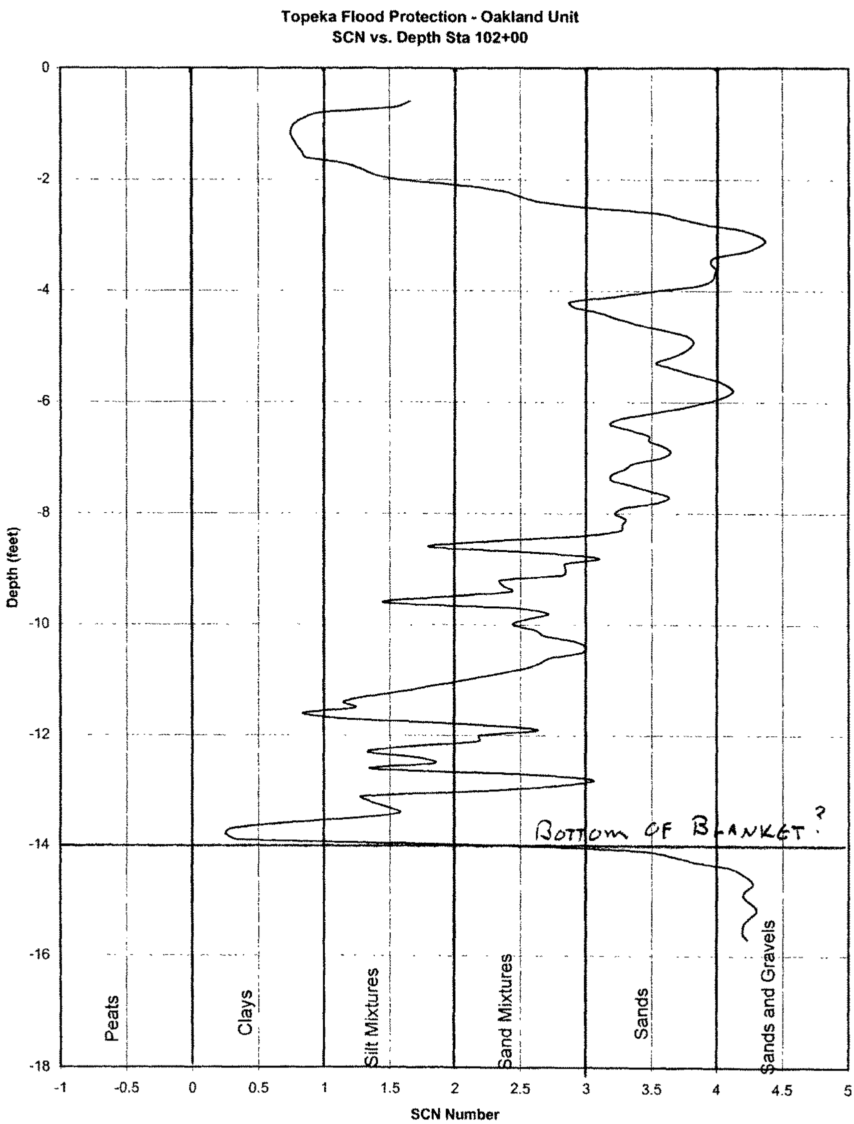

Topeka Flood Protection - Oakland Unit
Cone Resistance vs. Depth Sta 96+00
Depth (feet)
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
-20
0
20
40
60
80
100
120
140
160
180
200
Cone Resistance (tons/sf)
PILE TIP 25' TO 30'

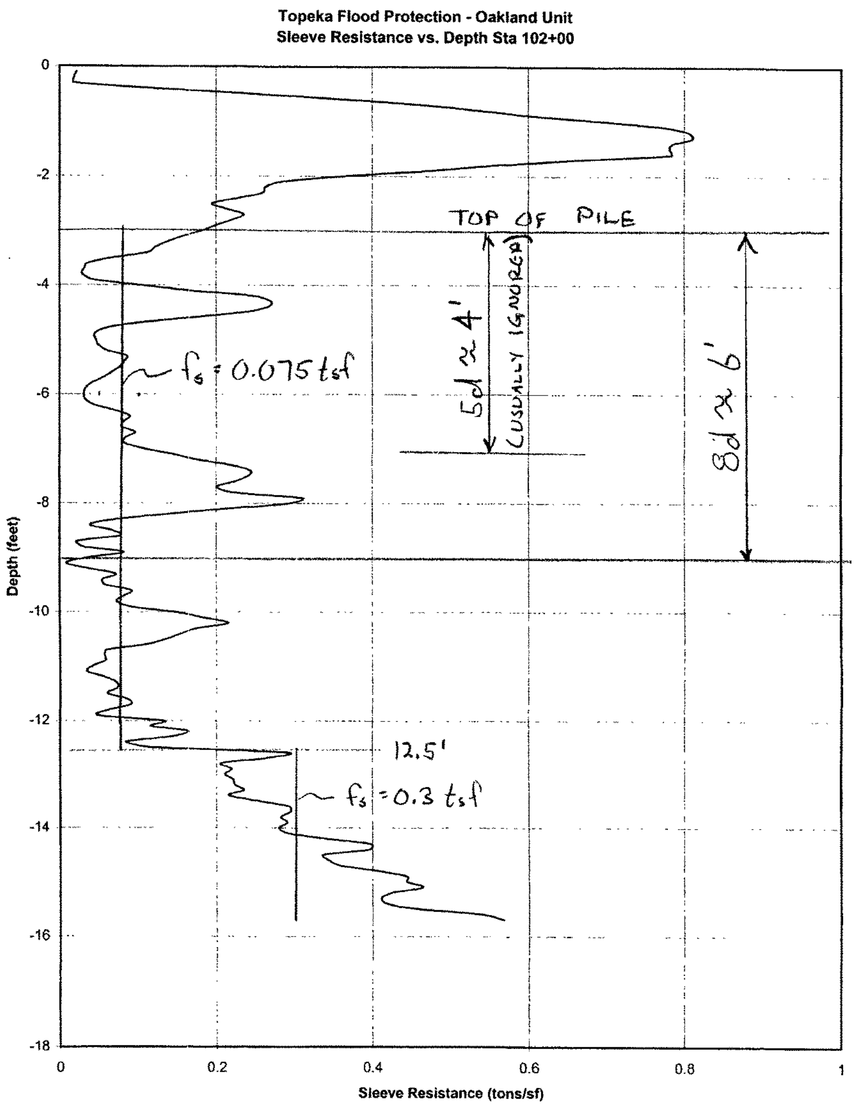
41

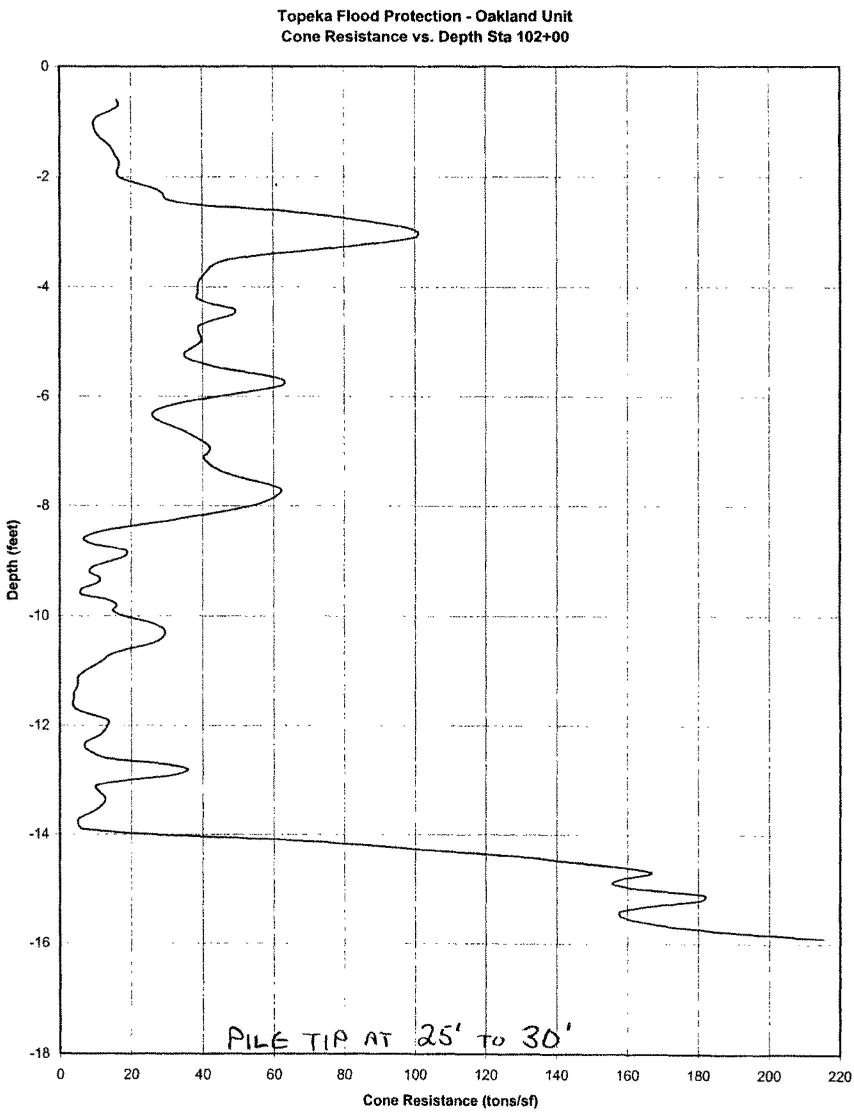

Topeka Flood Protection - Oakland Unit
Push Force vs. Depth Sta 96+00
Depth (feet)
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
-20
0
1
2
3
4
5
6
7
8
9
10
Push Force (tons)

42

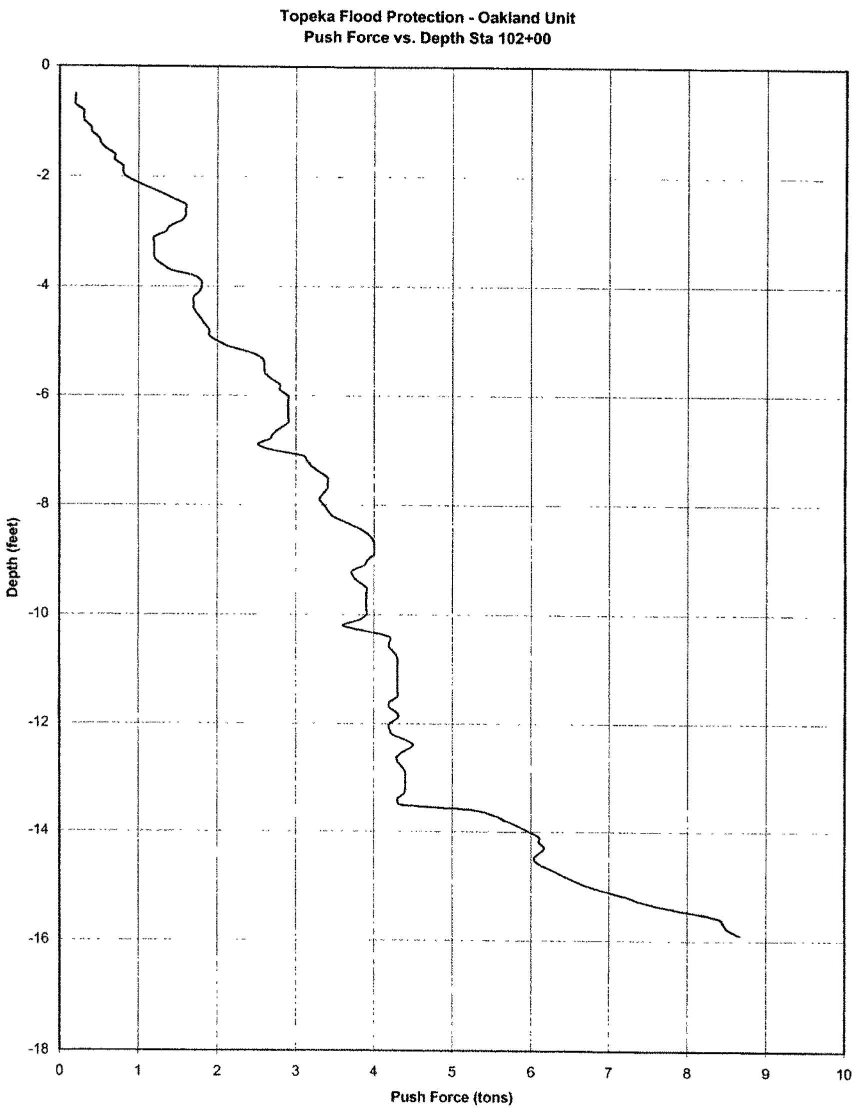
OAK ROE 1


Topeka Flood Protection - Oakland Unit
SCN vs. Depth Sta 102+00
Depth (feet)
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
-1
-0.5
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
SCN Number
Peats
Clays
Silt Mixtures
Sand Mixtures
Sands
Sands and Gravels
BOTTOM OF BLANKET ?


Topeka Flood Protection - Oakland Unit
Sleeve Resistance vs. Depth Sta 102+00
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
Depth (feet)
0
0.2
0.4
0.6
0.8
1
Sleeve Resistance (tons/sf)
TOP OF PILE
5d ≈ 4'
(USUALLY IGNORED)
8d ≈ 6'
fs = 0.075 tsf
12.5'
fs = 0.3 tsf

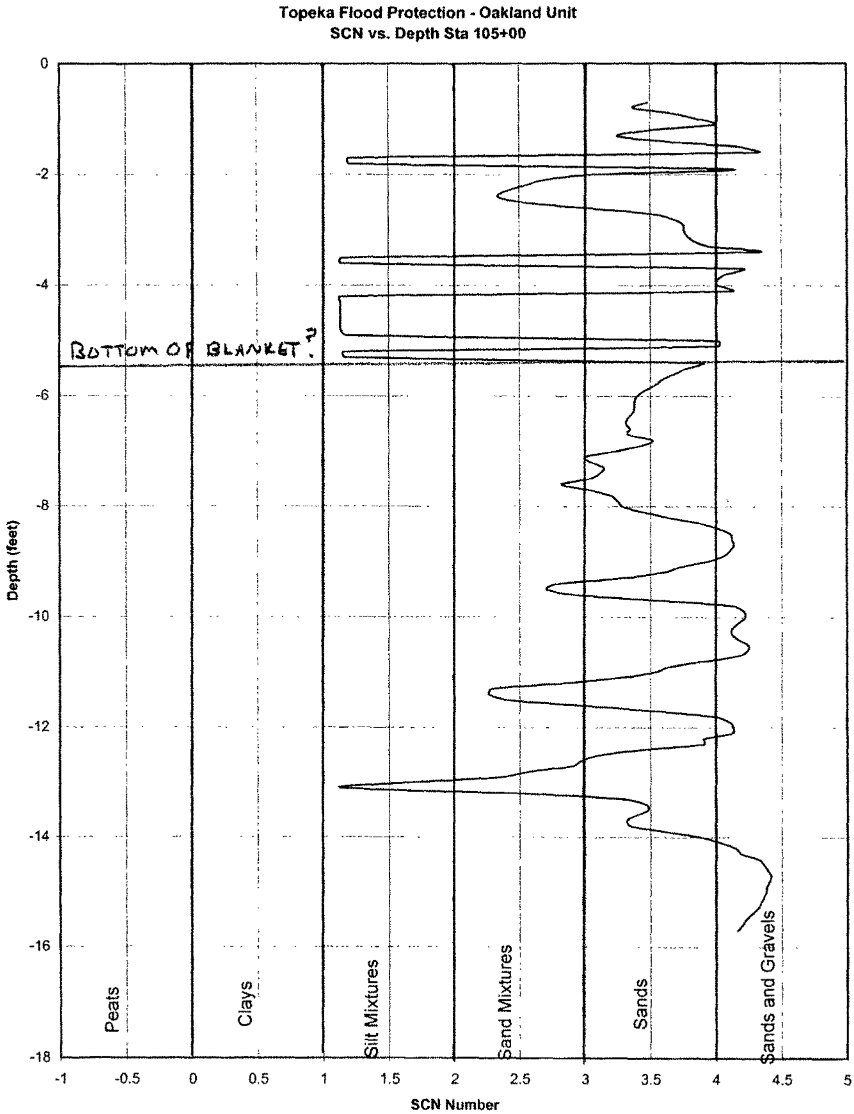

Topeka Flood Protection - Oakland Unit
Cone Resistance vs. Depth Sta 102+00
Depth (feet)
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
0
20
40
60
80
100
120
140
160
180
200
220
Cone Resistance (tons/sf)
PILE TIP AT 25' TO 30'

45


Topeka Flood Protection - Oakland Unit
Push Force vs. Depth Sta 102+00
Depth (feet)
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
0
1
2
3
4
5
6
7
8
9
10
Push Force (tons)

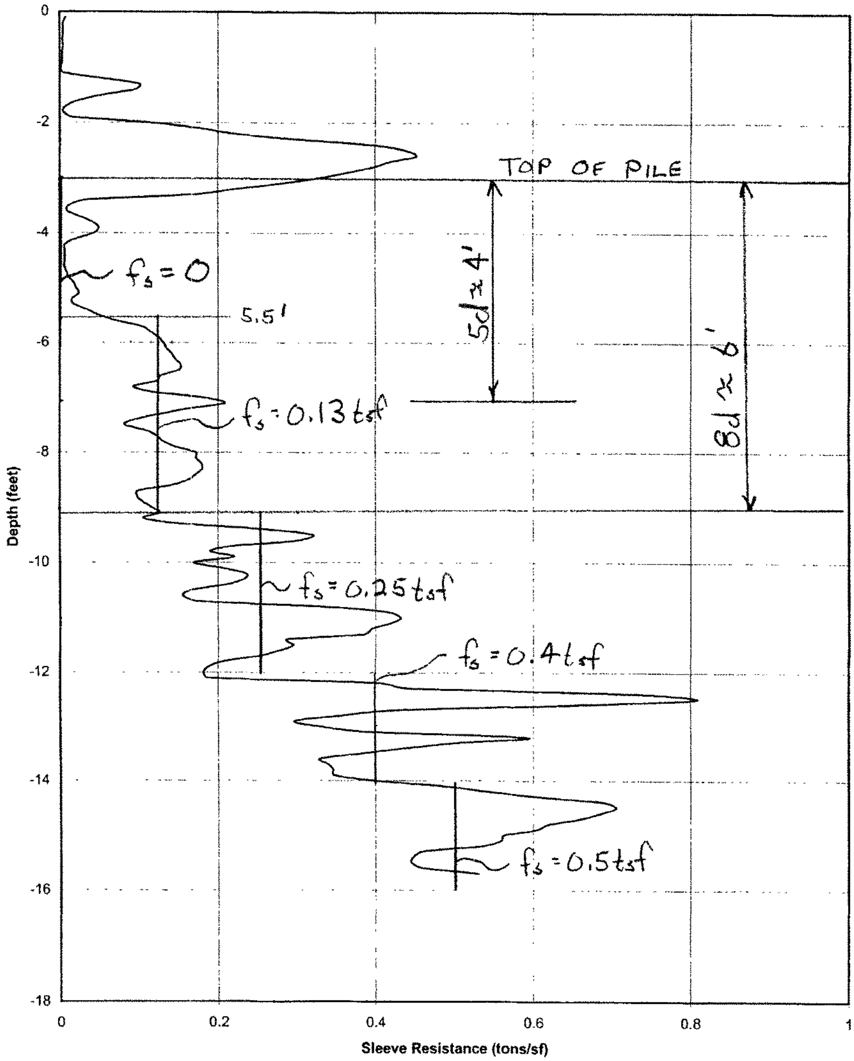
46

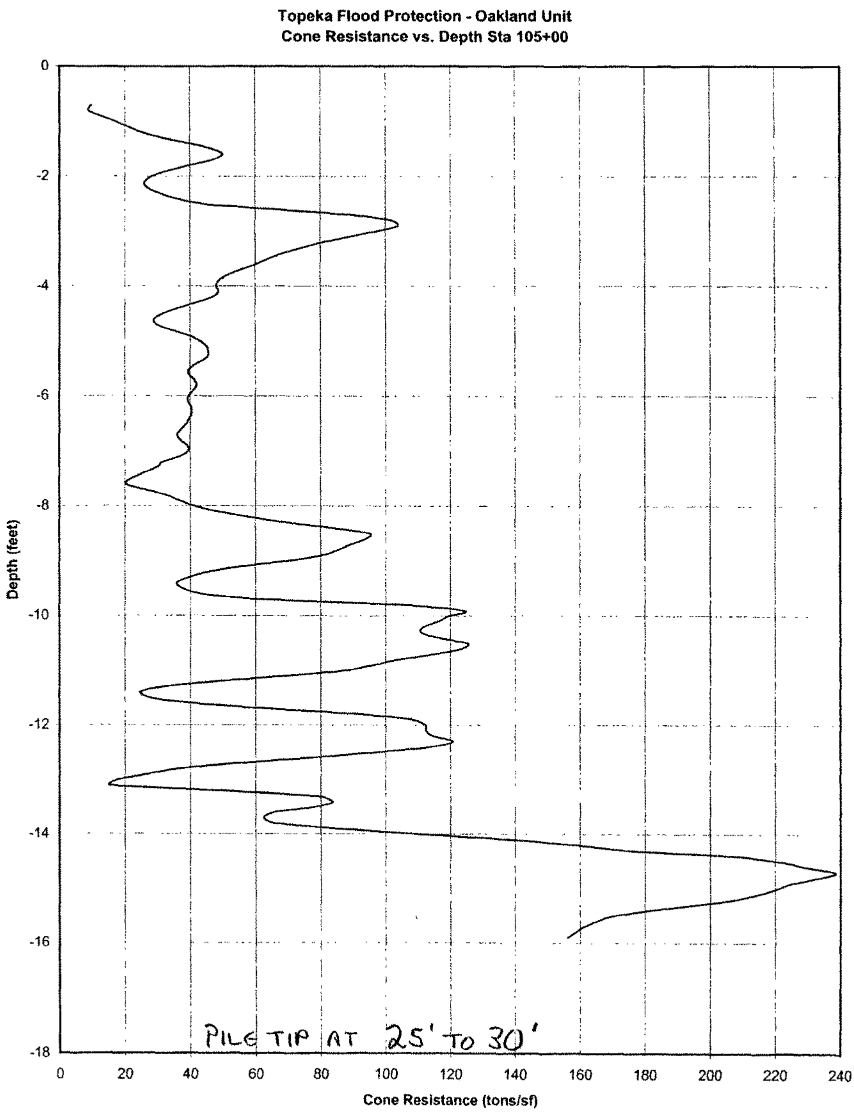
OAK ROE 2

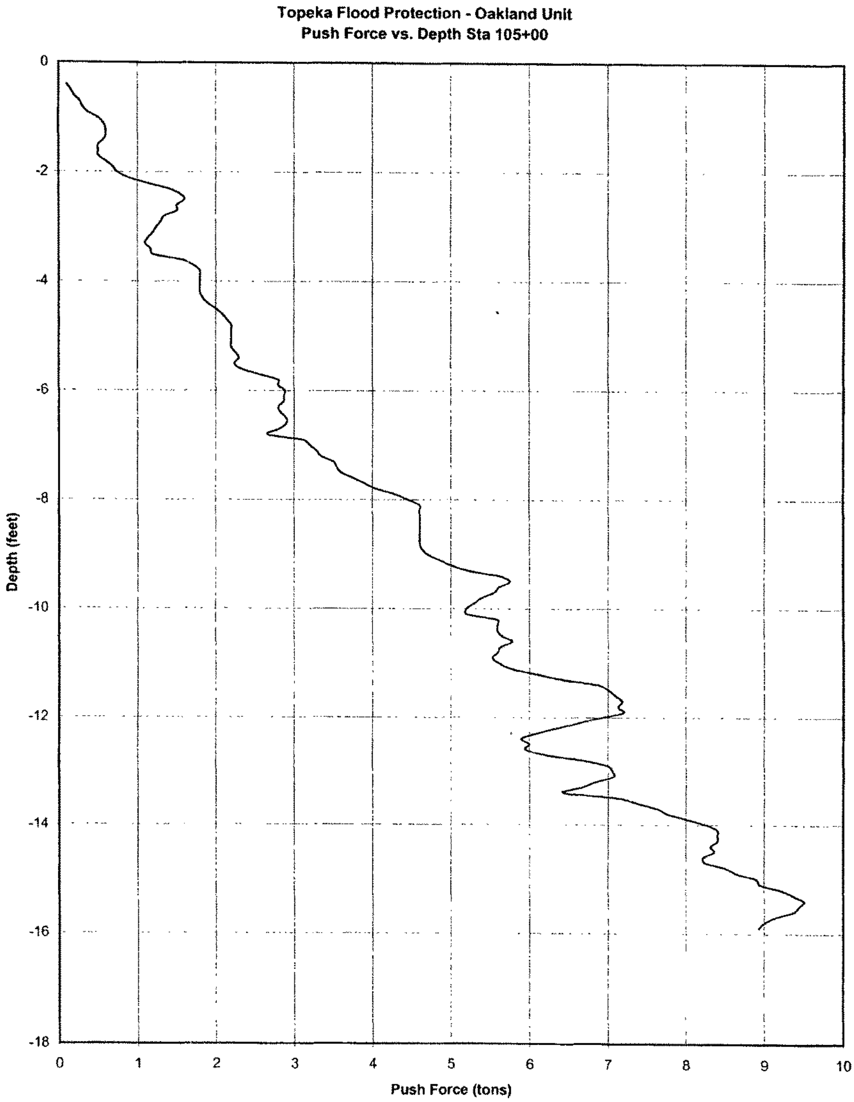

Topeka Flood Protection - Oakland Unit
SCN vs. Depth Sta 105+00
BOTTOM OF BLANKET?
Depth (feet)
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
Peats
Clays
Silt Mixtures
Sand Mixtures
Sands
Sands and Gravels
-1
-0.5
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
SCN Number

47

Topeka Flood Protection - Oakland Unit
Sleeve Resistance vs. Depth Sta 105+00




Topeka Flood Protection - Oakland Unit
Cone Resistance vs. Depth Sta 105+00
Depth (feet)
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
0
20
40
60
80
100
120
140
160
180
200
220
240
Cone Resistance (tons/sf)
PILE TIP AT 25' TO 30'



Topeka Flood Protection - Oakland Unit
Push Force vs. Depth Sta 105+00
Depth (feet)
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
0
1
2
3
4
5
6
7
8
9
10
Push Force (tons)

50

FEASIBILITY STUDY REPORT
TOPEKA, KANSAS, FLOOD RISK MANAGEMENT PROJECT

APPENDIX B

PUBLIC INVOLVEMENT AND COORDINATION

DEPARTMENT OF THE ARMY
Kansas City District, U.S. Army Corps of Engineers
Kansas City, Missouri

PUBLIC INVOLVEMENT

The Draft Feasibility Report was released on September 30, 2008, for a thirty (30) day public review and comment period. A public information open house was held in Topeka, on October 22, 2008, to present the recommendations of the Draft Feasibility Report and obtain public comment.

Notice of the report availability, public comment period, and the public information open house, was distributed to Kansas congressional offices, local elected officials, Federal, State, County, and City agencies, environmental interest groups, Indian tribes, and businesses and property owners within the project area.

Electronic copies on compact disc were provided to the offices of elected officials and review agencies. Hard copies of the report were provided to two local libraries for public availability and an electronic copy of the report was posted on the internet for download at http://www.nwk.usace.army.mil/projects/topeka. A press release announcing the public information open house was sent to media outlets in Topeka, Lawrence, and Wichita, Kansas, and Kansas City, Missouri. Written comments were requested to be submitted by mail, at the public meeting, or through the project website.

The mailing list of all parties who were contacted, the notice letter, and the meeting press release are included in this appendix as Exhibits 1, 2, and 3, respectively. The notification list includes contacts obtained from the Environmental Protection Agency, Region VII, to ensure compliance with Environmental Justice requirements.

Twenty-three attendees were present at the meeting representing the local sponsors, local municipal and elected officials, state agencies, and land and business owners in the study area. Corps of Engineers staff answered questions and assisted the meeting attendees in understanding the need for the project, the process that was undertaken to arrive at the recommended plan, and the scope and impacts of implementing the recommendations. Two local television stations were present and subsequently aired stories concerning the levee project including interviews with Corps staff and local citizens who attended the meeting. A summary of the media response is included in Exhibit 6.

Comments were received during the public review period from the following entities: City of Topeka, Friends of the Kaw, North Topeka Drainage District, U.S. Fish & Wildlife Service, Kansas State Historical Society, Natural Resources Conservation Service, and Federal Aviation Administration. The comment letters received are included in this appendix as Exhibit 4. Responses to comments are included in Exhibit 5.

Public workshops were previously held in the Topeka area in 1996 in conjunction with the Reconnaissance Study. Information gathered at those meetings was included in the Reconnaissance Report and helped to guide the initial work of the Feasibility Study phase.

Regular contact and coordination has been maintained throughout the Feasibility Study with the local sponsors to provide updates on the status and findings of the study. Continually throughout this process, the local sponsors have expressed their desire to see their levee system restored to acceptable reliability. The local sponsors have initiated contact with their congressional representatives to urge continued support for the project.

As detailed in the Environmental Assessment, the views of several State and Federal resource agencies were considered in the study, including the U.S. Fish & Wildlife Service, the Natural Resources Conservation Service, the Kansas Department of Wildlife and Parks, and the Kansas State Historic Preservation Office.

The Corps has also been a planning partner with local interests in identification of potential alternatives for redevelopment of the Topeka riverfront. The City of Topeka and Shawnee County are exploring ways to enhance the economic development and cultural and community aspects of the Kansas River corridor. As part of this process, the Corps has participated in meetings and discussions with local businesses, the Topeka Chamber of Commerce, and local and state agencies, to coordinate the status of the feasibility study and the operational needs of the levee system with possible development opportunities. The Corps also provided assistance with the early conceptual plans for the riverfront area that would maintain the integrity of the levee system through the Planning Assistance to States Program.

Exhibit 1 – Public Notice Mailing List

Congressional Offices

Representative Nancy Boyda
Senator Pat Roberts
Senator Sam Brownback

Local Elected Officials

Governor Kathleen Sebelius
Honorable Shelly Buhler, Chair, Shawnee County Commission
Honorable Bill Bunten, Mayor, City of Topeka

Federal Agencies

Environmental Protection Agency, Region 7
Federal Aviation Administration
Federal Executive Board
Federal Highway Administration
Federal Railroad Administration
Federal Transit Authority
FEMA Region 7
National Park Service
Natural Resources Conservation Service
U.S. Census Bureau
U.S. Coast Guard
U.S. Commission on Civil Rights
U.S. Department of Energy
U.S. Department of Health and Human Services
U.S. Department of Housing and Urban Development
U.S. Department of Justice
U.S. Department of Labor
U.S. Fish and Wildlife Service
U.S. Geological Survey
U.S. Postal Service
U.S. Small Business Administration

State Agencies

KS Biological Survey
KS Department of Agriculture
KS Department of Health and Environment
KS Department of Transportation
KS Department of Wildlife and Parks
KS Division of Budget
KS Division of Emergency Management
KS Forest Service
KS Geological Survey
KS State Conservation Commission
KS State Historical Society
KS State Printing Division
KS Water Congress
KS Water Office

Local Agencies

Shawnee County Emergency Management
Topeka City Manager's Office
Topeka Public Works Department
Topeka Water Department
Topeka Water Pollution Control Department

Environmental Interest Groups

Jayhawk Audubon Society (Lawrence, KS)
Burrough's Audubon Society (Kansas City, MO)
Audubon of Kansas (Manhattan, KS)
Sierra Club
Nature Conservancy Flint Hills
Friends of the Kaw
Keep America Beautiful

Businesses and Property Owners

A.P. Wildgrube
American Commercial Marine Fleeting and Barge Lines
Ameripride Services
Big River Construction Company
Billard Airport
BNSF Railroad
BRB Contractors
Cargill
Catholic Community Service
Central Park Community Center
Central State Underwater Contracting Inc.
Chamber of Commerce of Greater Topeka
CJS Industries
Community Action

Exhibit 1 – Public Notice Mailing List

Community Resources Council
Concerned Citizens for Topeka
Dean Wilson
Del Monte
Dickens Demolition
Dredge America
El Centro De Servicios
Express Card & Label
F.W. Dodge Company
Falley Farms II, LP
FM Global
Garfield Community Center
Goodyear
Great Overland Station
Greater Auburndale Neighborhood Improvement Association
Hallmark
Hill's Pet Nutrition
Hillcrest Community Center
J and H Construction
John G. Levin
Justicia, Inc.
Kansas Chamber of Commerce
Kansas Corporation Commission
Kansas State University
Kaw Valley State Bank & Trust
Kriz Davis Co.
Langley Recycling of Topeka, Inc.
Lindy Spring
Michael Kruger
Midwest Construction Company
Missouri Parks Association
NAACP
NAACP – Topeka Branch
North Topeka Business Alliance
North Topeka On The Move Association
North Topeka West Neighborhood Improvement Association
Oakland Community Center
Oakland Neighborhood Improvement Association
Payless Shoesource Distribution
Rice Community Center
Riviana Foods
Rose Meier et. al.
Sagebrush Education Resources
Shawnee County Resource Center
Southwest Publishing
St. Francis Health Park
Sylvester and Nancy Meier
Topeka Cellular
Topeka Juvenile Correction
U.S. Foods
United Building Centers
United Way
Unity Council of Topeka
Whelans, Inc.

<u>Indian Tribes</u>

Cheyenne River Sioux Tribe
Citizen Potawatomi Nation
Crow Creek Sioux Tribal Council
Delaware Nation
Ho-Chunk Nation
Iowa Tribe of Kansas and Nebraska
Iowa Tribe of Oklahoma
Kickapoo Traditional Tribe of Texas
Kickapoo Tribe of Kansas
Kickapoo Tribe of Oklahoma
Miami Tribe
Northern Cheyenne Tribal Council
Ogallala Sioux Tribal Council
Omaha Tribe of Nebraska
Osage Tribe
Pawnee Nation of Oklahoma
Ponca Tribe of Nebraska
Prairie Band Potawatomi Nation
Rosebud Sioux Tribe
Sac and Fox Nation of Missouri
Sac and Fox Nation of Oklahoma
Sac and Fox Tribe of the Mississippi in Iowa
Santee Sioux Tribe
Shawnee Tribe
Spirit Lake Tribe
Three Affiliated Tribes
Wichita and Affiliated Tribes
Winnebago Tribe of Nebraska
Wyandotte Tribe of Oklahoma
Yankton Sioux Tribe

<u>Media Outlets</u>

Exhibit 1 – Public Notice Mailing List

13 News Saturday Morning Edition-WIBW-
TV KTKA-TV KTWU-TV
27 News at 6 PM-KSNT-TV
49 News, KTKA-TV
6News Lawrence
Daily Kansan
Good Morning Kansas-KTKA-TV
Kansas City Star-Topeka Bureau
Kansas Information Network
Kansas Public Radio
KCVT-FM
KMAJ-AM
KQTP-FM
KSNT-TV
KTOP-AM
KWIC-FM
Lawrence Journal-World
Live at 5PM-WIBW-TV
Morning Show- KWIC-FM
The Workd Company
Topeka Capital Journal
Topeka Metro News
WIBW-AM
Wichita Eagle-Topeka Bureau

Exhibit 2 – Public Notice Letter

DEPARTMENT OF THE ARMY
KANSAS CITY DISTRICT, CORPS OF ENGINEERS
700 FEDERAL BUILDING
601 E 12TH STREET
KANSAS CITY, MISSOURI 64106-2896

REPLY TO
ATTENTION OF:

Planning, Programs and
Project Management
Planning Branch

Dear Interested Party:

In accordance with the National Environmental Policy Act of 1969 (NEPA), the Draft Environmental Assessment (EA) and Draft Feasibility Report for the Topeka, Kansas, Flood Risk Management Study is available for public review at the location below.

http://www.nwk.usace.army.mil/projects/topeka/

This Draft Environmental Assessment (EA) is prepared pursuant to NEPA to assess the environmental and social impacts associated with improving the level of flood risk management for the existing levee system in the Topeka metropolitan area. The EA examines impacts with and without the proposed alternatives. Written comments on the EA and Feasibility Report should be directed to the individual identified below no later than October 30, 2008.

Mr. Eric S Lynn, PE
Topeka Levees Project
Corps of Engineers, Kansas City District
601 E. 12th Street
Kansas City, Missouri 64106-2896

Written comments can also be submitted via electronic mail through the project website.

A public information open house will be held Wednesday, October 22, 2008, from 4:30 to 6:30 p.m., to allow interested persons to obtain additional information and ask questions of project staff. Written comments will also be accepted at that time. The open house will be held in the Holliday Conference Room located on the first floor of the Cyrus K. Holliday Building, 620 SE Madison, Topeka, Kansas. Anyone needing special support to attend the public meeting should contact Shawn Bruns, City of Topeka Engineering Division, at 785-368-3842, or by e-mail at sbruns@topeka.org, at least five days prior to the meeting date to request auxiliary aids.

The Corps of Engineers will respond to all written comments received as a result of issuance of the Draft EA and Feasibility Report during preparation of the Final Environmental Assessment and Final Feasibility Report.

Sincerely,

David L. Combs.
Chief, Planning Branch

Exhibit 3 – Public Information Open House Press Release

US Army Corps of Engineers ®
Kansas City District

News Release

U.S. Army Corps of Engineers Public Affairs
Kansas City, Missouri 64106-2896
Phone: (816) 389-3486 Fax (816) 389-2021

October 8, 2008

Release #PA-2008-28

For immediate release

Corps to hold public meeting for Topeka Levee Project

TOPEKA, Ks.— U.S. Army Corps of Engineers Kansas City District personnel will be available to the public to answer questions regarding the Topeka Levee Project at a meeting on Oct. 22, 2008, from 4:30 p.m. to 6:30 p.m. on the first floor of the Cyrus K. Holliday Building, 620 SE Madison, Topeka, Ks.

The project consists of six levee units located on the Kansas River and two of its tributaries and protects residential, commercial, industrial and public utilities areas as well as transportation infrastructure.

The Corps recently completed a feasibility study which addresses the existing reliability level of the levee system and recommends a comprehensive and cost-effective plan to restore an acceptable level of reliability. This study can be found at the Topeka and Shawnee County Public Library and the Kansas State Library. It is also available at www.nwk.usace.army.mil/projects/topeka. The plan to restore the levee will be presented during the public meeting.

This project was completed in 1974 and has prevented an estimated $229.3 million in flood damages through 1994, with an estimated $57.8 million worth of damage prevented in the '93 flood alone. The current cost of the recommended plan is estimated at $22 million, which includes design and construction of the project.

The Corps is also accepting written comments about the project by mail through Oct. 30, 2008. Comments may also be submitted through the project Web site, www.nwk.usace.army.mil/projects/topeka/. Written comments may be mailed to Eric Lynn, Topeka Levees Project, U.S. Army Corps of Engineers, Kansas City District, 601 E. 12th Street, Room 843, Kansas City, Mo., 64106-2896.

For more information, call the Kansas City District Public Affairs office at (816) 389-3486.
www.nwk.usace.army.mil

EXHIBIT 4

Written Comments Received During the Public Comment Period

Written comments were received from the following organizations on the dates indicated:

October 30, 2008	Friends of the Kaw
October 28, 2008	U.S. Department of the Interior, Fish and Wildlife Service
October 25, 2008	North Topeka Drainage District
October 22, 2008	City of Topeka, KS, Public Works
October 10, 2008	Kansas State Historical Society
October 7, 2008	U.S. Department of Agriculture, Natural Resources Conservation Service
October 3, 2008	U.S. Department of Transportation, Federal Aviation Administration

Message sent from Topeka Levee Feasibility Study Website
(http://www.nwk.usace.army.mil/projects/topeka/)

October 30, 2008

Mr. Eric S Lynn, PE
Topeka Levees Project
Corps of Engineers, Kansas City District
601 E. 12th Street
Kansas City, MO 64106-2896

RE: Topeka, Kansas, Local Flood Protection Project

Dear Mr. Lynn,

Friends of the Kaw is a grassroots environmental advocacy group based in northeastern Kansas with over 450 household or business memberships and a mailing list that reaches over 1,200 individuals. Since we incorporated as a 501 (c) (3) organization in 1997, our mission has been to protect and preserve the Kansas River--known as the Kaw--for present and future generations. In 2001 we joined the International Waterkeeper Alliance, and as a condition of our Alliance membership, FOK maintains a full-time, professional Riverkeeper. A non-governmental public advocate, the Riverkeeper's job includes the roles of leader, educator, investigator, media spokesman, and scientist. This river guardian serves as eyes, ears, ombudsman, and advocate for the Kaw and thus for all who those who live in the Kansas River valley.

As the Kansas Riverkeeper I am very familiar with the Kansas River and have surveyed the Kaw through the city of Topeka in 2007 and 2008 to document the location of physical structures and areas in need of restoration and protection. Our survey team photographed impacts to the river channel using a camera that recorded GPS locations, and made detailed observations of the riparian zone recorded on aerial photographs provided by the Army Corps of Engineers. Quite frankly the Kansas River through the city of Topeka is the least attractive section of the river due to the construction of levees so close to the channel.

Friends of the Kaw believes that it is important to protect the people and property of Topeka from the risk of flood damage caused by Kansas River and its tributaries. Based on the recent assessment we agree that improvements need to be made to the levee system. However, we believe the levee system on the Kaw through Topeka is very constricting, and agree with comments made by the U.S. Fish and Wildlife Service that the levees limit the amount of floodplain habitat by narrowing the river as it passes through the city. As the river flows through this narrow, rock lined ditch there is nothing to slow or dissipate floodwaters. During flood events the water literally fills the manmade ditch; this exacerbates the problem and potentially endangers downstream structures. Every attempt should be made to provide additional riparian habitat between the river channel and levees, which would reduce the potential of erosion and damage to the levees, reduce the possibility that floodwaters will be amplified and create more problems downriver, and provide important wildlife habitat and recreational opportunities. What little riparian habitat that is left is by far the highest quality habitat in the area, and every attempt should be made to not only protect this habitat but to expand it.

We ask that wherever possible the Army Corps of Engineers consider widening the area between the river channel and levees and establish additional riparian trees and vegetation—not simply as a mitigation for riparian habitat removed for construction on the proposed project, but to improve the flawed design of the existing flood control structures. It is obvious from our surveys that previous construction of the levee system did not include any mitigation for habitat that had been destroyed and as a result there has been a long-term loss of riparian habitat on the river as it runs through Topeka. We would like to see a reversal of this trend, with an increase in the amount of riparian zone vegetation created during each new bout of construction. We believe that such an increase in riparian vegetation would not only improve the ecological services provided by the river, but it would also aid in flood control and stabilization of the banks and levee system.

One of Friends of the Kaw's long-term goals is to establish the Kaw as a 171-mile recreational trail from Junction City to Kansas City. To that end we have helped communities along the river add boat ramps and parks along the river so that the public can conveniently access the river with canoes, kayaks and small boats. We would ask the Corps whenever possible to consider providing additional public access to the river in conjunction with proposed and future construction projects, and to ensure that boat traffic can move across any in-river structures. Recent construction projects, including the new bridge in Topeka, have created dangerous situations for boaters; we ask that any construction that will create hazards to boat traffic be conspicuously identified and that safe passageways be provided. This has been an on-going problem, particularly in the Topeka stretch of the river, and we are very concerned that future construction projects improve on the poor record of recent years.

We strongly oppose any alternatives that would use borrow obtained by river dredging. During the past ten years, the Kansas River has been listed as one of American Rivers' Most Endangered Rivers three times. The Kaw headwaters lie at the junction of the Republican and Smoky Hill Rivers, and it runs 171 miles to join the Missouri River in Kansas City; there are ten (10) permitted in-stream dredge sites in the Kansas River. In-stream sand dredging is an activity that causes great damage to riverbanks, bed morphology and native habitat. The Army Corps of Engineers recently retired three (3) other permits due to unacceptable riverbed degradation. The Corps has identified riverbed degradation due to dredging in the Topeka reach of the Kaw (river miles 84 through 91), and no attempt should be made to encourage additional dredging in the Kansas River channel. Friends of the Kaw understands that sand is needed for a healthy construction economy but believes sand can be reasonably and efficiently obtained from pit mines in the Kansas River valley. Friends of the Kaw has actively promoted this philosophy for the past ten years. Borrow for the proposed levee project must be obtained outside of the river channel to prevent further channel degradation and head cutting which would be counterproductive to the goal of improving levee stability.

Sincerely,

Laura Calwell
The Kansas Riverkeeper
Friends of the Kaw

United States Department of the Interior

FISH AND WILDLIFE SERVICE
Kansas Ecological Services Office
2609 Anderson Avenue
Manhattan, Kansas 66502-2801

October 28, 2008

Eric S Lynn, PE
Topeka Levees Project
Corps of Engineers, Kansas City District
601 East 12th Street
Kansas City, Missouri 64106-2896

FWS Tracking # 2009-FA-0005

Dear Mr. Lynn:

We have reviewed the Draft Environmental Assessment (EA) and Draft Feasibility Report for the Topeka, Kansas, Flood Risk Management Study received October 2, 2008 The following comments on the EA are provided by the U.S. Fish and Wildlife Service (Service) for your consideration. We do not have any comments on the Draft Feasibility Report.

GENERAL COMMENTS

The Service appreciates the coordination between the Service and the U.S. Army Corps of Engineers (Corps) throughout the development of this project and values the efforts made to address our concerns. Four alternatives were carried forward for analysis in the EA. Alternative 1, the Locally Preferred Plan and NED preferred alternative, appears to meet the objectives of the project with minimal impacts to fish and wildlife habitat including wetlands. Proposed mitigation for these impacts appears to be adequate by replacing the 7.5 acres of disturbed habitat with 15 acres of mitigation. After accounting for the time lag to reach a comparable maturity to existing habitat, the mitigation for this alternative may provide a more diverse habitat than currently exists.

The Pressure Relief Wells Alternative would also meet the objectives of the project. This plan may have fewer impacts to wildlife habitat as it would result in less land needed for borrow, therefore possibly decreasing the amount of woodland habitat disturbed.

The Commercial Fill Alternative would also meet the objectives of the project and minimize the environmental impact of the borrow operations. However, the commercial fill would likely come from permitted dredging operations in the Kansas River, which would compete with existing commercial demands and could result in increased environmental impacts to the aquatic environment of the Kansas River.

The No-Action Alternative would not meet the objectives of the project. However, it would also not have impacts to fish and wildlife habitat as no fill would be needed.

SPECIFIC COMMENTS

Section 10.5: Subsection - Future Conditions With Recommended Plan (page 13)

The EA states "any grassland areas disturbed from construction activities would be re-seeded following construction with rye, brome, fescue and then mulched. The entire mitigation plan can be found in Appendix F."

In our previous reviews of this project, we recommended that disturbed areas be re-seeded with native grasses such as buffalo grass. Native grasses offer many benefits over domestic grasses such as drought tolerance, minimal maintenance, wildlife benefits, and better erosion control qualities. We continue to recommend that native grasses be used to reseeded disturbed areas. In addition, the use of native grasses to reseed disturbed areas, which may have previously been in non-native grasses, would contribute to the successful implementation of the Corps Environmental Operating Principles 1 and 5 which were discussed in the Draft Feasibility Report.

The use of brome and fescue is not discussed in the Mitigation Plan, Appendix F. However, annual rye (*Lolium multiflorum*) is listed as a temporary cover crop in the mitigation areas and is acceptable for this application. We are opposed to the use of exotic, non-native grasses, which can be invasive, in the mitigation areas.

Section 10.5: Subsection – Endangered or Threatened Species (page 14)

The bald eagle (*Haliaeetus leucoccephalis*) is no longer federally listed as a threatened or endangered species. However, as it is still protected by the Bald and Golden Eagle Protection Act and the Migratory Bird Treaty Act we encourage you to implement the measures outlined under <u>Future Conditions with Recommended Plan</u> to avoid and minimize impacts to bald eagles.

Section 16.0 Coordination (page 30)

The Fish and Wildlife Service office, which provided the Fish and Wildlife Coordination Act reports, is in the Service's Region 6. Therefore, the correct listing for your coordination with the Fish and Wildlife Service should be "U.S. Department of the Interior, Fish and Wildlife Service, Region 6".

Section 17.0 Compliance (page 31)

The EA states that the Draft Fish and Wildlife Coordination Act (FWCA) report was received in your office on September 29, 2007 and the Final FWCA report was received on March 16, 2007. We believe that the date of the Draft FWCA report is in error and should have been the year 2006.

Thank you for the opportunity to comment on this project. If you have any questions, please contact me or Susan Blackford of my staff at (785) 539-3474.

Sincerely,

Mike LeValley
Field Supervisor

cc: EPA, Kansas City, KS (Wetland Protection Section)
KDWP, Pratt, KS (Environmental Services)
KDHE, Topeka, KS (Bureau of Water)

MJL/shb

US Army Corps
of Engineers ®
Kansas City District

TOPEKA, KANSAS, FLOOD RISK MANAGEMENT PROJECT
FEASIBILITY STUDY AND ENVIRONMENTAL ASSESSMENT
COMMUNITY INFORMATION MEETING
OCTOBER 22, 2008

Name: Dale Sandberg	Address:
Affiliation: North Topeka Drainage District	
Email: [illegible]	Phone Number:

Please write your comments in the space below. Comments may also be sent to the address on the reverse side or submitted through the internet from http://www.nwk.usace.army.mil/projects/topeka. Comments are due by October 30, 2008, to be considered in the final project report.

In the high water of 1993 I was in charge of operations for all the Topeka Flood Protection Units except the Water Works Unit. The biggest concern that occurred was how spongy the ground got landward of approx. Sta. 420 to 470 of the North Topeka Unit. No sand boils occurred, but water could be seen oozing up from the ground. Flood waters were 8 feet from top of levee at this location. If not already done, a review of the sub-soil conditions be done to determined if they are adequate for the up-lift pressures.

As part of the 1993 operation it was necessary to round up portable pumps to pump over the levees at flood gate structures at Sta. 177+40 (drainage for Industrial Park) and Sta. 493+70. Some consideration should be given to small permanent pumping plants at these locations, especially for Sta. 177+40.

On the South Topeka Unit at Sta. 46+74 there is a drainage structure that was constructed in the 1930's and is part of today's system. The sluice gate operator is located at the riverside toe of the levee and must be remembered to be closed before it is necessary or it will be under water. Someone not aware of this could cause a major failure.

On the North Topeka Unit at Soldier Creek Pumping Plant there are 3 relief wells in Old Soldier Cr. just west of the plant. These wells tested poorly when they were installed and became plugged to the point they cannot be tested and serve no purpose. Do we need new wells?

CITY OF TOPEKA

PUBLIC WORKS, Administration
620 SE Madison, 3rd Flr
Topeka, KS 66607
Tel: (785) 368-3801

TOPEKA Public Works

Mike Teply, Director
Email: mteply@topeka.org
Fax: (785) 368-3806
www.topeka.org

October 22, 2008

Mr. Eric S. Lynn, PE
US Army Corps of Engineers
Kansas City District
601 E. 12th Street
Kansas City, MO 64106-2896

RE: Comments on Draft Feasibility Report for the Topeka, Kansas, Flood Risk Management Study

Dear Mr. Lynn:

The City of Topeka Public Works Department offers the following comments for the Feasibility Report for the Topeka, Kansas, Flood Risk Management Study.

- At the Water Works Floodwall location where fill is proposed between Station 10+00 and Station 16+50, there is an area where an existing railroad siding is near the floodwall and in conflict with the proposed fill. Water Treatment Plant operations require that the railroad siding be maintained.

- Near River Mile 87 on the north side of the river opposite the Water Treatment Plant, a borrow area is proposed for the North Topeka Underseepage Berm. This is an area where a boat ramp, portage route, and associated public river access and park facilities are proposed.

The City of Topeka requests that these issues be considered in the final Environmental Assessment and Feasibility Reports. Public Works staff will work with the Corps of Engineers to clarify and resolve these concerns.

Sincerely,

Mike Teply, Director
City of Topeka Public Works

KANSAS

R&C No. 06-07-001

Kansas State Historical Society
Jennie Chinn, *Executive Director*

KATHLEEN SEBELIUS, GOVERNOR

October 10, 2008

Eric Lynn
Topeka Levees Project
Corps of Engineers, Kansas City District
601 E. 12th Street
Kansas City, Missouri 64106-2896

RE: Draft Environmental Assessment (EA)
Draft Feasibility Report
Topeka, Kansas Flood Risk Management Study
Shawnee County

Dear Mr.Lynn:

In accordance with 36 CFR 800, the Kansas State Historic Preservation Office has reviewed the above-referenced documents noted in your recent letter that describe proposed upgrades to the flood control system in Topeka, Kansas. Our office has already reviewed this project and responded in two letters, dated July 5, 2006 and August 25, 2006. At that time, we concluded that levee construction and use of the proposed borrow areas would have no effect on historic properties as defined in 36 CFR 800. Since we see no significant changes, this office continues to have no objection to implementation of the project.

Any changes to the project, which include additional ground disturbing activities, will need to be reviewed by this office prior to beginning construction. If construction work uncovers buried archeological materials, work should cease in the area of the discovery and this office should be notified immediately.

This information is provided at your request to assist you in identifying historic properties, as specified in 36 CFR 800 for Section 106 consultation procedures. If you have questions or need additional information regarding these comments, please contact Tim Weston at 785-272-8681 (ext. 214).

Sincerely,

Jennie Chinn, Executive Director and
State Historic Preservation Officer

Timothy Weston for

Patrick Zollner
Deputy SHPO

6425 SW Sixth Avenue • Topeka, KS 66615-1099
Phone 785-272-8681 Ext. 205 • Fax 785-272-8682 • Email jchinn@kshs.org • TTY 785-272-8683
www.kshs.org

United States Department of Agriculture

NRCS

Natural Resources Conservation Service
760 South Broadway
Salina, Kansas 67401-4604

Phone: 785-823-4500
FAX: 785-823-4540
www.ks.nrcs.usda.gov

October 7, 2008

Mr. Eric S. Lynn
Professional Engineer
Topeka Levees Project
U.S. Army Corps of Engineers, Kansas City District
601 East 12th Street
Kansas City, Missouri 64106-2896

Dear Mr. Lynn:

In response to your request for review of the Draft Environmental Assessment (EA) and Draft Feasibility Report for the Topeka, Kansas, Flood Risk Management Study, the Kansas Natural Resources Conservation Service (NRCS) has no additional comments.

Dennis J. Brinkman, Supervisory District Conservationist, Topeka, Kansas, assessed and explained NRCS Food Security Act wetland compliance responsibility on private land. Alan R. Boerger, Resource Conservationist, Manhattan, Kansas, completed Form AD-1006, Farmland Conversion Impact Rating, and these assessments are included in your Draft EA.

I agree with the project conclusion on Pages 29 and 30 of the EA. The recommended plan is the environmentally-preferred alternative.

If you need further information, contact Terry M. Conway, State Resource Conservationist, at 785-823-4547 or by e-mail at terry.conway@ks.usda.gov.

Sincerely,

ERIC B. BANKS
State Conservationist

cc:
Terry M. Conway, State Resource Conservationist, NRCS, Salina, Kansas
Kenneth A. Kuiper, State Biologist, NRCS, Salina, Kansas

U.S. Department
Of Transportation

**Federal Aviation
Administration**

Central Region
Iowa, Kansas
Missouri, Nebraska

901 Locust
Kansas City, Missouri 64106-2325

October 3, 2008

Mr. Eric S. Lynn, P.E.
Topeka Levees Project
Corps of Engineers, Kansas City District
601 E. 12th Street
Kansas City, MO 64106-2896

Dear Mr. Lynn:

Re: Draft EA for Topeka, Kansas, Flood Risk Management Study

The Federal Aviation Administration (FAA) reviews other federal agency environmental from the perspective of the FAA's area of responsibility; that is, whether the proposal will have effects on aviation and other FAA responsibilities. We generally do not provide comments from an environmental standpoint. Therefore, we have reviewed the material furnished with the transmittal letter regarding the draft Environmental Assessment for the Topeka, Kansas, Flood Risk Management Study, and we have no comments regarding environmental matters.

However, we remind you that you will need to consider whether or not the project will require formal notice and review from an airspace standpoint. The requirements for this notice may be found in Federal Aviation Regulations (FAR) Part 77, Objects Affecting Navigable Airspace. This regulation is contained under Subchapter E, Airspace of Title 14 of the Code of Federal Regulations. We would like to remind you that if any part of the project exceeds notification criteria under FAR Part 77, notice should be filed at least 30 days prior to the proposed construction date. For instructions on how to file and who to contact with any questions, please visit the following web site:
https://oeaaa.faa.gov/oeaaa/external/portal.jsp

Sincerely,

Todd M. Madison, P.E.
Environmental Specialist

Exhibit 5—Comment/Response Summary

Agency	Nature of Contact/Date	Comment Summary	Response Summary
Friends of the Kaw	Submitted via project website on 10/30/2008	• Concerned that the levees limit the amount of floodplain habitat by narrowing the river as it passes through the city, and potentially endangering downstream structures. Additional riparian habitat should be placed between the river channel and levees. The existing riparian habitat should not only be protected but expanded • Request to widen the area between the river channel and levees and establish additional riparian trees and vegetation in order to mitigate the riparian habitat removed for construction and to improve the flawed design of the existing structure. • Asked Corps to consider providing additional public access to the river. • Oppose borrow for the proposed levee project to be obtained in the river. It must be obtained outside of the river channel to prevent degradation and head cutting.	• Existing development and infrastructure found on both sides of the Kansas River through downtown Topeka prevents any significant relocation of the levee system to establish a wider riparian corridor. The recommended project does not propose to change the scope or location of the original project. • Majority of work proposed will take place on the landward side of the river and avoid impacts to habitat along the riverbank. The proposed area for mitigation of these impacts is located on the riverward side of the levee, adjacent to the already existing riparian habitat. • Authority under which this project is being conducted does not allow the Corps to consider or construct facilities for public recreation. However, we have been working with the Topeka/Shawnee County Riverfront Authority to assist them in their planning for economic and cultural development. • Material borrow activities are proposed for areas that are currently clear of riparian habitat. Sand dredging was considered as an alternative source; however, our study was based on land-based borrow acquisition.

Agency	Nature of Contact/Date	Comment Summary	Response Summary
U.S. Department of the Interior, Fish and Wildlife Service	Submitted via letter on 10/28/2008	• General Comments--The Locally Preferred Plan and NED preferred alternative appears to meet the objectives of the project with minimal impacts to fish and wildlife habitat including wetlands. The Pressure Relief Wells Alternative would also meet the objectives of the project and have fewer impacts to wildlife habitat as it would result in less land needed for borrow. The Commercial Fill Alternative would also meet the objectives of the project and minimize the environmental impact of the borrow operations; however dredging would be permitted in the Kansas River, which would compete with existing demands and increase environmental impacts. The No-Action Alternative would not meet project objectives, and it would not have any impacts on fish and wildlife. • Specific Comments—Recommend that disturbed areas be re-seeded with native grasses such as buffalo grass. However, rye is listed as a temporary cover crop in the mitigation areas and is acceptable for this application. • Encourage implementation of measures outlined under Future Conditions with Recommended Plan to avoid and minimize impacts to bald eagles. • Correct the listing on page 31 to U.S. Department of the Interior, Fish and Wildlife Service, Region 6. • Correct the date on page 29 that the draft was received on to September 29, 2006.	• General comments noted. • Buffalo grass is not amenable for use on levee/berm slopes. Levees must be mowed on a regular basis for close inspection to detect settlement, slope instability, presence of burrowing animals, depressions or other effects. Also, deep rooted grasses like buffalo grass provide a path for water to seep through the impervious layer of the levee, which could create potential failure locations within the levee system. • Editorial comments noted and have been revised as recommended.

Agency	Nature of Contact/Date	Comment Summary	Response Summary
North Topeka Drainage District	Submitted via comment form from the public meeting on 10/22/08	• Review sub-soil conditions esp. between Sta. 420 to 470 to determine if they are adequate for the up-lift pressures. • During 1993 operation, it was necessary to round up portable pumps to pump over the levees at flood gate structures (Sta 177+40 and Sta 493+70). Consider small permanent pumping plants at these locations. • Sluice gate at Sta 46+74 needs to be closed before it is necessary or it will be under water. • There are three relief wells in Old Soldier Creek, just west of the plant. The wells tested poorly and became plugged to the point they cannot be tested and serve no purpose. Do we need new wells?	• Sub-soil conditions were reviewed for the entire levee area by geotechnical staff and the critical areas for the levee stability identified. • Addition of new permanent pump stations to the existing levee system was not founds to be necessary to protect the levee. • The "Topeka, Kansas, Master Flood Emergency Operation and Maintenance Manual" directs that the structure at Station 46+74 be closed at a Sardou Gage of 12.7. Strict adherence to the order by the local sponsor should ensure that this and all structures are operated at the proper time to avoid levee failure. • We are consulting with our Geotechnical Branch regarding this question and will provide a response via letter. We believe that the integrity of the levee is not affected.

Agency	Nature of Contact/Date	Comment Summary	Response Summary
City of Topeka, KS Public Works	Submitted via letter on 10/22/08	• Fill is proposed between Station 10+00 and Station 16+50. There is an area where an existing railroad siding is near the floodwall and in conflict with the proposed fill. Water Treatment Plant operations require that the railroad siding be maintained. • Near River Mile 87, a borrow area is proposed for the North Topeka Underseepage Berm. This is an area where a boat ramp, portage route, and associated public river access and park facilities are proposed.	• It is not the intent of the project to substantially impact the existing facilities and operations of the treatment plant. Specific locations and fill placement will be further refined during the PED phase. • Area near River Mile 87 is not actually proposed for borrow but instead activities to offset environmental impact occurring at other proposed project locations in the levee system.

Agency	Nature of Contact/Date	Comment Summary	Response Summary
Kansas State Historical Society	Submitted via letter on 10/10/2008	• The office reviewed this project and responded in two letters dated July 5, 2006 and August 25, 2006. Since we see no significant changes, this office continues to have no objections to implementation of the project. • If construction work uncovers buried archeological materials, work should cease in the area of discovery and the office should be notified immediately.	Comments noted.

Agency	Nature of Contact/Date	Comment Summary	Response Summary
U.S. Department of Agriculture, Natural Resources Conservation Service	Submitted via letter on 10/07/2008	• The Kansas Natural Resources Conservation Service has no additional comments. • We agree with the project conclusion on page 28 of the EA. The recommended plan is the environmentally-preferred alternative.	Comments noted.

Agency	Nature of Contact/Date	Comment Summary	Response Summary
U.S. Department of Transportation, Federal Aviation Administration	Submitted via letter on 10/03/2008	• We have no comments regarding environmental matters. • Please consider whether or not the project will require formal notice and review from an airspace standpoint.	Comments noted.

Exhibit 6—Media Coverage

October 22, 2008—Channel 49, ABC
Story by: Kendall Jones
Link:
http://www.ktka.com/news/2008/oct/22/23_million_dollar_solution_levees/

Summary: The U.S. Army Corps of Engineers aims to fix the problems and other flood control issues in the city of Topeka. The Corps plans to repair the levees by replacing portions of the walls and adding more soil in other places. Quote from Eric Lynn, Project Manager, "Even though it's $23.5 million to implement these improvements," Lynn said defending the high cost, "It would be in the hundreds of millions worth of damage were the levee to fail during the flood".

Script:

"We have been looking at the existing levee system in Topeka and evaluating its effectiveness and reliability against the Kansas River flooding and we have identified some areas that could use improvement," said Army Corps of Engineer Project Manager, Eric Lynn.

A meeting was held Wednesday evening at the Cyrus K. Holliday building in Topeka. From 6:30-8:30 citizens could stop by and review the project proposal.

To restore the levee would cost $23.5 million. "The way that the project is set up is that the federal government will pay 65% of that project cost and so we're only asking the city to come up with at 35% or a little over $8 million," said Lynn.

"We are hoping that this can be moved quickly because a lot of our economic development activities rely on the river and can be impacted by the river status. So we're anxiously looking to see this happen," said Deputy City Manager, Randy Speaker.

The project is at a standstill, however, until Congress gives its ok and the federal funds can be allocated or until the Water Resources Development Act can be re-visited.

To hear what Topekans thought of the project click on the video icon at the top of this story.

October 22, 2008—WIBW Channel 13, CBS
Story by: Rae Chelle Davis
Link: http://www.wibw.com/home/headlines/32665019.html

Summary: "We have been looking at the existing levee system in Topeka and evaluating its effectiveness and reliability against the Kansas River flooding and we have identified some areas that could use improvement," said Army Corps of Engineer Project Manager, Eric Lynn. "We are hoping that this can be moved quickly because a lot of our economic development activities rely on the river and can be impacted by the river status.

So we're anxiously looking to see this happen," said Deputy City Manager, Randy Speaker.

Script:

It's a $23.5 million project to keep Topekans dry.

In August, 49 News was the first to tell you about the deficiencies in the levees along the Kansas River.

Now, the U.S. Army Corps of Engineers aims to fix the problem and other flood control issues in the city of Topeka.

For life-long Topekan Ted Mize, fixing levees around Topeka is long over due.

"I did sandbags to try and save the water plant in 1951," he said referring to the last major flood.

Thursday, Mize got his first look at a plan by the US Army Corps of Engineers to help keep the Kansas River in its banks.

"Those things are not just a 6-month deal," Mize said. "I mean, it's over a great length of time, but I think we're kind of late on a lot of it."

Late, is kind of an understatement.

"You have a system here that dates back to the '30s even," said Project Manager Eric Lynn.

The biggest problem with the levees is that over time water has seeped underneath the walls. Lynn said that makes them more likely to fail during a flood.

"Right now we have identified that there is potential for risk," Lynn said.

The corps of engineers plans to fix the levees by replacing portions of the walls and adding more soil in other places.

The entire project will cost more than $20 million dollars.

"Even though it's $23.5 million to implement these improvements," Lynn said defending the high cost, "It would be in the hundreds of millions of dollars worth of damage were the levee to fail during a flood."

The federal government will pay 65 percent of that, but the remaining 35 percent will be up to the city.

With the economy flooding with turmoil, Lynn says multiple projects from the Corps are already on hold.

That's not the news Mize wanted to hear.

"Let's see, 1908, '51," he said recounting old floods. "Guess what? That's nothing that's 50 years away or anything like that. We've already had our 50 years."

See the US Army Corps of Engineers study here. You can also make suggestions.

October 21, 2008—The Topeka Capital-Journal
Story by: Tim Hrenchir
Link: http://www.cjonline.com/stories/102108/loc_346687083.shtml

Levee restoration price rises

Estimated cost of project about $6M more than originally thought

The estimated price tag for restoring the Kansas River levee in Topeka has risen from $17 million to $23.5 million.

Eric Lynn, Topeka levees project manager for the Army Corps of Engineers in Kansas City, Mo., shared the latter figure with members of the Topeka-Shawnee County Riverfront Authority at their monthly meeting Monday.

LEARNING ABOUT LEVEE RESTORATION

Representatives from the Army Corps of Engineers will answer questions and hear public comments about the Topeka levees feasibility study from 4:30 to 6:30 p.m. Wednesday on the first floor at the city of Topeka's Cyrus K. Holliday Building, 620 S.E. Madison. The corps also is accepting written comments about the project by mail through Oct. 30. Comments may be mailed to Eric Lynn, Topeka Levees Project, U.S. Army Corps of Engineers, Kansas City District, 601 E. 12th Street, Room 843, Kansas City, Mo. 64106-2896. A review of the study can be found online at www.nwk.usace.army.mil/projects/topeka/. Comments also can be submitted at that Web site.

The federal government will pay for 65 percent of the restoration costs if Congress decides to go ahead with the project, Lynn said.

Monday's estimate comes after Topeka public works director Mike Teply told city council members April 15 that the anticipated cost for the levee project would be $17 million, with the city being expected to pay about $6 million of that. The council voted that day to levy an increase in stormwater runoff fees expected to raise enough revenue to would cover the $6 million.

But Lynn told riverfront authority members Monday that in 2008 dollars, the cost for the project is estimated to be almost $20 million. That rises to about $23.5 million when factoring in interest and inflation, he said.

Lynn said officials with the Corps of Engineers' Kansas City District are conducting a feasibility study regarding the project and plan to seek its approval from the corps at a meeting in Washington, D.C., on Jan. 29. That will be Kansas Day, noted riverfront authority chairman Mike Hayden, a former governor of Kansas.

Lynn said for the project to become a reality, it then would need to be listed in the next Water Resources Development Act approved by Congress. Hayden said Congress appears likely to consider such an act late next year. Lynn suggested it would be at least three to five years before levee restoration work began.

Riverfront authority members Hayden, Beth Fager, Doug Kinsinger, Bob Sachs, Ralph Skoog and Larry Tenopir all attended Monday's meeting, where Lynn told them the corps is looking at potential levee restoration at other sites that include Manhattan, the Kansas City area and St. Joseph, Mo. He said estimated $85 million for the project in Kansas City and $35 million at St. Joseph, Mo. Lynn didn't have an estimate for Manhattan.

The riverfront authority also made plans Monday to present copies to the Shawnee County Commission and Topeka City Council next month of the Kansas Riverfront Master Plan it voted to accept Sept. 29. That document lays out a plan for developing a mixed-use district along the riverfront just north of downtown Topeka as well as trails and access points elsewhere along the river between S.W. Urish Road and Seward Avenue.

Hayden said the riverfront authority will make presentations to the commission Nov. 13 and to the council Nov. 18.

The master plan is available online at www.topekachamber.org/downloads/08_riverfront_final.pdf.

The plan estimates overall costs will be $62.33 million for riverfront development planning, design and construction between 2009 and 2017, with potential funding sources including tax-increment financing and federal, state and local government. That figure doesn't include levee restoration costs.

Tim Hrenchir can be reached at (785) 295-1184 or tim.hrenchir@cjonline.com.

FEASIBILITY STUDY REPORT
TOPEKA, KANSAS, FLOOD RISK MANAGEMENT PROJECT

APPENDIX C

REAL ESTATE PLAN

DEPARTMENT OF THE ARMY
Kansas City District, U.S. Army Corps of Engineers
Kansas City, Missouri

REAL ESTATE PLAN
For
TOPEKA, KS, FLOOD RISK
MANAGEMENT PROJECT

SHAWNEE COUNTY, KANSAS

This Real Estate Plan (REP) information is developed in support of the Feasibility Study for the subject project. The authority for this feasibility study is the continuing authority of Section 216 of the 1970 Flood Control Act. The Reconnaissance Report published in September 1997 identifies a potential Federal interest in flood damage reduction measures. The non-Federal sponsor (NFS) for the Feasibility Study is the City of Topeka. The purpose of this plan is to include information on any real estate activities that may be involved for the identified project. The project is located on the Kansas River in Shawnee County, Kansas. The project is currently estimated to involve approximately 22 parcels and 217 acres (Table 2.1).

1. **PROJECT PURPOSE:** To raise the level of protection to provide greater protection against rare flood events as identified in the Reconnaissance Study and in support of the Feasibility Study. All of Topeka and most of South Topeka are located in the protected flood plain. The Federal Levee System which protects the Topeka area includes approximately 38 miles of levee.

Geotechnical concerns are related to underseepage beneath the levee which may occur during high flow events. If underseepage is allowed to surface on the land side uncontrolled during a flood, it can create a failure of the levee foundation by piping. Underseepage pressures can be countered using either underseepage berms (additional soil placed on the ground surface) to prevent flow to the surface, or by pressure relief wells that provide a controlled path for the underseepage. Berms are the preferred method based on lower installation cost and maintenance needs, but require more real estate for installation and borrow areas.

Stability concerns have been identified at several of the concrete floodwall and closure gap structures. The direct pressure of high water on one side of the structure during a flood may cause either sliding, overturning, or breaking of the structure. The primary method to counter this concern is the installation of a stability berm on the land side of the structure to provide additional support. Structures that cannot be corrected using stability berms require replacement.

2. **DESCRIPTION OF LANDS, EASEMENT, RIGHTS-OF-WAY, RELOCATION, DISPOSAL (LERRD):** Project purposes require acquisition at a minimum of temporary easements that will include borrow area sites and temporary access. Temporary work area construction easements will be utilized for the underseepage berms because they will fall outside of the critical zone of the levee and will not be impacted by land management activities. No Fee Simple Acquisition is required for levee right-of-way (r-o-w) on this project. A disposal site is not required as the project plan is for all trees and branches to be burned on site and all topsoils to be used on the new surfaces. Construction debris will be hauled to a commercial landfill and therefore included as a construction cost.

Estates to be acquired by the NFS(s) are explained below and further detailed in Table 2.1:

a. Temporary Work Area Construction Easement: A temporary easement and right-of-way in, on, over and across (the land to be described) for a period not to exceed three (3) years, beginning with the date of possession by the City of Topeka, for use by the United States, its representatives, agents, and contractors as a temporary ingress and egress route, construction area, and work area, including the right to move, store and remove equipment and supplies, and erect and remove temporary structures on the land and to perform any other work necessary and incident to the construction of the Topeka Local Levee Protection Project, Flood Damage Reduction Project, together with the right to trim, cut, fell and remove therefrom all trees, underbrush, obstructions, and any other vegetation, structures, or obstacles within the limits of the right-of-way; reserving, however, to the landowners, their heirs and assigns, all such rights and privileges as may be used without interfering with or abridging the rights and easement hereby acquired; subject, however, to existing easements for public roads and highways, public utilities, railroads and pipelines.

b. Temporary Work Area Construction Easement, Borrow: A temporary easement and right-of-way in, on, over and across (the land to be described) for a period not to exceed three (3) years, beginning with the date of possession by the City of Topeka, for use by the United States, its representatives, agents, and contractors as a temporary borrow area, including the right to ingress and egress, move, store and remove equipment and supplies, and erect and remove temporary structures on the land and to perform any other work necessary and incident to the construction of the Topeka Local Levee Protection Project, Flood Damage Reduction Project, together with the right to trim, cut, fell and remove therefrom all trees, underbrush, obstructions, and any other vegetation, structures, or obstacles within the limits of the right-of-way; reserving, however, to the landowners, their heirs and assigns, all such rights and privileges as may be used without interfering with or abridging the rights and easement hereby acquired; subject, however, to existing easements for public roads and highways, public utilities, railroads and pipelines.

Below is a summary of estates and project features to be acquired or utilized, estimated acres and estimated land values for the Non-Federal sponsor. **Note:** Land values are based on a Gross Appraisal, performed by Omaha District, U.S. Army Corps of Engineers, dated February 8, 2007.

Table 2.1: City of Topeka, Kansas

ESTATE/Project Feature	ESTIMATED ACRES	ESTIMATED LAND VALUE
Temporary Construction Easement, Access and Work Area (3- year period) 5.5% FMV	12	$115,383.00
Temporary Construction Easement, Borrow (3- year period) 100% FMV*	179	$539,800.00
Deed Restriction (mitigation site on sponsor-owned land)	26	$102,638.00
Estimated TOTAL	22 parcels 217	$757,821.00

***Note**: Borrow is 100% Fair Market Value (FMV) due to the extent of top soil removal, up to 5 feet in some locations which will leave the land unusable for its current agricultural purposes. A safe assumption for planning purposes is to expect paying nearly 100% of FMV for this property. Final locations and quantities that will be taken from each site have not been finalized. Given these circumstances it would be irrelevant to estimate a residual value of the lands after the borrow has been removed without the assistance of a timely appraisal.

3. **NON-FEDERAL OWNED LANDS:** The City of Topeka owns seven parcels of land in fee adjacent to the existing levee within the city boundary. Only temporary construction easement is needed over these seven parcels, so the non-federal sponsor shall only receive LERRD credit for this estate. In addition the project will require that one of the parcels be subject to a deed restriction for a mitigation site, and therefore the non-federal sponsor will receive LERRD credit for the "encumbered" value of the site. Of the seven city-owned parcels of land none were previously provided as an item of cooperation for another federal project.

The City of Topeka also has a permanent easement for the levee system and will not receive LERRD credit for this property (see paragraph 5).

4. **NON-STANDARD ESTATES**: There will be no non-standard estates required for this project.

5. **EXISTING FEDERAL PROJECT IN AREA**: The current levee systems in the City of Topeka are existing Federal projects, managed by the City of Topeka, and are located on opposite sides of the Kansas River and provide local flood protection for the metropolitan area of Topeka, Kansas and surrounding communities. These units were designed by the Corps of Engineers, Kansas City District, and constructed between 1962 and 1968. The sponsors will only receive credit for the newly provided lands, easements and right-of-ways.

6. **FEDERALLY OWNED LAND IN PROJECT AREA**: No federally owned land exists in the project area.

7. **NAVIGATIONAL SERVITUDE**: All of the proposed improvements are above the ordinary high water marks, so navigational servitude doesn't apply (CENWK-EC-HH memo dated March 12, 2007).

8. **REAL ESTATE MAPPING**: Maps of the proposed project areas are attached as EXHIBIT "A" Pages 1 – 10. Project scope is either a floodwall stability berm or an underseepage berm and the corresponding borrow areas and mitigation site. Mapping is consistent with the preferred alternative footprint, easements will be clearly defined as the feasibility issues are resolved.

9. **FLOODING INDUCED BY PROJECT**: The feasibility study requires the analysis of any induced damages due to raises in the water surface profile caused by raises of the studied levee unit. No levee raises are being proposed in the Topeka Levees Feasibility study; therefore, no induced damages are expected. In accordance, no physical takings analysis will be required.

10. **BASELINE COST ESTIMATE FOR REAL ESTATE**: Table 10.3 provides a summary of the Real Estate Baseline Cost Estimate for LERRD, including NFS incidental costs. The baseline costs for each unit were originally prepared on a Fiscal Year 2007 price basis. The total cost only was updated to FY 2008 for inclusion in the total project cost estimate presented in the Feasibility Report.

Table 10.3: City of Topeka, KS, Project Costs (15% contingency included in all values)

FY 2007 Prices	Waterworks	North Topeka Berm	North Topeka Mitigation	North Topeka Relief Well	South Topeka Borrow	South Topeka Berm	South Topeka Floodwall Berm	Oakland Floodwall Berm	Oakland Berm	Oakland Borrow	TOTAL
Land Values	$465	$54,101	$12,075	$12,588	$461,909	$8,910	$5,516	$1,677	$43,142	$158,827	$759,210.00
PL 91-646	$0	$0	$0	$0	$0	$0	$14,031	$0	$0	$0	$14,031.00
Utilities	$0	$0	$0	$0	$0	$240,000	$120,000	$0	$0	$0	$360,000.00
NON Fed. Incidental Costs	$1012	$16,767	$7,682	$7,682	$9,706	$8,464	$24,840	$13,156	$782	$9,706	$99,797.00
TOTAL	$1,477	$70,868	$19,757	$20,270	$471,615	$257,374	$164,387	$14,833	$43,924	$168,533	$1,233,038.00

Note: Government in-house labor costs for real estate assistance are estimated at $28,771.00.

Note: Utility LERRD Values will continue to be updated due to lack of information on compensable rights of the utility relocations. See Section 16, paragraph 1.

11. **RELOCATION ASSISTANCE (P.L. 91-646)**: The non-federal sponsor has been advised of the Uniform Relocation Assistance and Real Property Acquisitions Policies Act of 1948, as amended (Public Law 91-646). Relocation assistance may be needed for property owned by the Riviana Foods Inc. since its storage and business activities may be affected by the project construction activities.

12. **MINERAL ACTIVITY IMPACTED PRESENT/FUTURE**: At this time the COE is not aware of any outstanding mineral interests that need to be acquired or subordinated in the project area.

13. **ASSESSMENT OF NON-FED SPONSOR LEGAL/PROFESSIONAL CAPABILITY**: The non-Federal sponsor has land acquisition capabilities either through contract or in-house personnel and are fully capable of acquiring any lands necessary for the project. See Exhibit "B" for the Assessment of Non-Federal Sponsor's RE Acquisition Capabilities Checklist. Financial capability is addressed in the main report.

14. **ZONING ORDINANCES CONSIDERED IN LIEU OR/SUPPORT OF LERRD REQUIREMENTS**: There are no zoning ordinances proposed in connection with the project.

15. **REASONABLE, DETAILED, & COORDINATED TIMELINE FOR LERRD ACQUISITION**: The following are proposed milestones for project implementation:

Activity	Project TimeLine
Div. & HQ Review and Approval	*June 2007*
Feasibility Complete	*December 2008*
PED (2 years)	*2010*
Acquisition Plan to Sponsor	*2010*
Acquisition (18 months)	*2011-2012*
LERRD Certification	*2011-2012*
Construction (2 years)	*2014*

16. **FACILITY/UTILITY RELOCATION**: There are known utilities in the area of which eight of the utility crossings will require possible replacement or relocation. Continued coordination with the project sponsor will occur to identity the real property interests and any compensable interests. A railroad exists near the South Topeka underseepage berm, but the project is not expected to interfere with railroad operations. Preliminary Attorney's Opinion's of Compensability Interest, as required by paragraph 12-17 (c) of Engineering Regulation 405-1-12 will be completed for all utility relocations during the beginning of PED as project requirements are further defined.

17. **IMPACT OF HTRW**: The land in the project is not known or suspected to contain hazardous and/or toxic wastes. The Kansas City District of the US Army Corps of Engineers did complete the Feasibility Study (FS) Hazardous, Toxic, and Radiological Waste (HTRW) assessment of the project area in 2005. Based on site visits and data search information, the known or suspected contaminant areas located in, on, under, or adjacent to the land required for the construction, operation and maintenance of the project are identified in Appendix E.

18. **OPPOSITION/SUPPORT OF PROJECT BY LOCAL LANDOWNERS**: The Corps of Engineers is not aware of any public opposition to this project at this time. All comments received during the public review period for the Draft Report will be added to the Public Involvement Appendix of the Final Report. Corrective actions or reconsiderations of alternatives will be implemented as needed based upon the comments received.

19. **NOTIFICATION TO NON-FEDERAL SPONSOR OF EARLY ACQUISITION OF LERRD**: The non federal sponsor will be issued a risk letter explaining the risk of acquiring lands prior to execution of the PCA and a final project design. During PED the construction limit will be clearly defined and an acquisition schedule set.

20. **OTHER RE ISSUES:** RE assumes that storage and/or disposal of excess material will be part of the construction contract.

A temporary easement will be needed on railroad property, so significant delays could result when negotiating acquisition instruments with the railroad.

Two parcels near the North Topeka site (see attached map, North Topeka Mitigation Site), owned by the non-federal sponsor, have been identified to mitigate the loss of habitat at the South Topeka borrow site. A "Notice and Declaration of Land Use Restriction" will need to be recorded to ensure that the parcels are maintained in accordance with a mitigation site plan prepared by CENWK-PM-PF. Any other use shall be restricted to a use that is compatible and subordinate to the Project purposes. This restriction shall run with the land and shall be binding on the heirs, successors and assigns of the Declarant.

Topeka Levee Protection Project, Real Estate Site Plan

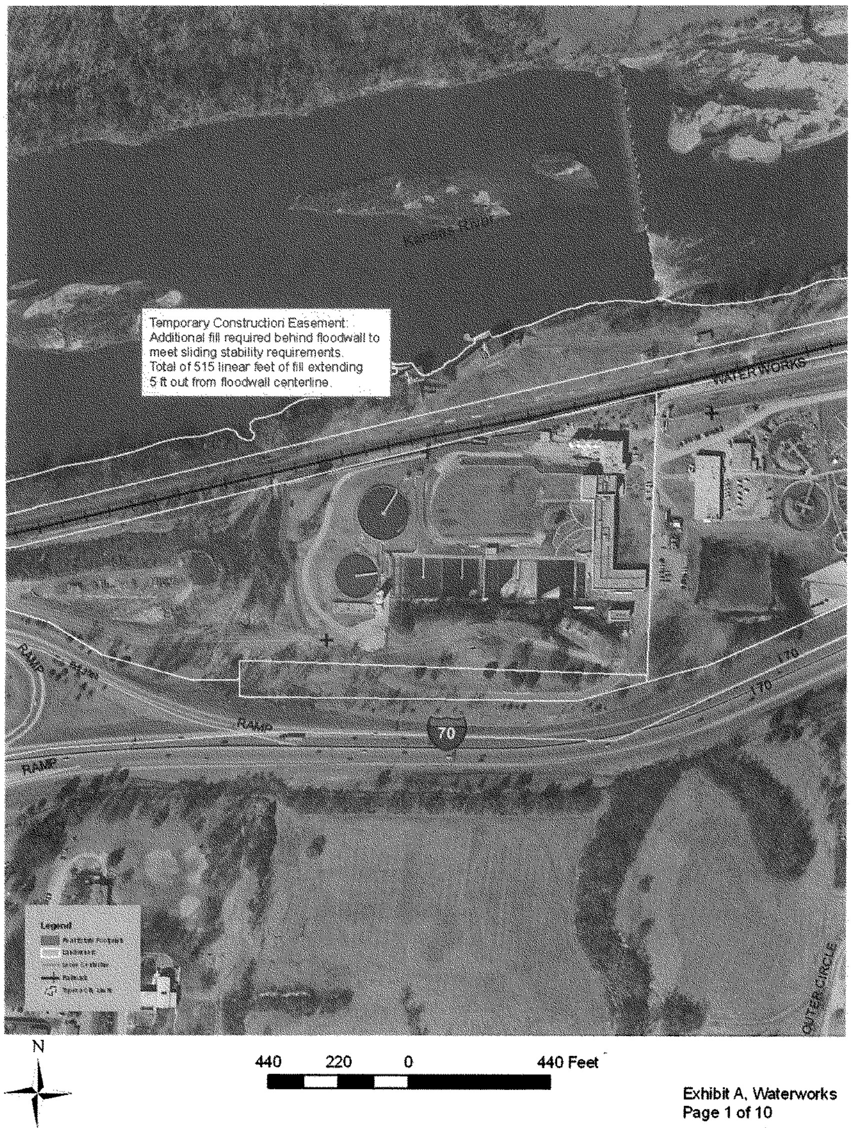


Exhibit A, Waterworks
Page 1 of 10

Topeka Levee Protection Project, Real Estate Site Plan

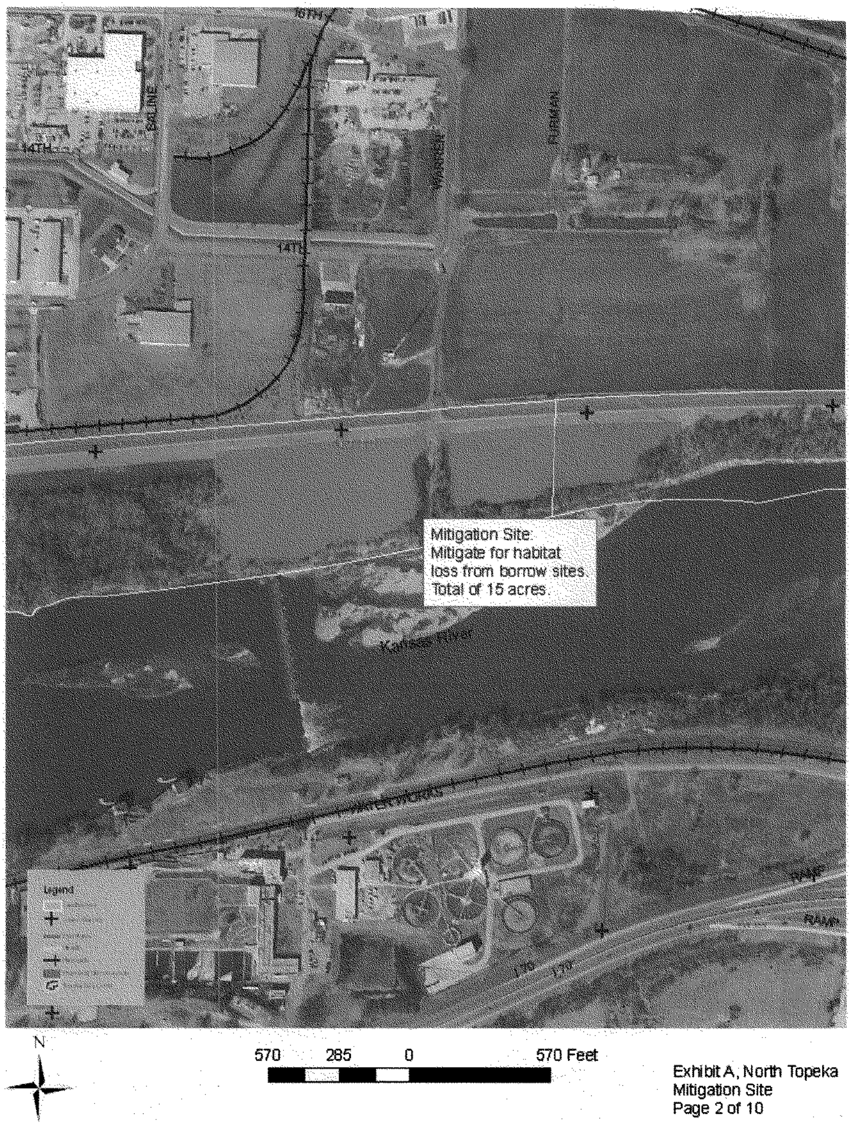


Exhibit A, North Topeka
Mitigation Site
Page 2 of 10

Topeka Levee Protection Project, Real Estate Site Plan

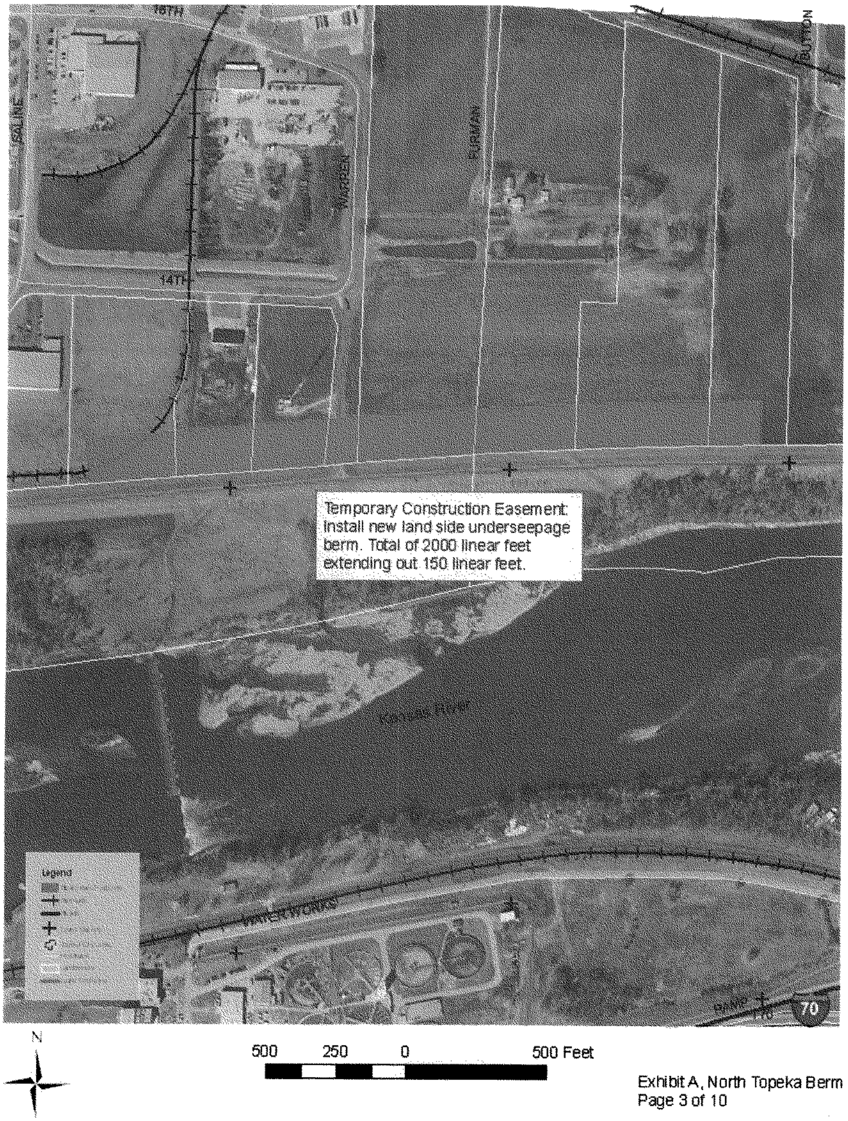


Exhibit A, North Topeka Berm
Page 3 of 10

Topeka Levee Protection Project, Real Estate Site Plan

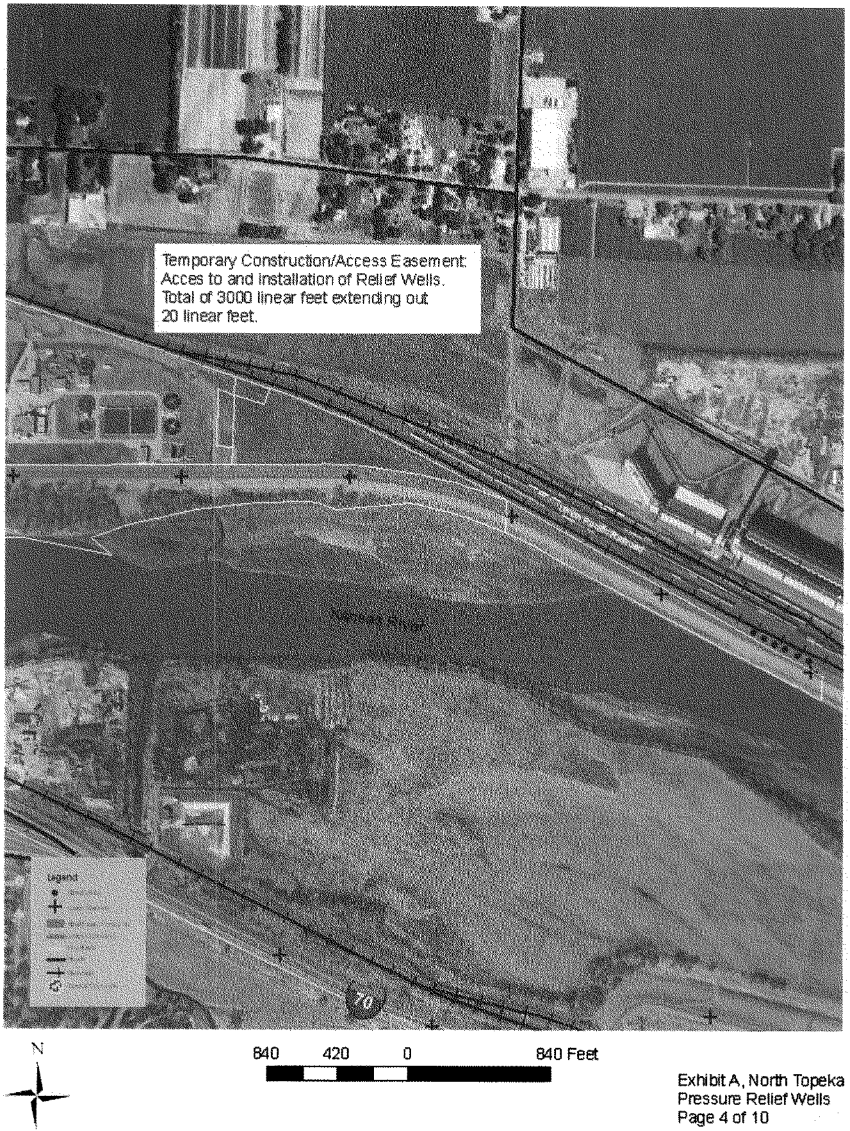


Exhibit A, North Topeka
Pressure Relief Wells
Page 4 of 10

Topeka Levee Protection Project, Real Estate Site Plan

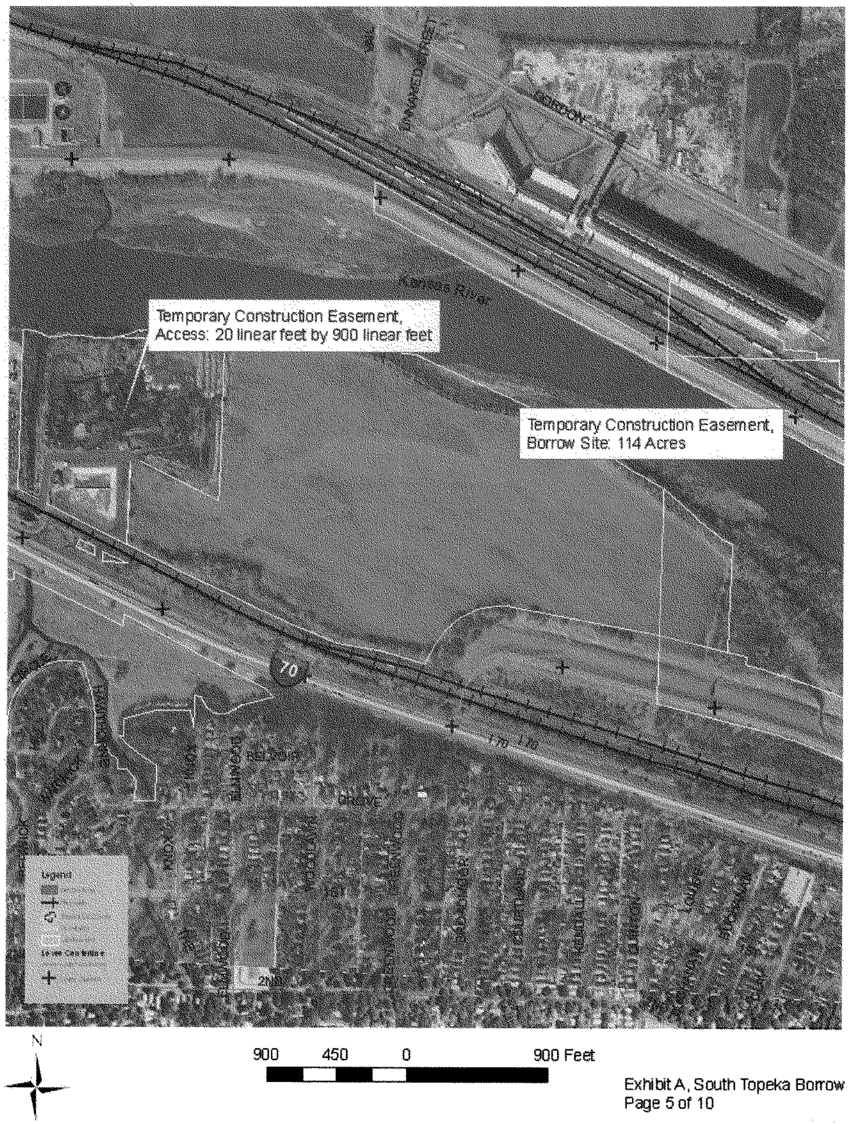


Exhibit A, South Topeka Borrow
Page 5 of 10

Topeka Levee Protection Project, Real Estate Site Plan

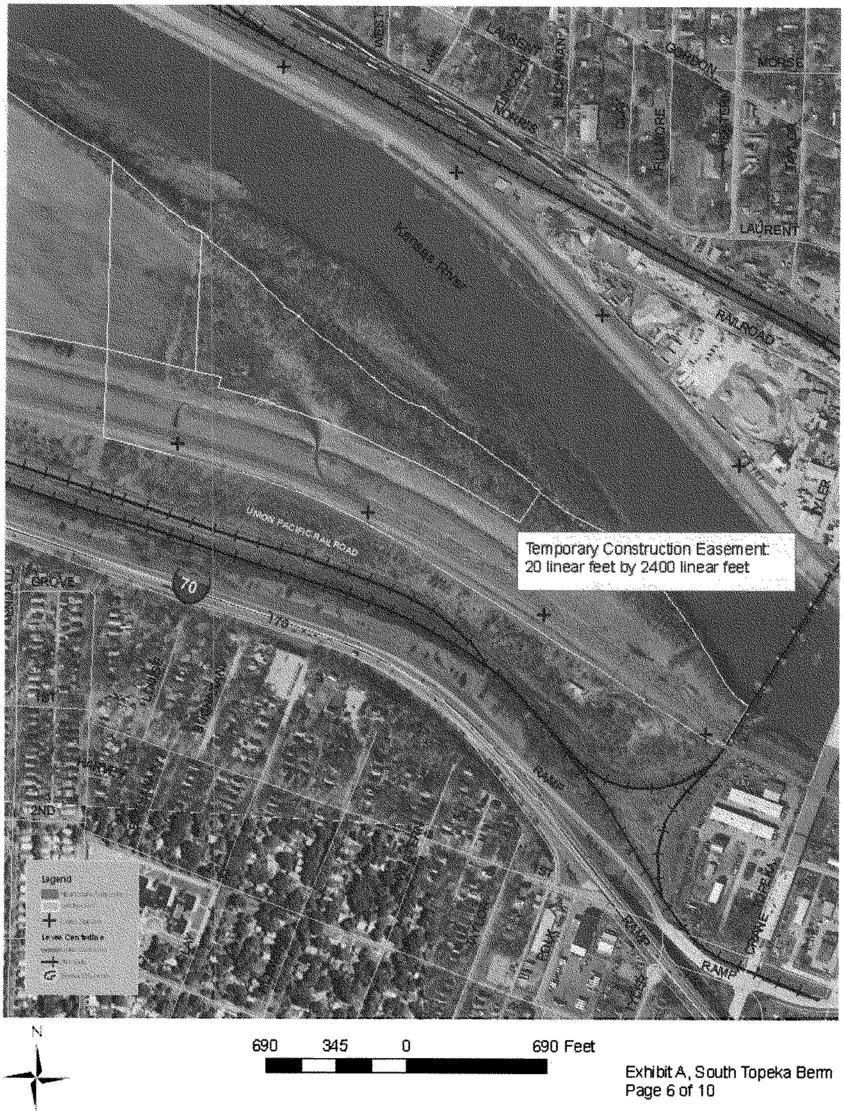


Exhibit A, South Topeka Berm
Page 6 of 10

Topeka Levee Protection Project, Real Estate Site Plan

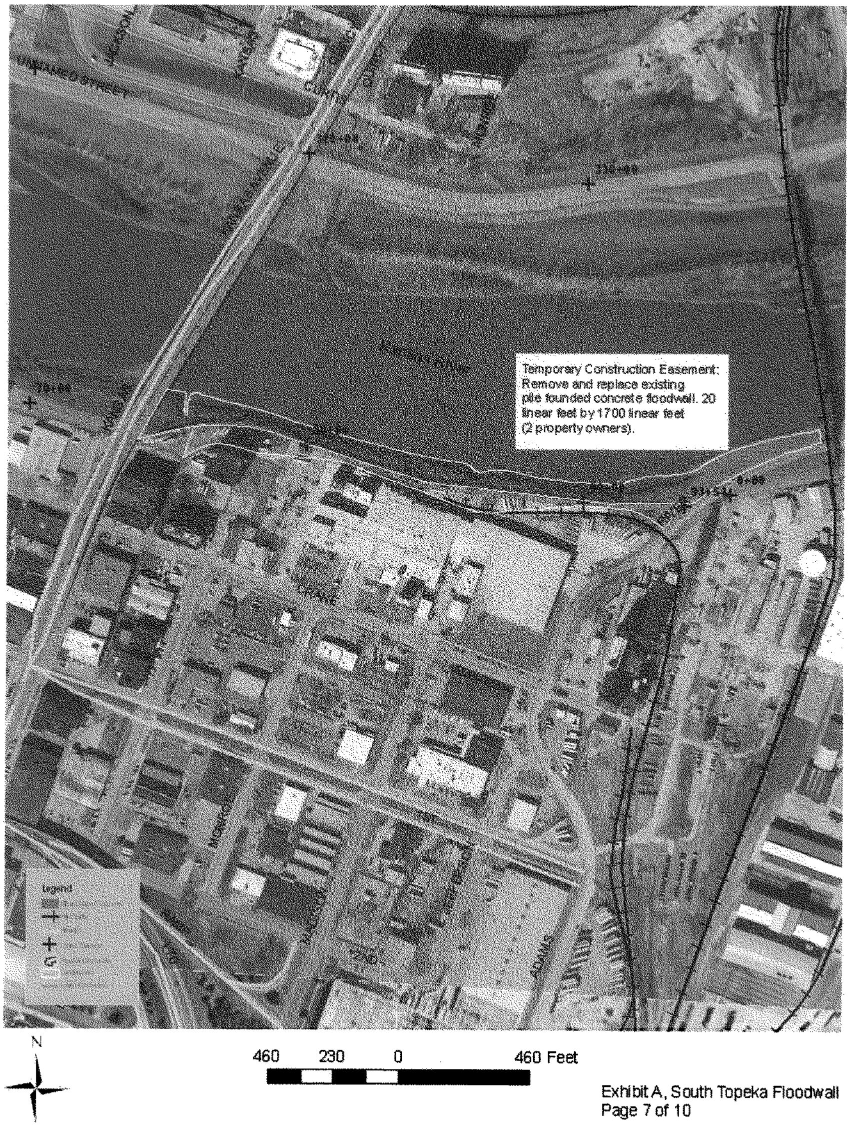


Exhibit A, South Topeka Floodwall
Page 7 of 10

Topeka Levee Protection Project, Real Estate Site Plan

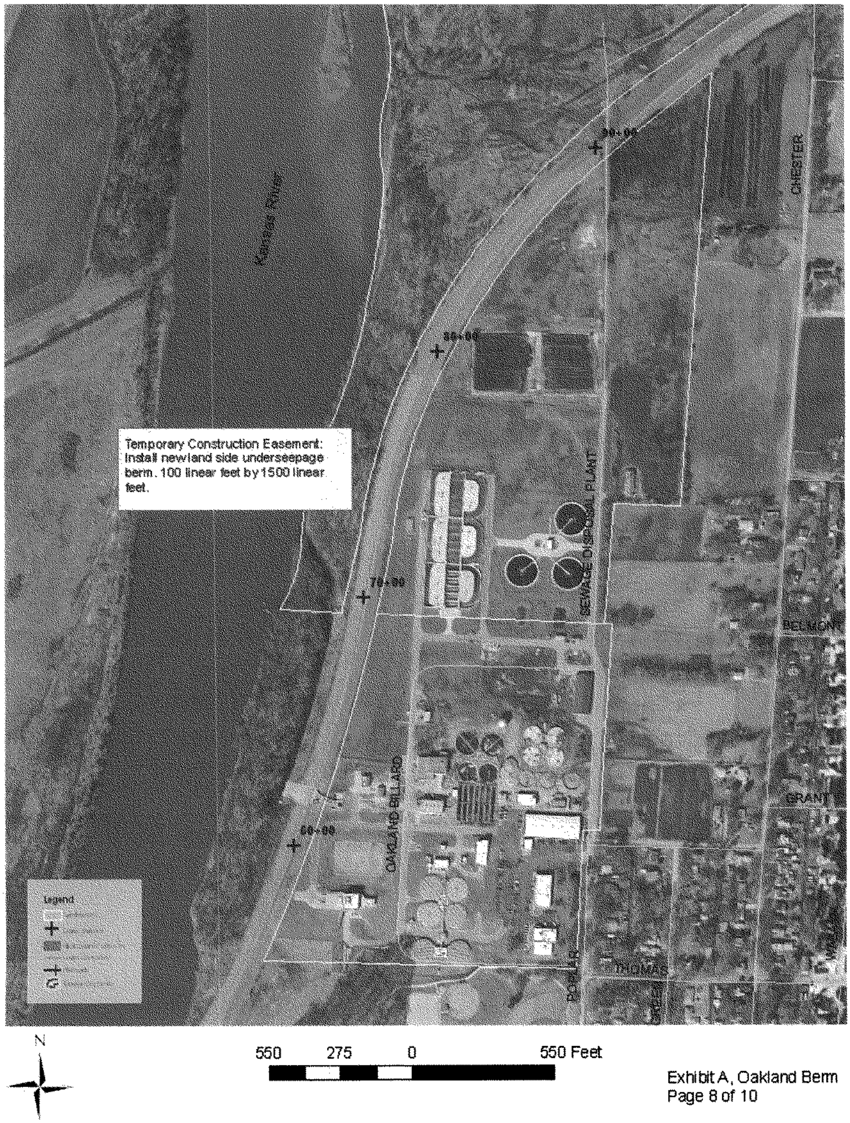


Exhibit A, Oakland Berm
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Topeka Levee Protection Project, Real Estate Site Plan

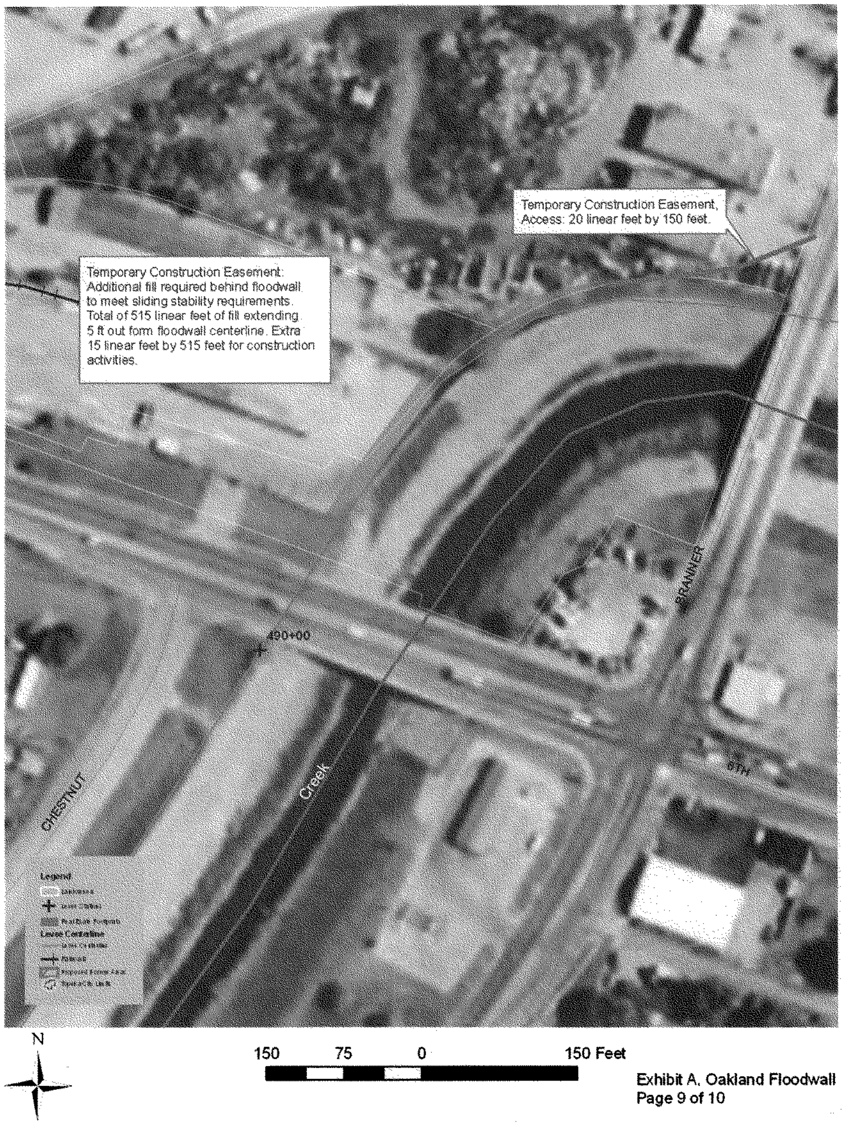

Exhibit A. Oakland Floodwall
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Topeka Levee Protection Project, Real Estate Site Plan

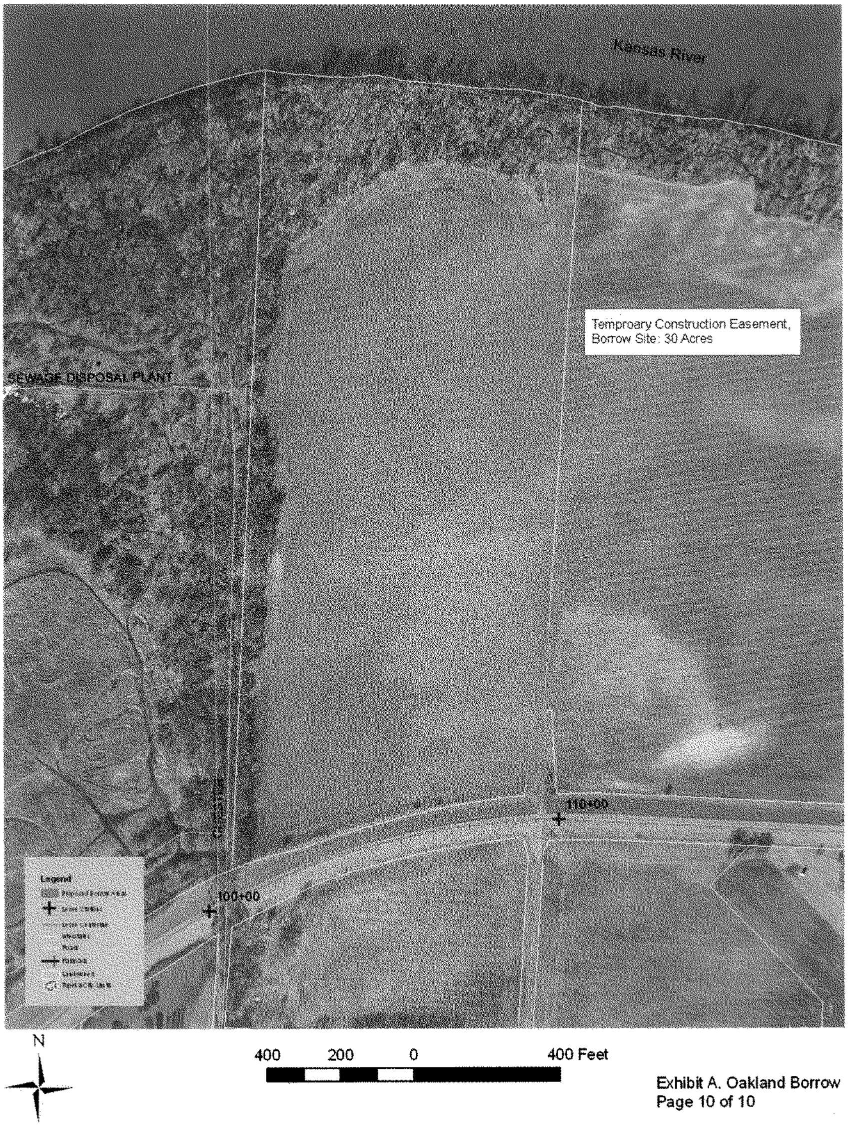


Exhibit A. Oakland Borrow
Page 10 of 10

Exhibit B
ASSESSMENT OF NON-FEDERAL SPONSOR'S REAL ESTATE ACQUISITION CAPABILITY

TOPEKA LOCAL LEVEE PROTECTION PROJECT

I. Legal Authority:

a. Does the sponsor have the legal authority to acquire and hold title to real property for project purposes? **Yes**

b. Does the sponsor have the power of eminent domain for this project? **Yes**

c. Does the sponsor have "quick take" authority for this project? **No**

d. Are any of the lands/interests in land required for the project located outside the sponsor's political boundary? **No**

e. Are any of the lands/interests in land required for the project owned by an entity whose property the sponsor cannot condemn? **No**

II. Human Resource Requirements:

a. Will the sponsor's in-house staff require training to become familiar with the real estate requirement of Federal projects including P.L. 91-646, as amended? **No**

b. If the answer to II.a. is "yes", has a reasonable plan been developed to provide such training?

c. Does the sponsor's in-house staff have sufficient real estate acquisition experience to meet its responsibilities for the project? **Yes**

D. Is the sponsor's projected in-house staffing level sufficient considering its other workload, if any, and the project schedule? **Yes. However, contract consultants may be hired.**

e. Can the sponsor obtain contractor support, if required, in a timely fashion? **Yes, once project has been approved by the Governing Body.**

f. Will the sponsor likely request USACE assistance in acquiring real estate? **Possibly advisory services**

III. Other Project Variables:

a. Will the sponsor's staff be located within reasonable proximity to the project site? **Yes**

b. Has the sponsor approved the project/real estate schedule/milestones? **Only the feasibility study. Property acquisition has not been approved.**

IV. Overall Assessment:

a. Has the sponsor performed satisfactorily on other USACE projects? **Yes (Topeka Levee)**

b. With regard to this project, the sponsor is anticipated to be **fully capable**.

V. Coordination:

a. Has this assessment been coordinated with the sponsor? **Yes**

b. Does the sponsor concur with this assessment? **Yes**

Prepared by:

/S/
Willem Helms
Real Estate Specialist

Approved by:

/S/
Gregory G. Wilson
Chief, Real Estate Division

FEASIBILITY REPORT
TOPEKA, KANSAS, FLOOD RISK MANAGEMENT PROJECT

APPENDIX D

Socioeconomic Analysis

DEPARTMENT OF THE ARMY
Kansas City District, U.S. Army Corps of Engineers
Kansas City, Missouri

APPENDIX D - SOCIOECONOMIC ANALYSIS
TABLE OF CONTENTS

1.0 INTRODUCTION

1.1 PURPOSE

This feasibility-level economic analysis provides an accounting of all properties protected by the units of the Topeka Federal Local Protection Project. The inventory serves as the database for a risk-based analysis which evaluates project performance by simulating a large number of possible flood events, taking into account all pertinent economic and engineering data including uncertainty factors. This analysis yields several outputs:

- Description and quantification of economic and social flood damage impacts to properties within the study area in the existing condition;
- Statistical estimates of project engineering performance or reliability under existing conditions in the context of a range of possible flood events;
- Estimated economic performance of alternatives formulated to improve project performance, in terms of residual damages, damages prevented, annualized benefits and costs;
- Statistical estimates of enhanced project engineering performance provided by each alternative;
- Economic optimization of alternatives and identification of the most economically efficient alternative;
- Characterization of the selected plan in terms of economic performance (annual benefits and costs, residual damages) and engineering performance.

1.2 STUDY GUIDANCE

Pertinent guidance governing economic analysis procedures includes:

- "Economic and Environmental Principles and Guidelines for Water and Related Resources Implementation Studies" (P&G), dated March 1983;
- Engineering Regulation (ER) 1105-2-100, "Planning Guidance Notebook," dated 22 April 2000 (partially updated subsequently);
- Engineering Regulation (ER) 1105-2-101, "Risk-Based Analysis for Flood Damage Reduction Studies," dated 3 January 2006

- Engineer Manual (EM) 1110-2-1619, "Risk-Based Analysis for Flood Damage Reduction Studies," dated 1 August 1996.

1.3 STUDY AREA LOCATION

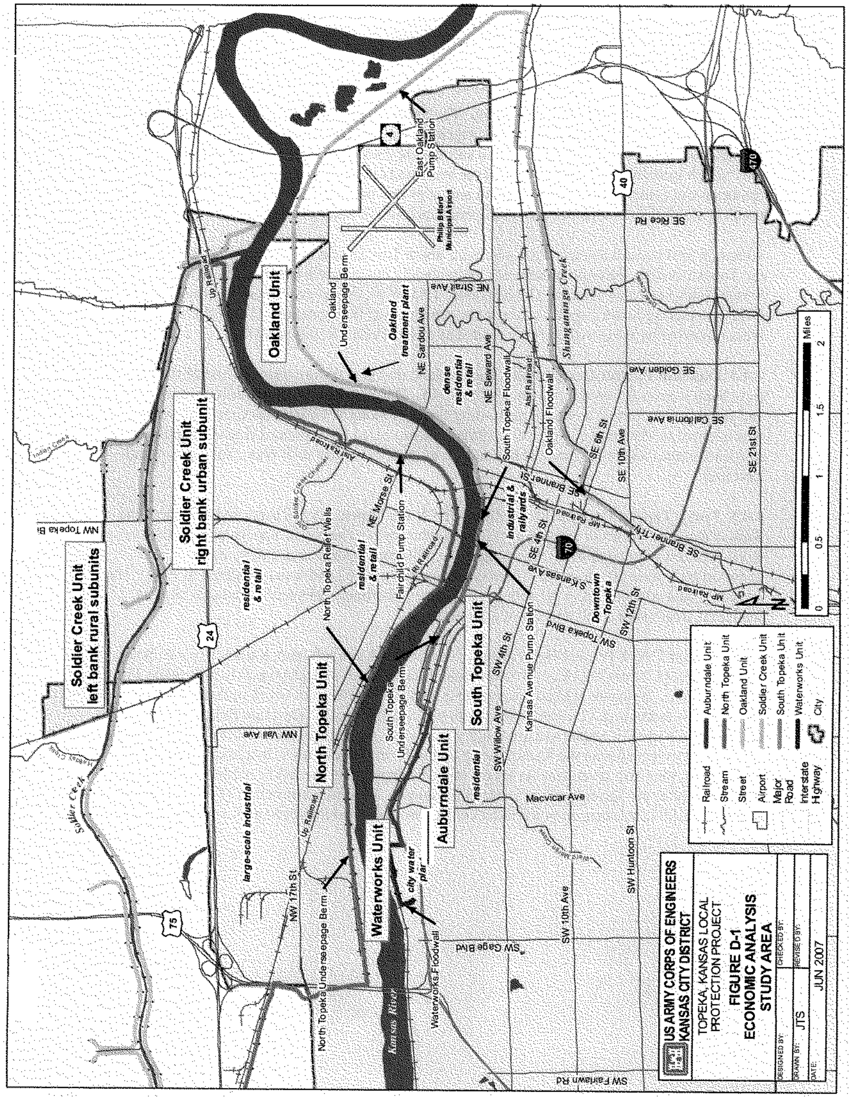
Topeka, the state capital of Kansas, is located in Shawnee County in east central Kansas, about 60 miles west of Kansas City, Missouri. It is situated on the main stem of the Kansas River, covering the area between river miles 76 and 90. The city's downtown and the capitol building are at mile 84. Within this broad area, this analysis specifically is concerned with leveed portions of the floodplains of the Kansas River, Soldier Creek and Shunganunga Creek in Topeka and adjoining areas. Adjacent unprotected areas along the right bank of Shunganunga Creek and the left bank of Soldier Creek are also considered in certain contexts. However, the term "study area," as used in this report, will refer to those portions of the metropolitan Topeka area protected by the Federal project.

1.4 FEDERAL PROJECT OVERVIEW

The Topeka Local Protection Project was originally authorized in the Flood Control Act of 1936, while subsequent modifications were authorized in the Flood Control Act of 1954. The project primarily consists of six units. Four of the six – Waterworks, Auburndale, South Topeka, and Oakland – form a continuous levee system protecting areas of central and eastern Topeka along the right or south bank of the Kansas River main stem. A fifth unit, North Topeka, protects most of the urban area on the opposite or left bank of the main stem. The sixth unit, Soldier Creek, protects the same North Topeka area from Soldier Creek and additionally protects several rural areas along the northern edge of the study area. The original project also included two additional units comprised of railroad and street bridge and approach alterations as well as channel and floodway improvements in the same areas as the levee units. This analysis is mainly concerned with the six levee units, which are shown on Figure 1 and described below.

1.4.1 Waterworks Project Description. This unit, which protects the city's water plant, is at the upstream end of the four levee units on the Kansas River's right or south bank (Kansas River miles 87.2 to 86.7). The downstream end of the unit ties into the Auburndale Unit. The levee and floodwall have a combined length of 0.8 miles. This unit was one of the first units constructed in the Topeka system. The original project was completed in 1938 and was operational during the 1951 flood. Subsequent construction to augment the project was completed in 1959.

1.4.2 Auburndale Project Description. Immediately downstream from the Waterworks unit on the Kansas River right bank, the Auburndale levee ties into the Waterworks unit at its upstream end (river mile 86.7) and the South Topeka unit at its downstream end (mile 85.5). The levee is approximately 1.5 miles long, including tieback, and is largely constituted by the I-70 highway embankment. Construction was initiated in 1959 and completed in 1962. The levee protects portions of an older neighborhood and a few businesses serving the neighborhood.


US ARMY CORPS OF ENGINEERS
KANSAS CITY DISTRICT
TOPEKA, KANSAS LOCAL PROTECTION PROJECT
FIGURE D-1
ECONOMIC ANALYSIS STUDY AREA
DESIGNED BY:
CHECKED BY:
DRAWN BY: JTS
REVISED BY:
DATE: JUN 2007
Railroad
Stream
Street
Airport
Major Road
Interstate Highway
Auburndale Unit
North Topeka Unit
Oakland Unit
Soldier Creek Unit
South Topeka Unit
Waterworks Unit
City
0
0.5
1
1.5
2
Miles
N
Soldier Creek Unit
left bank rural subunits
Soldier Creek Unit
right bank urban subunit
Oakland Unit
North Topeka Unit
Waterworks Unit
Auburndale Unit
South Topeka Unit
large-scale industrial
residential & retail
residential & retail
dense residential & retail
industrial & railyards
residential
Downtown Topeka
Oakland treatment plant
Oakland Underseepage Berm
East Oakland Pump Station
Philip Billard Municipal Airport
North Topeka Relief Wells
Fairchild Pump Station
South Topeka Underseepage Berm
Kansas Avenue Pump Station
South Topeka Floodwall
Oakland Floodwall
North Topeka Underseepage Berm
Waterworks Floodwall
city water plant
Kansas River
Soldier Creek
Shunganunga Creek
NW Topeka Blvd
NW Vail Ave
NW 17th St
NE Morse St
NE Strait Ave
NE Sardou Ave
NE Seward Ave
SE Branner St
SE 6th St
SE 10th Ave
SE Golden Ave
SE California Ave
SE 21st St
SE Rice Rd
SE 4th St
S Kansas Ave
SW Topeka Blvd
SW 12th St
SW 4th St
SW Willow Ave
Macvicar Ave
SW 10th Ave
SW Huntoon St
SW Gage Blvd
SW Fairlawn Rd
Up Railroad
Atsf Railroad
MP Railroad
24
75
40
70
470
4

1.4.3 South Topeka Project Description. The South Topeka unit, like the Waterworks unit, is one of the older units in the system. The original levee was built in 1938 and was operational on a smaller scale during the 1951 flood, and subsequent construction was completed in 1971. The unit, which includes about 1.8 miles of levee and floodwall, ties into the Auburndale unit at its upstream end (mile 85.5) and the Oakland unit at its downstream end (mile 83.7). This unit protects a significant industrial area and a small quantity of homes.

Although the Oakland levee and the adjoining South Topeka unit are ostensibly separate units of the Topeka system, the two units are not hydraulically independent inasmuch as flooding in South Topeka can also enter the Oakland area. (However, the reverse situation - flooding in Oakland entering South Topeka - cannot occur because of the topography.) For this reason, the areas protected by these two units are treated as a single reach in this analysis.

1.4.4 Oakland Project Description. The Oakland unit is at the downstream end of the four right bank Kansas River units (miles 83.7 to 76.0). The unit consists of about 10.2 miles of levee and floodwall, including a tieback preventing flooding along Shunganunga Creek. Construction was initiated in 1962 and completed in 1969. The protected area contains densely populated residential areas and retail/service hubs as well as an airport, treatment plant, and agricultural land uses.

1.4.5 North Topeka Project Description. The North Topeka area is protected from both the Kansas River on the south and Soldier Creek on the north. The North Topeka unit on the Kansas River left (or north) bank is a 9 mile-long levee protecting a large area extending from approximately mile 80.8 to 88.8. Construction started in 1962 and was completed in 1967. The protected area contains many densely populated neighborhoods and service areas as well as industrial areas and a small amount of agriculture.

1.4.6 Soldier Creek Project Description. Soldier Creek is a left bank Kansas River tributary running through North Topeka and entering the Kansas River at approximately mile 80.6. Prior to its diversion, the creek entered the river at mile 82.2. The Soldier Creek unit consists of a series of levees totaling 17.9 miles along both banks of the creek. The main Soldier Creek levee, on the creek's right or south bank from miles 0.2 to 7.2, protects the same North Topeka urban area that is protected from the Kansas River by the North Topeka unit. In addition to the large urban levee, there are seven smaller levees (six of which are on the left or north bank) protecting rural areas of either agricultural or residential land use. Federal construction of the unit was initiated in 1957 (building on much older construction by local interests) and completed in 1961.

2.0 SOCIOECONOMIC DESCRIPTION

2.1 CITY AND GENERAL STUDY AREA SOCIOECONOMIC CHARACTERISTICS

2.1.1 Study Area Land Use. The Federal project protects a total of 11,059 acres in Topeka, representing about 31% of the city's total land area. As summarized in Table D-1, the largest leveed areas are North Topeka and Oakland. The North Topeka area includes 6,076 acres that are protected by two units of the system: North Topeka and Soldier Creek. The Oakland area contains 3,208 acres. The four right bank Kansas River main stem units account for a total of 10.7 miles of leveed riverfront and protect 3,926 acres, while the left bank main stem unit accounts for 8 miles of leveed riverfront and protects 6,076 acres. In addition to the urban North Topeka area, the Soldier Creek unit protects an additional 1,057 acres in rural areas. These seven leveed areas range from 39 to 449 acres in area.

Densely populated urban neighborhoods characterize Auburndale, most of the western two-thirds of Oakland, and the eastern two-thirds of North Topeka. Industrial land uses dominate the Waterworks area, the western portion of North Topeka, almost all of South Topeka, and the southwestern and eastern portions of the Oakland area. A number of neighborhood retail and service areas are scattered throughout Oakland and North Topeka, which also has a riverfront old town area of offices, stores and services. Agricultural land uses are found primarily in the northern portions of Oakland, the western portions of North Topeka, and especially along the left bank of Soldier Creek.

TABLE D-1

PROTECTED AREA ACREAGE

Reach	Acres
Waterworks	35.8
Auburndale	308.5
South Topeka	301.0
Oakland	3,280.8
North Topeka	6,076.3
Soldier Creek left bank	1,056.5
TOTAL PROTECTED AREA	**11,058.9**

Source: KC District USACE GIS estimates

2.1.2 Study Area Population and Social Characteristics. Topeka, with a 2006 estimated population of 122,113, is the fourth largest city in Kansas, after Wichita, Kansas City, and Overland Park. The city ranks 195th among all U.S. cities in population. Population is down slightly from the 123,101 recorded in the 2000 Census, as the area's population continues to redistribute itself from the center city to the suburbs, but is up about 2% from the 1990 total of 119,883. Shawnee County grew 5.5% during the 1990-2000 period and has grown 1.5% since the 2000 Census to its current (2006) estimated population of 172,693. The Topeka

Metropolitan Statistical Area (MSA), meanwhile, has seen a 1.9% increase in population from 224,551 in 2000 to 228,894 in 2006. (Note: The Topeka MSA has been redefined since the 2000 Census when it was defined as Shawnee County, and is now a much larger area.)

Table D-2 lists the Census areas defining the study area, including tracts, block groups and blocks. Census blocks, the smallest area units defined by the Census Bureau, are small areas that often correspond to a city block in urban areas but can be much larger in rural areas. Blocks usually contain somewhat more than a thousand residents. The specific blocks within the study area are noted in the table. Population and housing units data from the 2000 Census are available for Census blocks and allow a fairly accurate accounting of study area population, as summarized in Table D-3. By this reckoning, the 2000 population of the study area was 16,098, with 7,153 housing units. (1990 data are not summarized here since they are not available for all blocks.) If the adjacent unprotected areas along Shunganunga and Soldier Creeks are included, the total population was 17,535 with 7,724 housing units. The study reaches with the largest population are Oakland and North Topeka, which respectively account for 43.7% and 41.8% of the total study area population. Auburndale accounts for an additional 9.1%, the rural Soldier Creek left bank reaches account for 4.1%, and South Topeka accounts for 1.3%. The Waterworks reach has no residents. About 13.1% of the city's total population resided within the study area in 2000.

Most other socioeconomic data besides population and number of households are not readily available at the block level. Instead, Tables D-4 and D-5 summarize a range of socioeconomic indicators from the 2000 Census for the block groups comprising the study area. Block groups are subdivisions of tracts and are the smallest areas for which the Census Bureau tabulates sample data. (Tracts, in turn, are socioeconomically homogeneous subdivisions of counties that usually average about 4,000 residents.) The totals for each area are weighted averages, weighted by either the population or the number of housing units in the block group. Note that the block group data cover areas that sometimes go beyond the study area, especially in the Soldier Creek left bank area, resulting in larger (sometimes much larger) estimates of population, housing and other characteristics than a block-level accounting.

A number of conclusions can be drawn concerning the study area population and housing stock from the data in Tables D-4 and D-5. Per capita income (2000) in the study area was $17,596, which was only 90% of the Topeka per capita income ($19,555), 84% of Shawnee County ($20,904), 86% of the state ($20,506), and 82% of the national total ($21,587). Study area residents were more likely to have incomes below the poverty level (12.6% vs. 12.4% in the city and 9.6% in the county) or to be unemployed, and were somewhat less educated. The study area population was 83.6% white, slightly higher than the Shawnee County percentage (82.9%) and significantly higher than the city (78.5%) and the nation (75.1%). The percentage of whites in the overall population varies a great deal between different parts of the study area, as will be seen below. Hispanics account for 12% of the population, which is about on a par with the national average but much higher than the city, county and state totals. African Americans account for only 5.4% of study area population, slightly lower than the state total of 5.7% and much lower than the Topeka total of 11.7% and the national total of 12.3%.

In housing, the average value of owner units in the study area was $66,148, which was only 81% of the Topeka average, 70% of the county average, and 64% of the statewide average. The relatively low home values undoubtedly are related to the age of the study area housing stock, which was 46.1 years old on average compared to 39.7 for Topeka and 36.9 for the county. The statistics showed somewhat greater neighborhood stability in the study area relative to larger areas. Renter-occupied housing was less prevalent in the study area at 29.8%, compared to 32.5% in Shawnee County and 39.2% in Topeka, and a larger percentage of home owners had lived in the same home for five years prior to the 2000 Census - 53% in the study area vs. 46.7% in the city and 49.9% in the county. However, the latter statistics are somewhat skewed by the rural Soldier Creek left bank block groups, which are large areas that include numerous residents outside the study area. The study area vacancy rate of 7.9% exceeded the city rate of 7.5% and the county rate of 6.6%.

TABLE D-2

CENSUS AREAS INCLUDED IN STUDY AREA

Census tract	Block group	Blocks included	Portions of study area included
6	1	1000, 1007-1011	South Topeka (upstream portion)
7	1	all	North Topeka (central)
7	2	all	North Topeka (US 24 Highway area)
8	1	1001-1002, 1040-1046, 1050-1055	Soldier Creek left bank rural (downstream end)
8	1	1004-1006, 1009-1032, 1034-1035, 1056-1060	North Topeka (downstream end)
8	2	all	North Topeka (central)
8	3	all	North Topeka (central)
8	4	all	North Topeka (old town area)
9	1	all	Oakland (extreme NW portion)
9	2	all	Oakland (treatment plant area)
9	3	all	Oakland (west of airport)
9	4	4000-4029, 4037	Oakland (airport area)
10	1	all	Oakland (airport area)
10	2	all	Oakland (central)
10	3	all	Oakland (central)
10	4	all	Oakland (central)
11	1	1003-1004	Oakland (central)
11	2	2000-2006, 2025-2035	Oakland (central)
11	3	3005-3011	Oakland (central)
21	4	4005-4006	Auburndale (southern)
21	5	5001-5005, 5009-5012	Auburndale (southern)
22	1	1001-1019, 1021-1024, 1027, 1030-1031	Auburndale (northern potion)
22	1	1000	South Topeka (extreme southern end)
22	3	3000-3012, 3014-3017, 3020-3021	Auburndale (central)
33.01	1	1020-1023, 1025	Soldier Creek left bank rural
34	1	1029, 1033	Soldier Creek left bank rural
34	2	2056-2058	Soldier Creek left bank rural
34	2	2061-2063	North Topeka (NW portion)
35	1	1083, 1090-1091	Soldier Creek left bank rural
35	1	1117-1122, 1124-1125, 1132-1134	North Topeka (upstream end)
40	1	1000-1047, 1053-1063, 1078-1083, 1087-1088	South Topeka (RR yards)
40	2	2002-2005, 2040-2043	South Topeka (southern)
40	3	3000	South Topeka (southern end)
41	1	1014	Waterworks; Auburndale (W edge)
41	2	2000	Auburndale (SW portion)

TABLE D-3

STUDY AREA POPULATION AND HOUSING

Based on 2000 Census blocks contained in study area

	Population	Households
WATERWORKS		
Tract 41, Block Group 1	0	0
TOTAL WATERWORKS	0	0
AUBURNDALE		
Tract 21, Block Group 4	29	14
Tract 21, Block Group 5	260	139
Tract 22, Block Group 1	565	273
Tract 22, Block Group 3	584	267
Tract 41, Block Group 1	0	0
Tract 41, Block Group 2	30	18
TOTAL AUBURNDALE	**1,468**	**711**
SOUTH TOPEKA		
Tract 6, Block Group 1	101	54
Tract 22, Block Group 1	0	0
Tract 40, Block Group 1	110	62
TOTAL SOUTH TOPEKA	**211**	**116**
OAKLAND		
Tract 9, Block Group 1	634	239
Tract 9, Block Group 2	1,110	464
Tract 9, Block Group 3	799	374
Tract 9, Block Group 4	296	100
Tract 10, Block Group 1	863	437
Tract 10, Block Group 2	902	394
Tract 10, Block Group 3	616	270
Tract 10, Block Group 4	1,105	485
Tract 11, Block Group 1	0	0
Tract 11, Block Group 2	444	217
Tract 11, Block Group 3	66	25
Tract 40, Block Group 1	191	74
Tract 40, Block Group 2	4	3
Tract 40, Block Group 3	0	0
TOTAL OAKLAND	**7,030**	**3,082**

	Population	Households
NORTH TOPEKA		
Tract 7, Block Group 1	1,211	549
Tract 7, Block Group 2	2,097	779
Tract 8, Block Group 1	635	308
Tract 8, Block Group 2	883	447
Tract 8, Block Group 3	884	433
Tract 8, Block Group 4	925	435
Tract 34, Block Group 2	39	15
Tract 35, Block Group 1	51	22
TOTAL NORTH TOPEKA	**6,725**	**2,988**
SOLDIER CREEK LEFT BANK		
Tract 8, Block Group 1	135	58
Tract 33.01, Block Group 1	211	73
Tract 34, Block Group 1	81	37
Tract 34, Block Group 2	146	55
Tract 35, Block Group 1	91	33
TOTAL SOLDIER CREEK LB	**664**	**256**
(UNPROTECTED) SOLDIER CREEK LEFT BANK		
Tract 33.01, Block Group 1	442	167
Tract 35, Block Group 1	4	2
TOTAL UNPROTECTED SOLDIER	**446**	**169**
(UNPROTECTED) SHUNGANUNGA CREEK RIGHT BANK		
Tract 9, Block Group 4	55	20
Tract 11, Block Group 1	744	313
Tract 11, Block Group 2	192	69
TOTAL SHUNGANUNGA RB	**991**	**402**
TOTAL, PROTECTED AREAS	**16,098**	**7,153**
TOTAL, UNPROTECTED	1,437	571
TOTAL STUDY AREA	**17,535**	**7,724**

TABLE D-4
STUDY AREA POPULATION CHARACTERISTICS

(Data from 2000 Census)	Population									
	Population	% White	% Black or African American	% Hispanic	% Foreign Born	Median Age	% Adults over 25 with H.S. Diploma or More	Per Capita Income	% Indiv. Below Poverty Level	Unemploy. Rate (%)
U.S.	281,421,906	75.1	12.3	12.5	11.1	35.3	80.4	$21,587	12.4	5.8
Kansas	2,688,418	86.1	5.7	7.0	5.0	35.2	86.0	$20,506	9.9	4.2
Shawnee County / Topeka MSA	169,871	82.9	9.0	7.3	2.7	37.1	88.1	$20,904	9.6	4.0
Topeka city	122,377	78.5	11.7	8.9	3.3	36.3	85.9	$19,555	12.4	4.8
STUDY AREA TOTAL OR AVG.	**36,775**	**83.6**	**5.4**	**12.0**	**26.6**	**n.a.**	**81.1**	**$17,596**	**12.6**	**5.8**
AUBURNDALE										
Tract 21 BG 4	703	91.0	3.8	3.4	1.7	36.4	86.4	$22,168	1.7	3.2
Tract 21 BG 5	538	90.1	3.7	3.2	0.0	36.7	96.1	$18,002	5.8	6.7
Tract 22 BG 1	780	89.1	3.7	4.1	1.2	36.1	93.0	$18,707	10.3	4.1
Tract 22 BG 3	810	90.4	1.9	7.0	0.0	39.1	81.3	$16,263	9.6	0.0
Tract 41 BG 1	1,357	89.4	5.4	0.9	1.5	40.2	86.8	$21,438	5.7	1.9
Tract 41 BG 2	996	93.7	2.3	3.3	1.3	35.1	94.5	$18,791	3.2	0.7
Total Auburndale	**5,184**	**90.6**	**3.6**	**3.4**	**37.6**	**n.a.**	**89.3**	**$19,452**	**6.0**	**2.4**
SOUTH TOPEKA										
Tract 6 BG 1	1,140	80.5	5.1	11.6	0.4	30.6	78.0	$10,140	42.0	10.6
Tract 40 BG 1	713	62.7	8.8	34.6	18.1	32.7	61.3	$10,570	35.2	14.9
Total South Topeka	**1,853**	**73.7**	**6.5**	**20.4**	**31.4**	**n.a.**	**71.6**	**$10,305**	**39.4**	**12.3**
OAKLAND										
Tract 9 BG 1	634	82.8	1.9	16.1	1.4	31.1	83.8	$14,801	0.0	9.9
Tract 9 BG 2	1,110	85.6	1.8	13.1	0.0	32.1	83.2	$14,431	7.3	11.6
Tract 9 BG 3	799	87.3	1.5	10.4	0.0	37.4	84.0	$13,124	12.9	6.3
Tract 9 BG 4	1,048	86.4	3.1	12.3	1.5	41.4	71.8	$16,192	12.4	1.1
Tract 10 BG 1	863	84.0	2.1	22.6	4.9	43.7	67.2	$17,133	8.2	18.9
Tract 10 BG 2	902	78.0	1.9	25.9	8.7	34.4	73.3	$13,785	10.8	0.0
Tract 10 BG 3	616	66.4	0.5	52.9	4.5	38.2	79.1	$15,695	10.9	9.8
Tract 10 BG 4	1,105	68.5	2.8	40.6	2.9	36.8	68.1	$17,551	16.0	2.6
Tract 11 BG 1	1,033	52.3	23.4	28.6	11.4	30.3	62.7	$14,113	20.4	4.7
Tract 11 BG 2	995	44.0	19.0	41.5	19.1	28.4	60.1	$10,660	32.1	10.3
Tract 11 BG 3	1,148	44.3	18.9	51.1	32.3	28.6	53.3	$9,206	27.1	13.3
Tract 40 BG 2	770	58.6	28.8	16.5	5.6	33.4	80.8	$5,784	36.0	14.9
Tract 40 BG 3	792	49.2	34.8	15.3	4.2	34.8	58.4	$10,753	41.0	13.4
Total Oakland	**11,815**	**67.7**	**10.9**	**27.1**	**8.1**	**n.a.**	**70.3**	**$13,361**	**18.4**	**8.7**
NORTH TOPEKA										
Tract 7 BG 1	1,211	87.4	5.9	4.3	2.6	35.1	76.1	$13,125	12.4	7.6
Tract 7 BG 2	2,097	86.7	6.5	5.8	1.3	29.3	80.0	$13,227	15.2	7.3
Tract 8 BG 1	829	94.6	1.2	3.1	0.0	35.7	74.8	$27,109	8.6	4.7
Tract 8 BG 2	883	92.2	2.9	3.3	0.8	40.2	80.7	$15,429	17.0	5.9
Tract 8 BG 3	884	86.0	4.2	8.3	1.5	40.6	71.3	$12,738	24.3	10.9
Tract 8 BG 4	925	82.5	5.1	6.4	0.7	37.8	58.5	$12,138	27.9	11.1
Tract 35 BG 1	1,867	96.8	0.6	1.5	1.0	39.0	95.1	$23,001	2.0	1.3
Total North Topeka	**8,696**	**89.8**	**3.9**	**4.5**	**36.0**	**n.a.**	**79.1**	**$16,693**	**13.8**	**6.4**
SOLDIER CREEK LEFT BANK										
Tract 33.01 BG 1	2,240	95.2	0.8	5.0	0.0	40.9	91.5	$24,218	0.5	1.7
Tract 34 BG 1	3,953	96.9	0.3	2.6	1.3	41.7	95.0	$23,647	2.9	2.7
Tract 34 BG 2	3,034	96.2	1.0	2.2	1.1	38.7	95.7	$25,178	3.0	1.3
Total Soldier Creek rural	**9,227**	**96.3**	**0.7**	**3.1**	**40.5**	**n.a.**	**94.4**	**$24,289**	**2.4**	**2.0**

Note This table shows the Topeka MSA (metropolitan statistical area) as being equivalent to Shawnee County Although the Census Bureau's definition of the Topeka MSA has expanded recently, the MSA and the county are the same in the 2000 Census data

TABLE D-5
STUDY AREA HOUSING CHARACTERISTICS

(Data from 2000 Census)	Housing					
	# Housing Units	Average Value of Owner Units	Average Age of Units	Vacancy Rate (%)	% Renter Occupied Units	% Lived in Same House 5 Yrs Ago
U.S.	115,904,614	$158,934	34.2	9.0	33.8	51.2
Kansas	1,131,200	$103,669	37.9	8.2	30.7	50.4
Shawnee County / Topeka MSA	73,768	$93,969	36.9	6.6	32.5	49.9
Topeka city	56,435	$81,283	39.7	7.5	39.2	46.7
STUDY AREA TOTAL OR AVG.	**15,131**	**$66,148**	**46.1**	**7.9**	**29.8**	**53.0**
AUBURNDALE						
Tract 21 BG 4	360	$60,066	59.0	3.8	17.1	39.0
Tract 21 BG 5	272	$54,112	56.7	0.0	27.6	46.0
Tract 22 BG 1	369	$62,746	57.9	6.4	24.0	55.4
Tract 22 BG 3	404	$53,750	57.3	8.2	40.7	43.8
Tract 41 BG 1	764	$61,614	31.7	5.0	69.1	36.3
Tract 41 BG 2	489	$64,894	58.2	3.3	11.7	62.8
Total Auburndale	**2,658**	**$60,202**	**50.4**	**4.7**	**36.7**	**46.3**
SOUTH TOPEKA						
Tract 6 BG 1	500	$41,932	59.1	20.9	44.1	42.6
Tract 40 BG 1	380	$40,132	66.8	24.1	58.6	29.7
Total South Topeka	**880**	**$41,155**	**62.4**	**22.3**	**50.4**	**37.0**
OAKLAND						
Tract 9 BG 1	239	$48,140	51.8	3.7	21.5	37.8
Tract 9 BG 2	464	$49,542	56.3	6.4	26.7	66.5
Tract 9 BG 3	374	$87,302	49.1	5.5	27.0	53.4
Tract 9 BG 4	424	$56,067	44.3	6.0	18.3	71.3
Tract 10 BG 1	437	$53,251	41.3	5.5	36.5	62.5
Tract 10 BG 2	394	$42,561	61.3	8.0	29.4	56.9
Tract 10 BG 3	270	$47,031	60.4	8.2	12.5	69.5
Tract 10 BG 4	485	$42,248	66.0	7.1	20.9	60.8
Tract 11 BG 1	395	$35,442	42.0	16.7	46.4	52.4
Tract 11 BG 2	430	$34,563	44.9	10.5	64.9	33.4
Tract 11 BG 3	434	$27,198	57.8	13.3	38.6	48.8
Tract 40 BG 2	188	$57,639	64.5	0.0	80.5	33.7
Tract 40 BG 3	435	$47,384	66.7	22.5	73.6	36.8
Total Oakland	**4,969**	**$47,546**	**54.0**	**9.3**	**37.5**	**53.7**
NORTH TOPEKA						
Tract 7 BG 1	596	$48,291	47.2	9.7	43.3	46.5
Tract 7 BG 2	732	$59,622	35.2	3.7	10.2	47.8
Tract 8 BG 1	423	$82,694	31.0	16.8	27.6	34.9
Tract 8 BG 2	441	$45,971	46.7	7.7	23.3	48.2
Tract 8 BG 3	433	$36,336	52.2	12.1	43.5	51.9
Tract 8 BG 4	435	$25,079	61.1	13.0	50.9	36.6
Tract 35 BG 1	685	$133,340	29.6	4.3	9.7	71.0
Total North Topeka	**3,745**	**$65,596**	**41.9**	**8.8**	**27.5**	**49.6**
SOLDIER CREEK LEFT BANK						
Tract 33.01 BG 1	835	$99,675	33.1	2.3	5.8	77.7
Tract 34 BG 1	938	$106,089	33.5	2.3	7.0	66.2
Tract 34 BG 2	1,106	$126,583	21.6	3.4	7.3	60.7
Total Soldier Creek rural	**2,879**	**$112,102**	**28.8**	**2.7**	**6.8**	**67.4**

2.1.3 Study Area Economy.

2.1.3.1 Historical Development. Topeka originally developed in the mid-19th century at a point on the Kansas River long known for its fords. A ferry service developed to facilitate traffic along the Oregon Trail. Soon the town became an important rail center, which it remains today as home to one of the largest railroad shop operations in the world. It was also well situated as an agricultural hub since it lies at a juncture where southwestern cattle ranches meet the Corn Belt. Rail traffic, meat packing, and agriculture dominated the city's economy well into the 20th century as the Kansas River continued to play an enormous role in the city's development.

Nearly one-third of Topeka's land area is in the Kansas River floodplain, and much of the city's earlier industrial and commercial base was alongside the river. A major flood in 1903 caused enough devastation to spark initial efforts to protect the town with levees. During World War II, the city's economic base turned toward military spending and manufacturing with the establishment of Forbes Air Force Base and the Goodyear Tire Company plant. The 1951 Kansas River flood of record destroyed much of the older economic base in North and East Topeka. The 1974 closing of Forbes Air Force Base was an enormous blow to the regional economy, resulting in a population loss of about 10,000 that hobbled the city for years afterward.

2.1.3.2. Industrial Structure. According to the Topeka Chamber of Commerce, the largest individual employers in the Topeka metropolitan area are the state of Kansas (8,400 employees), Stormont-Vail Health Care (3,100 employees), and the Topeka School District (2,540 employees). Other major area employers with between 1,000 and 2,000 employees include Blue Cross and Blue Shield insurance (1,800+); St. Francis Health Center (1,800+); Payless Shoe Source (1,600); City of Topeka (1,400); Goodyear Tire Manufacturing (1,600); Washburn University (1,650); Federal government (1,250); Shawnee County (1,100); Burlington Northern Santa Fe Railroad (1,100); and Jostens Printing (1,000). In addition, the Target Corporation has built a major and growing distribution facility in Topeka employing about 650. Several major employers have substantial presences in the study area floodplain, including Goodyear Tire, Payless Shoe Source, and Burlington Northern Santa Fe Railroad. BNSF Railroad continues to maintain an important railroad shop operation in the South Topeka area. Goodyear Tire Company's plant in North Topeka is being revitalized at present with over $100 million in new investment. Other large private employers situated in the study area floodplain include Hill's Pet Nutrition (840 employees), which is headquartered in South Topeka; Hallmark Cards (725); Del Monte Pet Products (260); and Southwest Publishing (177).

Table D-6 summarizes Topeka's industrial structure according to the percentage employed in each industry. The figures are U.S. Bureau of Labor Statistics (BLS) 2005 annual averages. In general, the public sector continues to have a powerful presence in the city's industrial structure, employing 25.5% of the work force, which is much higher than the state total of 18.9% or the national total of 16.3%. Manufacturing has a smaller share of Topeka area jobs than in the state and nation, but unlike most other communities, Topeka continues to experience modest growth in the manufacturing sector, particularly food manufacturing. The financial services industry also continues to lead job growth in the area.

TABLE D-6 TOPEKA EMPLOYMENT BY INDUSTRY			
Industry	Topeka %	Kansas %	U.S. %
Construction	5.3	4.7	5.5
Manufacturing	7.7	13.5	10.7
Wholesale Trade	3.2	4.5	4.3
Retail Trade	10.4	11.2	11.4
Transportation & warehousing	4.5	3.9	3.3
Information	2.5	3.0	2.3
Finance	6.7	5.3	6.1
Professional & business services	7.4	9.9	12.6
Private educational & health services	15.1	12.4	13.0
Leisure & hospitality	6.9	8.3	9.6
Other services	4.7	4.0	4.9
Government	25.5	18.9	16.3
Source: Bureau of Labor Statistics, 2005 annual averages			

A further breakdown of industrial activity is provided by the count of businesses provided by the 2005 County Business Patterns (U.S. Census Bureau). There were 4,711 businesses in Shawnee County in 2005, which were distributed among the following major industries: retail trade, 15.6%; health care and social assistance, 10.7%; construction, 10.5%; professional, scientific and technical services, 10.3%; finance and insurance, 8.2%; accommodation and food services, 7.8%; real estate and rental/leasing, 5.2%; administration, management and waste remediation services, 4.8%; wholesale trade, 4.1%; manufacturing, 2.5%; transportation and warehousing, 2.5%. Other industries comprised less than 2% of Shawnee County businesses.

2.1.3.3 Income and Employment. Per capita personal income (PCPI) in the Topeka MSA, as defined by the Bureau of Economic Analysis (BEA), was $31,074 in 2005. This total ranked the Topeka MSA 155th among MSAs in the U.S. The total amounted to 90% of the national average and a 3.4% increase over the 2004 figure compared to the 4.2% national increase in the same period. Over the 1995-2005 period, PCPI grew at an average annual rate of 3.9%, a little less than the national average of 4.1%. Total personal income (TPI) for the MSA in 2005 was $7,092,816, which was 182nd in the U.S. TPI increased 4.3% over the 2004-2005 period, and the average annual growth rate over the 1995-2005 period also was 4.3%. The comparable national increases for TPI were 5.2% in each case. Earnings by Topeka employees increased 3.5% from 2004 to 2005 and 4.1% from 1995 to 2005, according to the BEA. National increases over the same periods were stronger: 5.6% for 2004-2005 and 5.5% for 1995-2005.

BEA also publishes data for the 18-county Topeka EA (Economic Area). The PCPI for the EA was $30,483, which was 88% of the national average. The 4.9% increase over 2004 exceeded the national increase of 4.2% over the same period. The average annual growth rate since 1995 for the Topeka EA was 4.7%, which was more than the national rate of 4.1%. TPI as of 2005 was $13,768,609. TPI had increased 4.6% over 2004 and had averaged 4.5% annually since

1995. The comparable national increase for each period was 5.2%. Increases in earnings in the EA were 4.1% since 2004 and an annual average of 4.6% since 1995. Both of these rates were well below the national increases of 5.6% and 5.5%.

Unemployment for the Topeka MSA in June 2007 was 5.0%, according to the BLS, up slightly from 4.8% a year earlier. (The Topeka MSA, or metropolitan statistical area, is a 5-county area that also includes the counties of Jackson, Jefferson, Osage and Wabaunsee in addition to Shawnee.) The median hourly wage for all occupations in Topeka as of May 2006 was $14.13, according to BLS.

2.1.3.4 Transportation and Access. Access generally has been a strength for Topeka throughout its existence. Topeka's rich, sandy loam Kansas River bottomlands were long used by Indians, who also favored the superior fords available here. Later settlers established ferry services for crossing the river, facilitating the rise of the future town site as a significant post on the Oregon Trail which crossed the river here. Incorporated in 1857, the early city was strongly influenced by railroads. Rail continues to have a strong role in today's city. Topeka is a shipping and distribution hub linking the corn and wheat production region of northeastern Kansas, as well as cattle producing Southwestern states, with markets nationwide. The city is well-positioned on the Chicago-to-Los Angeles Transcon route that has boomed in recent years. Topeka has successfully retained a large and important maintenance and testing facility for the Burlington Northern Santa Fe Railroad, which has been a major employer in the city for many years. The BNSF rail yards are a dominating physical feature in the South Topeka/Oakland area, while the Union Pacific Railroad serves the North Topeka area with its grain elevators and is considering adding a third track in the area. As for the Kansas River, it is not today navigable for freight transport.

East-west highway access through the city is provided by Interstate Highway 70, which roughly parallels the Kansas River, while U.S. Highway 24 provides a secondary east-west route on the northern side of the area. The main north-south access route is U.S. Highway 75. Kansas Route 4, completed in the past few years, also is also a key component of the freeway loop on the east side of Topeka. Interstate Highway 335 runs from Topeka to the southwest, eventually joining Interstate Highway 35 which runs from the Canadian to the Mexican borders. The trucking industry benefits from this transportation network, with 300 motor carriers employing more than 7,000 workers locally. The city's transportation network of roads and streets has until recently been more than adequate in accommodating growth in the region, but growing pains are now perceived in the city and a long-term transportation plan has been developed in the past few years to plan for expansion and improvement of the transportation system.

Forbes Field, a former military base that is now the city's main airport, is on the south side of Topeka outside the study area. Billard Airport, a secondary facility rated as a Basic Transport Class General Aviation Airport that is located in the center of the Oakland area, emphasizes industrial usage but is still one of the busiest airports in the state. Both airports have significant capacity beyond their current usage, the demand for which is limited by easy access to Kansas City International Airport about an hour away.

2.1.3.5 Economic Development and Redevelopment. A fair and accurate overview of Topeka's relative economic position is given in a recent report advocating an economic development strategy for the city: "The area's basic economic trends have been positive, and closely match state trends, but generally lag U.S. and similar city trends. It is better off than many Midwest cities in that it continues to gain population, but the growth is below the national average." ("Creating Excellence in Economic Development: A Comprehensive Economic Development Strategy for Topeka and Shawnee County, Kansas," prepared by Competitive Strategies Group for the Topeka Chamber of Commerce, February 2007.)

The Topeka area has several advantages in attracting economic development. In addition to the relatively good access options described above, the work force has a fairly high percentage of high school graduates. Although the percentage of college graduates is not as high, the city does host Washburn University and is situated between the University of Kansas 20 miles to the east and Kansas State University about an hour to the west. The city has a strong manufacturing corridor, and attracting new manufacturers often is influenced by the presence of an existing work force with manufacturing skills. Construction employment has increased in the past few years, which often is a harbinger of future development. On the other hand, the city lacks sufficient office space to support major new development in the short term and tends to have an unfocused pattern of commercial development with no real center of gravity. In addition, much of the commercial growth in Topeka in the past 20 years has been on the south side of the area and along the Wannamaker corridor on the west side of the city, and continued growth on the southern edge of town is running up against sewer and water capacity constraints as well as the disincentives associated with the need to use a toll road.

The 2002 Economic Development Plan for Topeka/Shawnee County identified several areas that are targeted for economic development and redevelopment in the study area. Plans include commercial office and industrial park development. At least four major development sites are within or adjacent to areas protected by the Federal project: the Kanza Business and Technology Park (west edge of Auburndale); the Oakland Expressway area; the Northwest Topeka area; and the U.S. Highway 24 area in North Topeka. These areas are discussed below in connection with the individual protected areas.

For the year to date in August 2007, the Topeka public works department listed 122 residential permits accounting for $33,958,000 of new construction as well as 30 commercial permits for new buildings accounting for $24,489,000 and 35 alteration permits accounting for $4,998,000.

2.1.4 Study Area Investment. The Topeka Federal Levee system collectively protects property with an estimated value of $2.67 billion (October 2008 prices), as summarized in Table D-7. This total - based on a field survey and subsequent data development described in section 4 of this appendix - includes 6,487 homes and 790 businesses and public facilities as well as 164 miles of roads and streets and over 800 acres of crops. About 55.1% of total investment is in the North Topeka area, while Oakland accounts for 21.6%, South Topeka 15.2%, Auburndale 4.5%, Waterworks 2.4%, and rural Soldier Creek 1.1%.

TABLE D-7

STUDY AREA INVESTMENT

	WW	AUB	S TOP	OAK	N TOP	SOLD CK RURAL	TOTAL STUDY AREA	% OF TOTAL
Non-residential (businesses and public facilities)								
Quantity	1	18	142	89	539	1	790	
Structures	$26,961 1	$11,218 4	$151,326 4	$54,279 2	$250,341 5	$83 7	$494,210 3	
Contents (equipment/inventories)	$35,642 6	$11,028 6	$224,581 2	$151,588 0	$886,698 7	$107 1	$495,000 3	
Total Value	$62,603 7	$22,247 0	$375,907 6	$205,867 2	$1,137,040 2	$190 8	$1,803,856 5	67 5%
Residential								
# Homes	0	616	80	2,942	2,752	97	6,487	
Structures	$0 0	$47,711 3	$2,318 2	$186,925 9	$129,664 2	$14,638 0	$381,257 6	
Contents (including autos and landscaping)	$0 0	$33,397 9	$1,622 7	$130,848 1	$90,764 9	$10,246 6	$387,744 6	
Total Value	$0 0	$81,109 2	$3,940 9	$317,774 0	$220,429 1	$24,884 6	$648,137 8	24 3%
Roads & Streets (railroads, highways, city streets & county roads)								
Miles	0 6	11 2	20 0	45 9	82 9	3 3	163 9	
Total Value	$1,301 2	$15,824 6	$27,758 8	$53,750 3	$113,967 5	$3,561 6	$216,164 0	8 1%
Agriculture								
Cropped Acres	0	0	0	90	15	700	805	
Total Value	$0 0	$0 0	$0 0	$270 0	$45 0	$2,100 0	$2,415 0	0 1%
Total Value	**$63,904.9**	**$119,180.8**	**$407,607.3**	**$577,661.5**	**$1,471,481.8**	**$30,737.0**	**$2,670,573.3**	100 0%
% of total	2 4%	4 5%	15 3%	21 6%	55 1%	1 2%		

October 2008 prices, all structure and content values reflect depreciated replacement values

2.2 WATERWORKS SOCIOECONOMIC CHARACTERISTICS

2.2.1 Waterworks Land Use. The protected area totals only 36 acres, and the sole property in the protected area is the massive Topeka water treatment plant. This plant supplies drinking water to 160,000 people throughout Topeka as well as outlying areas of Shawnee County. The plant has a treatment capacity of 63 mgd (million gallons per day) with an average daily use of 25 mgd.

2.2.2 Waterworks Population and Social Characteristics. The Waterworks area is wholly industrial and has no population or housing

2.2.3 Waterworks Investment. Total investment in the Waterworks unit, in depreciated replacement value terms, is approximately $63.9 million. The treatment plant is the sole property, apart from a small amount of city streets. The investment total is 2.4% of total investment in the study area.

2.2.4 Waterworks Economic Development. The Topeka Water Division recently has crafted a master plan called Water for Growth intended to guide updating and expansion of the water distribution system in the city for the next 30 years. The project will involve some replacement of older infrastructure, but mainly aims to expand the current 800-mile water distribution system's capacity in areas of the city where growth is expected to occur.

2.3 AUBURNDALE SOCIOECONOMIC CHARACTERISTCS

2.3.1 Auburndale Land Use. The protected area is a portion of an older urban neighborhood clustered around the Ward-Martin Diversion. The area, which totals a little over 300 acres, is largely single-family homes. Most homes are older, but many have been rehabilitated in recent years. Also included in the Auburndale area is a small commercial strip at the south edge of the area and a few public facilities, notably a large state printing plant near the river which is the largest property (in terms of economic value) in the area.

2.3.2 Auburndale Population and Social Characteristics. The 2000 population of Auburndale was 1,468, which accounted for about 9% of the total study area population. The Census block groups containing the Auburndale area had a total population of 5,184. Compared to Topeka and Shawnee County residents in general, Auburndale residents on average are slightly older and somewhat better educated. Auburndale per capita income as a weighted average of the Census blocks included in the study area was $19,452 in 2000, which was comparable to the overall Topeka total of $19,555. The poverty rate of 6% was well below the city's 12.4% rate and the county's 9.6%, and the 2.4% unemployment rate was only half that of Topeka. Only 1.1% of Auburndale residents are foreign-born, which is significantly fewer than in the city and county. Whites account for 90.6% of the Auburndale population, much higher than comparable percentages for the study area, city, county, state or nation.

The average home value of $60,202 was about 64% of the Shawnee County average and 74% of the Topeka average. The lower Auburndale housing values probably are due chiefly to the older housing stock: Auburndale homes are on average about 50 years old, compared to the citywide and countywide average ages of 37 to 40 years. The home ownership rate of 63.3% is about midway between the Topeka rate of 60.8% and the Shawnee County rate of 67.5%, and vacancy rates in this stable, older neighborhood were lower than in the city and county.

2.3.3 Auburndale Investment. Total current investment (October 2008) in the Auburndale area is an estimated $119.2 million. The property base includes 616 homes valued at $81.1 million including contents. The neighborhood also had 18 businesses and public facilities valued at $22.2 million, and 11.2 miles of streets and highway valued at $15.8 million. The total investment for Auburndale represents 4.5% of the total for the study area.

2.3.4 Auburndale Economic Development. The main redevelopment project in this area of Topeka involves the old State Mental Hospital campus at the west edge of the area (and directly south of Waterworks). This 550-acre area has largely been bought up in anticipation of planned retail and office development, and MacVicar Street and 6th Street, which respectively run along the east and south sides of the campus, have recently been widened. The biggest player in the redevelopment is the St. Francis Health Center, one of the most dominant forces in the local and regional economy and already the tenant of a facility on the south edge of the Auburndale area. St. Francis plans to build a 250-bed hospital anchoring a state-of-the-art health park and incorporating the historic clock Tower Building. This project figures to involve large-scale investment; the hospital alone probably would cost on the order of $250 million, using the industry rule of thumb of $1 million in costs for every bed in a new hospital. Only a small portion of the redevelopment area is in the Kansas River floodplain. However, the scale of development could have future implications for the floodplain. The project should augur well for the continued health of the Auburndale neighborhood as well.

2.4 SOUTH TOPEKA SOCIOECONOMIC CHARACTERISTICS

2.4.1 South Topeka Land Use. The South Topeka protected area is a 300-acre area just north of downtown Topeka which includes some of the oldest riverfront blocks in the city. (South Topeka is "south" due to its location on the south bank of the Kansas River, not in the sense of being the southern portion of today's city.) It is primarily given over to industrial and office uses. Some of the area's largest employers are located in South Topeka, Hallmark Cards, Hill's Pet Nutrition, and a portion of the Burlington Northern Santa Fe Railroad maintenance shops and offices. A secondary use in the area is residential: South Topeka is not a large neighborhood but does have a number of homes.

2.4.2 South Topeka Population and Social Characteristics. The 2000 population of South Topeka, based on the block group statistics, stood at 211. For the larger area defined by block groups, the population was 1,853. The area contained 880 housing units with an average value of $41,155 and an average age of 62 years. The average value is about half that of Topeka and less than half the comparable figures for the county and state. Renters occupy 50.4% of housing units, a higher percentage than the 39.2% for the city or the 32.5% for Shawnee County. South Topeka also has a lower percentage (37%) of residents who lived in the same home in 1995; the city and county percentages are 46.7% and 49.9%. The vacancy rate of 22.3% is about triple the city and county vacancy rates of 7.5% and 6.6%.

Per capita income in South Topeka is $10,305, the lowest total in the study area, only about half of the city and county per capita incomes and less than half of the national figure. The poverty rate of 39.4% was more than triple that of Topeka (12.4%) and was four times that of Shawnee County (9.6%). The poverty rate in some South Topeka block groups is as high as 42%. The 12.3% unemployment rate was much higher than the city and county rates of 4.8% and 4.0%. South Topeka residents generally were much more likely to be foreign born and less likely to have high school diplomas than the area averages. Whites account for a smaller percentage of the population in South Topeka (73.7%) than in the study area as a whole, and the 20.4% of the population that is Hispanic is higher than the national figure of 12.5% and much higher than the city and state figures of 7.0% and 8.9%.

2.4.3 South Topeka Investment. The South Topeka area currently has 80 homes valued at $3.9 million including contents, 142 businesses and facilities valued at $375.9 million including equipment and inventories, and 20 miles of roads and streets valued at $27.8 million. Total investment is $407.6 million. This total is 15.2% of the investment for the entire study area.

2.4.4 South Topeka Economic Development. South Topeka has several of the Topeka area's largest employers, including the Burlington Northern Santa Fe Railroad (about 1,100 employees), Hill's Pet Nutrition (800 employees), and Hallmark Cards (725 employees). No significant future development plans are known to exist for this area apart from the city's riverfront development, which may include a hiking and biking trail.

2.5 OAKLAND SOCIOECONOMIC CHARACTERISTICS

2.5.1 Oakland Land Use. The Oakland protected area accounts for nearly 3,300 acres in east Topeka. The Oakland levee protects the city's main sewage treatment plant and Billard Airport as well as several older residential areas, retail service areas and a moderate amount of farmland.

2.5.2 Oakland Population and Social Characteristics. Based on the Census blocks accounting, Oakland had 7,030 residents in 2000, which was 44% of the study area total. There were 11,815 residents in the block groups containing the area. Oakland's 2000 per capita income of $13,361 was only 68.3% of Topeka's, 65.2% of the state and 61.9% of the nation. It was also well below the study area total of $17,596. However, some block groups in Oakland have per capita incomes that are less than 30% of the city, state and national figures. The poverty rate of 18.4% for Oakland was 48% higher than the rate for Topeka and 46% higher than the study area's rate. Four block groups in the area have poverty rates ranging from 27% to 41%. The unemployment rate of 8.7% was about twice those of Topeka and Shawnee County (4.8% and 4.0%). The percentage of the population that was foreign born amounted to 8.1%, which was triple the rate for Shawnee County and about two and a half time that of the city.

Of the 4,969 housing units in Oakland in 2000, the average value of owner units was $47,546, a total which was about 50%-60% of the average city and county values and about 72% of the study area average. Like the other components of the study area, Oakland has an older housing stock. The average age of homes was 54 years, compared to Shawnee County's 36.9% and Topeka's 39.7%. The vacancy rate of 9.3% and the 53.7% of residents who lived in the same house in 1995 were somewhat above comparable city and county totals.

2.5.3 Oakland Investment. Total investment in Oakland currently is estimated at $577.7 million, about 21.6% of total study area investment. Included in this total are 2,942 homes valued at $317.8 million, 89 businesses and facilities valued at $205.9 million, 46 miles of roads and streets valued at $53.8 million, and 90 acres of crops.

2.5.4 Oakland Economic Development. In the South Topeka/Oakland area the Kansas Department of Transportation has completed work on the Oakland Expressway along the city's eastern boundary. The Expressway connects I-70 to the south with U.S. Highway 24 to the north. This new corridor presents extensive long-term opportunities for economic development. Billard Airport lies at the northern end of the corridor. The airport possesses up to 100 acres of land that could be developed for commercial and industrial uses. Sewer and water lines are available to these sites. An additional 270 acres of undeveloped land, zoned for industrial purposes, lies immediately north and east of the airport. This land could be attractive for development by a large firm since there are available parcels that are large and near downtown. Additional sites that seem likely to develop include a potential node at the Oakland Expressway's intersection with Seward Avenue, where approximately 300 acres of industrial-zoned land await development. Just south of this area and north of Shunganunga Creek is another area of about 200 industrial-zoned acres. This land, however, lacks sewer and water connections at present. South of Shunganunga Creek and adjacent to the U.S. Highway 40 interchange with the Expressway, along both sides of the Expressway down to the I-70 interchange, is an area encompassing about 500 acres that is currently zoned for residential use but that could be developed for commercial or industrial uses. Since much of the residential and commercial building stock in Oakland is relatively old, there is a high likelihood that some or all of these sites will be developed during the 50-year period of analysis, adding to any damage potential associated with the existing levee system's condition.

2.6 NORTH TOPEKA SOCIOECONOMIC CHARACTERISTICS

2.6.1 North Topeka Land Use. The North Topeka protected area is a huge area of more than 6,000 acres accounting for the great majority of the portion of Topeka lying north of the Kansas River. North Topeka once was a separate community called Eugene with its own riverfront downtown. This old town area and many surrounding neighborhoods and service areas are protected by the levee, along with a number of large businesses, including a Goodyear Tire plant, the largest industrial concern in the city, and the world headquarters of Payless Shoe Source, Del Monte Pet Products, Cargill, and U.S. Foods. A large new sewage treatment plant is also located in the area.

2.6.2 North Topeka Population and Social Characteristics. The 2000 population of the North Topeka area was 6,725, which was 42% of the total study area population. The block groups comprising this reach had a population of 8,696. The per capita income for North Topeka, $16,693, was 95% of the study area total, 85% of the Topeka total, and 80% of the county total. Residents of this area were more likely to be unemployed (6.4%) than in the overall study area, city, county or state, and the poverty rate of 13.8% was higher than in those areas. North Topeka residents also were more likely to be white (89.8%) and less likely to be foreign born (1.2%).

The 2000 housing units total was 3,745. The housing vacancy rate of 8.8% was higher than the Topeka rate of 7.5% and the statewide rate of 8.2%. The average value of owner units was $65,596, which was only slightly lower than the average for the study area but was 81% of Topeka's, 70% of Shawnee County's and 63% of the Kansas average. Homes were 41.9 years old on average, somewhat older than in Topeka or Shawnee County but not as old as the study area average of 46.1.

2.6.3 North Topeka Investment. The North Topeka area contains 2,752 homes valued at $220.4 million, 539 businesses and facilities valued at $1.137 billion, and 83 miles of roads and streets valued at $114 million. The total estimated value of protected property is $1.471 billion, which is 55.1% of study area total investment.

2.6.4 North Topeka Economic Development. New development is slowly taking shape around the western and northern edges of the North Topeka area. The biggest development on the horizon at present is a $200 million ethanol plant that seems poised to be built on a parcel just west of the study area. Within the protected area, the northwest Topeka area, situated around the cloverleaf intersection of U.S. Highways 24 and 75 and the area northwest of the Lower Silver Lake Road intersection with Highway 75, is a prime focus of interest. About 80% of the area is zoned for industrial uses, but only about a quarter of the more than 2,000 acres in the area is currently used for industrial or commercial purposes. About 44% of the land is considered vacant, although some of it is farmed. The area has certain drawbacks, including inadequate infrastructure and fragmentation of parcels. Most of the land is divided into over 200 small parcels of generally 30 acres or less, requiring developers to consolidate developable parcels from several small property owners. In addition, much of this land is either just outside the corporate limits of the city of Topeka, or unplatted, or both. On the other hand, a recently constructed sewage treatment plant allows plenty of capacity for new development, and portions of the area have rail service.

Another corridor for new development is along U.S. Highway 24 and the nearby Soldier Creek. and the city recently announced a corridor study for U.S. Highway 24. One other development that may be on the horizon is the proposed Kaw Reserve Trail. This trail would follow the Kansas River from Highway 75 east to Happy Hollow Road near Soldier Creek at the downstream end of the North Topeka unit, turning the levee maintenance road into a hiking and biking trail.

2.7 SOLDIER CREEK SOCIOECONOMIC CHARACTERISTICS

The large area protected by the right bank portion of the Soldier Creek unit is essentially the same as the area protected by the North Topeka unit. Therefore, the discussion of land use, population and social characteristics for North Topeka in the preceding section also applies to the Soldier Creek unit. This section will cover the left bank area of Soldier Creek.

2.7.1 Soldier Creek Land Use. The small rural areas protected by the seven smaller portions of the Soldier Creek unit are along the northern edge of Topeka. These areas total 1,057 acres and range from 39 to 449 acres. Several of the units protect residential areas, but only one, the left bank area around Kansas Avenue, contains a significant amount of property, including more than three-quarters of the 97 homes in the rural floodplain. Only one business is found in these areas. Other land uses are primarily agricultural.

2.7.2 Soldier Creek Population and Social Characteristics. The 2000 population of the protected left bank portions of the Soldier Creek unit was 664. Other left bank areas that are unprotected and interspersed with the protected areas accounted for an additional 446 residents. The block groups that include these areas extend well beyond the floodplain, with the result that the population of the block groups was 9,227. Thus, the discussion of social characteristics based on the block groups data should be prefaced with the caveat that these totals are largely based on residents outside the study area.

The 2000 per capita income of $24,289 was 138% of the study area per capita income, 124% of the city total and 116% of the Shawnee County total. The 2.0% unemployment rate and 2.4% poverty rate were significantly less than the comparable figures for overall study area, city, county and state. Residents of this area were 96.3% white and only 0.9% were foreign born. The 94.4% of residents with high school diplomas or better was significantly higher than the study area total of 81.1% or the Topeka total of 85.9%.

The 2,879 housing units in 2000 were, on average, only 28.8 years old, making them much newer than in the overall study area or the city and county. The average owner unit value of $112,102 was 169% of the study area average and 119% of Shawnee County's average. Only 6.8% of residential units were occupied by renters, compared to 29.8% in the study area, 39.2% in Topeka, and 30.7% in the state. The vacancy rate of 2.7% was very low in comparison to city, county and state rates. The percentage of residents who lived in the same home in 1995 was 67.4% compared to 46.7% in Topeka and 53.0% in the study area.

2.7.3 Soldier Creek Investment. The rural subunits of the Soldier Creek unit protect a total property value of $30.7 million, including 97 homes, 1 business, 3.3 miles of roads and streets, and about 700 crop acres.

2.7.4 Soldier Creek Economic Development. This area has acquired a new Wal-Mart store within the past few years that has quickened the overall pace of development. Woodland Park at Soldier Creek, a $25 million affordable housing project that will include 236 units, was recently announced for an area just north of the study area. It will be one of the few new apartment complexes built in Topeka in the past 25 years. Similar projects are being discussed for other points along the left bank of Soldier Creek, although there are no definite details yet.

3.0 HISTORICAL FLOODS IN TOPEKA

3.1 EARLY KANSAS RIVER FLOODS AT TOPEKA

3.1.1 The 1844 Flood. The earliest known Kansas River flood event affecting the Topeka town site occurred in 1844. A legendary Kansas River flood event that year reportedly inundated the entire floodplain in eastern Kansas from bluff to bluff. The flood occurred before river stages and high water marks were recorded systematically, but legendary high water marks suggest a peak stage that exceeded any flood that has occurred since 1844, with the possible exception of 1951. However, the impact at Topeka was presumably slight since little of the future city existed then.

3.1.2 The 1903 Flood. The first flood event that seriously affected the city was in May 1903, and this flood proved to be one of the three worst flood events that have ever occurred in Topeka. The Kansas River reached a stage of 37.7 at Topeka on Memorial Day, a stage exceeded only two other times in Topeka history (including the 1844 event and its legendary high water marks), and the Corps has estimated that the discharge was about 253,000 cfs. (However, it should be noted that the National Weather Service estimates that the discharge was about 300,000 cfs.) Flood depths reached around 12 feet in North Topeka. The 1903 flood occurred after westward expansion had increased the city's population, resulting in urbanization of the riverfront, but long before Federal flood risk management measures were implemented along the river. As a result, the flood resulted in 38 deaths and 8,000 homeless persons, almost all in North Topeka. Damage estimates are very sketchy, but urban damage above Kansas City – much of which presumably would have occurred in Topeka - was estimated at $2.7 million by S.D. Flora of the National Weather Service in a 1948 review.

Other flood events affected the city in 1908 and 1935, but the 1903 event remained the benchmark for Topeka floods for the first half of the twentieth century.

3.2 MODERN KANSAS RIVER FLOODS AT TOPEKA

3.2.1 The 1951 Flood. In terms of damage, the 1951 Kansas River flood was the record flood event in Topeka history up to the present day. The peak flow was 469,000 cfs, and the Kansas River stage reached 40.8 on July 13th, a stage exceeded before 1951 only in 1844 (if then) and never exceeded since 1951. More than 23,000 Topeka residents were evacuated during the event. A degree of Federal flood damage protection had been implemented by 1951 in South Topeka and Waterworks on a limited scale, but the South Topeka levee failed, and Oakland and North Topeka had no significant protection. Depths reached 15 to 20 feet in these areas. Only two deaths were attributed to the flood. The relatively small number of deaths probably was due to two factors: a much more effective flood warning system than existed in the 1903 event, and another flood event 16 years before that was recent enough to have remained in the city's consciousness. But more than 6,600 homes and 500 businesses and facilities were affected by the flood. More than 15,000 people were homeless. Extensive post-flood surveys carried out by the Corps of Engineers estimated total damages at $34.12 million (about $414 million in 2008 prices), of which about $18.9 million occurred in North Topeka as well as $6.1 million in Oakland/South Topeka and $600,000 in Auburndale. North Topeka's residential and commercial areas, while strong today, never completely recovered from the 1951 devastation.

A rare bright spot during the event was the desperate flood fight at Waterworks involving more than 4,500 residents that shored up the limited Federal project which then existed and saved the city's water supply.

The peak flow of the 1951 event was 469,000 cfs. This flow would exceed a 0.001-chance event flow, according to current data. However, only one of the five upstream Kansas River reservoirs - and neither of the two largest ones - was in operation at that time. It has been estimated that, had all five upstream reservoirs been in operation in 1951, the peak flow would have been about 288,000 cfs, which would be in the range of a 0.04% to 0.033%-chance (250 to 300 year) flood.

Following the 1951 event, the design of the Federal flood risk management project at Topeka was reconceptualized and augmented. The existing levees and other elements of the project were completed during the 1960s and 1970s and were therefore fully operational for the next major flood event in 1993.

3.2.2 The 1993 Flood. A record Missouri River basin flood event occurred during that summer. The event gathered momentum along the Kansas River above its mouth at Kansas City, but did not reach the extremes that were recorded along the Missouri River main stem. A peak stage of 34.9 along with a discharge of 170,000 cfs was recorded at Topeka on July 25th. Both the stage and the discharge were the fourth-highest ever recorded, but the river was held in place by the Federal project. Only very minor damage occurred in Topeka during the 1993 flood, in contrast to the devastation downstream in portions of the greater Kansas City area and other locations along the main stem of the Missouri River. The peak discharge amounted to almost a 2%-chance (50 year) flood event, while the peak stage was equal to just over a 2%-chance event.

Apart from a May 1995 event when the stage at Topeka reached 29.5, no other major Kansas River events have occurred since 1993.

3.3 SOLDIER CREEK FLOODS

Little is known about Soldier Creek floods prior to the 1940s, and very little economic data is available concerning damage estimates. Records at the Soldier Creek gauge (at RM 6.0 near the upstream end of the Federal project) go back to 1929. An April 1929 flood had produced a stage of 28.25 which stood as the highest on record for many years, but this flood event is not well documented. The 1951 flood event, which was the flood of record on the Kansas River main stem, produced a flow of 11,400 cfs and a stage of 28.15 on June 22, virtually equaling the 1929 peak. It should be noted that pre-1961 Soldier Creek flood events are not directly comparable to subsequent ones since the Federal project constructed at that time deepened the stream bed by 5 feet and also widened it.

An October 1973 flood produced a peak stage of 23.9, a record up to that time for the post-Federal project years. The flow was 20,800 cfs. Damages of $120,000 in and near Topeka were cited for the 1973 event in Corps records; in 2007 prices, this total would amount to about a half million dollars. The damages primarily occurred in relatively rural areas. Another flow exceeding 20,000 cfs was produced by a September 1977 event.

Two larger events occurred in the early 1980s. A July 25, 1981 flood reached a peak stage of 25.9 with a peak flow of 25,000, both records up to that time for the post-1962 period. The following year, a flood of June 9, 1982 produced a new record flow of 30,400 cfs and also a new record stage of 27.4. According to current flow data, the 1982 event would have fallen in the range between a 2% and 1%-chance event, while the 1981 event would have fallen between a 5% and 2%-chance event. In the period from 1982 through 2004, only two additional flood events produced flows exceeding the 5%-chance event discharge of 21,500 cfs: the July 1993 event (23,400 cfs) and the June 1999 event (25,200 cfs). All of the flood events of the 1980s and 1990s appear to have been contained more or less successfully by the Federal project with little or no damage in Topeka.

On Oct. 2, 2005, Soldier Creek reached a new record stage of 34.5. The flow was 47,800 cfs, which would be rated as approximately a 0.4%-chance) event given current flow data. The flow resulted in damage to the levee exceeding $10 million. Limited overtopping occurred in North Topeka, where the Payless distribution center on Highway 24 was evacuated and closed for 14 hours, though it did not sustain damage. A small number of homes and businesses on both sides of the creek, especially the unprotected left bank areas, were damaged by up to six feet of water. But in general, the levee held, and known damage from the event was modest in light of the historic flow and stage.

4.0 DAMAGE ANALYSIS DATABASE PREPARATION

4.1 STUDY CONFIGURATION

4.1.1 Analysis Years and Period of Analysis. In addition to the existing conditions of 2008, we also analyze a base condition and a future condition. The base year for the economic analysis - i.e., the year when the project would be completed and operational - is 2015. The future condition year is 2038.

In this analysis, the economic database for the existing condition is also used to characterize the base and future conditions. These conditions initially were defined separately in order to allow the addition of planned development late in the study completion period based on the most current information about future development. Since economic development plans potentially affecting the future without-project condition tend to be fluid and speculative, we establish our assumptions in this area as late in the study as possible. Ultimately, however, while there were many possible projects on the horizon as we completed this study, none met our criteria for inclusion: (a) high likelihood of implementation, (b) firm identification of a location, and (c) availability of information on industrial classification and estimated investment. Some of these potential projects are touched on in the economic development portions of section 2 of this appendix, but none could be added to the economic analysis at this time. (Given the nature of the alternatives formulated for the feasibility study, the addition of any future development to the analysis would have affected estimates for the future without-project condition but would have had no effect on economic screening of alternatives. This is because the alternatives within each study reach accomplish the same purposes and have the same benefits. See section 6 of this appendix.)

Therefore, the economic database used in the existing conditions analysis is carried through to the base and future conditions without change. In addition, engineering data used in the risk-based analysis for hydraulic, hydrologic, structural and geotechnical conditions is also identical in all three conditions.

4.1.2 Interest Rate and Price Level. Annualized estimates of damages, benefits and costs in this analysis assume the FY 2009 Federal interest rate of 4.625% and a period of analysis of 50 years based on official guidance for evaluation of Federal levees. All estimates are expressed in October 2008 prices unless otherwise noted.

4.1.3 Study Streams and Reaches. Study reaches serve the basic purpose of allowing the aggregation of stage-damage data for all properties located in a particular portion of the stream's floodplain. Each reach is assigned an index point, and all property elevations in that reach are adjusted to the elevations at the index point. These adjustments in elevation compensate for variations in the lay of the land along the stream and particularly the gradual drop in ground elevations typically encountered when going downstream a river or creek.

The reaches used in this study are summarized in Table D-8, which indicates the beginning and ending river mile or station for each reach as well as the index point. In this analysis of areas protected by existing projects, the study reaches coincide with the areas protected by each unit or subunit. There are five units located along the Kansas River. Right bank units include (from upstream to downstream) Waterworks, Auburndale, South Topeka, and Oakland. The Oakland unit also includes a tieback running along Shunganunga Creek. North Topeka is the sole left bank Kansas River unit. The North Topeka area is protected from the Kansas River along its southern edge and is also protected along its northern edge by the main portion of the Soldier Creek unit. Soldier Creek has only one existing project unit, but it includes a number of discrete sections. Besides the main segment of the levee that protects North Topeka, other discrete portions of the Soldier Creek unit, primarily on the left bank, are very small rural areas with minimal property bases and very slight damage potential.

TABLE D-8

ECONOMIC STUDY REACHES

Name	Bank	Beg. Station	End Station	Index Station
KANSAS RIVER				
Waterworks	Right	86.7	87.2	87.0
Auburndale	Right	85.5	86.7	86.1
South Topeka	Right	83.7	85.5	84.8
Oakland	Right	76.0	83.7	82.3
North Topeka	Left	80.8	88.8	85.6
SOLDIER CREEK				
Right bank urban (North Topeka)	Right	0.2	7.2	4.2
Right bank rural @ Silver Creek ditch	Right	8.1	10.0	8.7
Left bank rural 1 @ Hwy 24	Left	0 2	0.6	0.4
Left bank rural 2 @ Kansas Ave.	Left	1.9	2.3	2.2
Left bank rural 3 @ Rochester Rd.	Left	2.7	3.1	3.0
Left bank rural 4 @ Brickyard Rd.	Left	5.5	6.7	6.2
Left bank rural 5 @ Menoken Rd.	Left	6.8	7.5	7.3
Left bank rural 6 @ NW 33rd St.	Left	7.6	8 0	7.9

4.1.4 Economic Categories. The economic structure inventory in this study is categorized in terms of four basic land uses: residential, non-residential (including businesses, non-profit institutions such as churches and schools, public facilities and utilities), roads and streets, and agriculture (i.e., crops – farm sets are categorized in residential). Two categories of non-physical costs of flooding, disaster relief and emergency costs, also are included in the analysis.

4.2 DATA COLLECTION METHODOLOGY

Data collection, the first phase of the economic database development, involved three steps: (1) obtaining relevant county and state tax records, GIS data and available mapping from the city and/or county; (2) design and execution of a structure-by-structure field survey; and (3) discussions of investment and damage potential with a series of owner/operators at selected critical businesses and facilities.

4.2.1 Tax Data. The Shawnee County Appraiser's property database provided structural values for businesses and homes in the study area. Protected areas of the city within the 0.1%-chance floodplain were identified and furnished to city GIS staff, who worked with the appraiser's office to sort county tax records and delineate the property records for the protected areas. Land values were separated from structure values for each property. The resulting records included not only structure values for each address but also such useful supporting data as area (square feet), condition, land use type, year in service, and number of stories. Values from the tax data were updated as the study progressed.

Most public buildings also had been assigned values in the county tax data. However, the appraiser's office cautions users that estimates for these properties are not done to the same level of detail as with residential and commercial properties, and most of the supporting data for the estimates are not readily available. Not included at all in the tax data are values for most utilities, telecommunications, or railroads. Railroads in particular are an important part of the economic base in the South Topeka/Oakland area, where the Burlington Northern Santa Fe (BNSF) Railroad has large rail yards and maintenance shops.

4.2.2 Mapping. The city GIS staff provided Kansas River mapping with 1-foot contours and spot elevations based on a 2002 survey. Real estate parcels and structure footprints were included in the GIS layers. This city mapping was further developed for purposes of the economic analysis by Kansas City District Corps of Engineers GIS staff. A floodplain map was developed based partially on existing mapping of the extent of the 1951 flood and partly on identification of a 0.1%-chance flood. This map was used to guide the field survey tasks. Ground elevations were also assigned to all floodplain structures based on the contours and spot elevations from the mapping.

4.2.3 Field Survey. Kansas City District economics staff carried out a structure-by-structure field survey of all buildings in the study area over 12 days in May-July 2003. The purpose of the survey was to build on the initial data from the county tax records in four areas. First, current occupancy as shown in the tax records was confirmed or updated for each building. Second, first-floor elevations relative to the ground were estimated by visual inspection, and the presence of basements also was noted. Third, other information from the tax data were verified or corrected. In particular, appraised values included in the tax data were evaluated for each structure in light of condition, make, age, area in square feet, and other qualities. The purpose was to obtain a generalized reality check on the usefulness of the appraised values by assessing whether obvious mismatches between data and reality occurred on a regular basis. Finally, where businesses and public facilities were concerned, the nature of the activity was not always obvious from the tax data or the business name, so properties were inspected for additional clues, as well as for the presence of significant outside inventory or equipment. Notes from the completed field survey were subsequently integrated with the tax data to form an adjusted initial structure inventory for the study area.

4.2.4 Key Businesses and Public Facilities. Discussions with business owners, managers, and plant foremen at selected businesses and facilities (on-site in some cases, by telephone in other cases) also yielded detailed information on values, types of inventory and equipment, elevations, and effects of inundation. The purpose was to develop a more accurate estimation of damage potential for businesses or facilities that are critical to the results of the damage analysis. Usually they are critical because they account for a significant portion of total property value in their area. Estimated damage potential developed based on these discussions also can be applied to similar businesses. The information provided by company representatives facilitated the subsequent preparation of detailed value estimates and depth-damage estimates for the company.

In selecting a series of key businesses and facilities for more detailed evaluation, the goal was to account for as much as possible of the investment, and therefore damage potential, in each protected area by emphasizing those firms controlling a disproportionately large percentage of the investment. Early in the feasibility process, the reconnaissance economics database from 1997 was utilized for an initial screening in which firms with the largest structure value in each area were identified. (Neither an organized feasibility-level database nor any reliable estimate of business contents was yet available at that time.) The list subsequently was refined based on other discussions with city and county officials and on observations during the field survey.

Ultimately, we spoke with representatives of 34 businesses and facilities. Based on the final estimates of non-residential structure and content values used in this analysis, these 34 firms and facilities account for 56% of non-residential investment (i.e., businesses and public facilities) in the study area. Of the 34, 22 were firms in North Topeka, an area with most of the larger companies in the study area and about half the property value, and the 22 firms accounted for 55% of the total non-residential value in that area. In Oakland and South Topeka, the other largest components of the study area, data from discussions with representatives of 10 companies and facilities accounted for 55% of non-residential value in that area. In Auburndale, we spoke with representatives of the only large facility in the floodplain. Other Auburndale businesses are few in number, small, and generally at the edge of the floodplain, minimizing their contribution to expected annual damage potential.

4.3 DATA DEVELOPMENT - ELEVATIONS

In the second phase of the database preparation for the economic analysis, the raw data obtained from the county and city tax and GIS data and from the field survey and discussions with businesses were further developed, refined, and organized to produce the three key variables for each property to be used in the damage analysis: beginning damage elevations, property values, and depth-damage relationships. The risk analysis program used for the damage analysis also requires specification of uncertainty factors for each of these variables.

Each property in a flood risk management analysis is assigned a mean sea level (m.s.l.) ground elevation. This includes crop acreage and roads as well as buildings. Buildings additionally are assigned a first-floor elevation expressed as a foundation height above the ground elevation.

Damage computations take into account ground elevation, first-floor elevation, and lowest opening elevation if it is different from the other two elevations. Property elevations help determine depths of flooding for each flood event evaluated.

Each structure in the study area was assigned a ground elevation using the 1-foot contour maps. Because of the large number of structures in the study area (about 6,500 homes and 800 businesses), elevations for homes and smaller businesses were assigned on a block-by-block basis in densely populated neighborhoods with very flat topography and structural homogeneity. In areas with more dispersed development, each structure was evaluated individually, particularly large business or public structures. Each structure also was assigned a station or stream mile for the purpose of allowing the stage-damage relationship for the structure to be transferred to the index point of the reach in the damage analysis.

In addition to the ground elevations and stations, each structure also was assigned a foundation height relative to the ground elevation. The foundation heights were estimated in half-foot intervals by visual observation during the field survey. The first-floor elevation (which is usually the beginning damage elevation) in the economic analysis model was determined by adding the foundation height to the ground elevation.

Using a flooded area map based on a 0.1%-chance event, we evaluated all city streets and county roads in the floodplain on a block-by-block basis, assigning an average elevation for each block. Highways and railroad track were similarly divided into short segments and assigned an average elevation for each segment.

The first-floor elevation for each type of structure is characterized by an uncertainty factor, usually expressed as a standard deviation around a normally distributed variable. According to EM 1110-2-1619, Table 6-5, the uncertainty associated with mapping based on an aerial survey with 2-foot contours would be characterized by a standard deviation of 0.3 feet. The table does not give the error associated with 1-foot contour maps, which by inference might have a standard deviation of 0.15 feet (or something less than 0.3 feet, in any case). However, at least three factors increased the uncertainty beyond this rule of thumb: (1) the generalized block-by-block method for assigning ground elevations in some areas; (2) the difficulty of estimating the correct ground elevation for properties where the structure footprint is traversed by multiple elevation contours; and (3) the uncertainty inherent in brief and somewhat distant visual observation and estimation of foundation heights in the field during surveys. These factors are bigger issues with some properties and areas than others, and the exact uncertainty associated with each limitation is unknown. But in order to accommodate the known uncertainty factors involved in estimating elevations for this study, all structures in the database, as well as all road segments, were assigned a standard deviation of 0.8 feet.

4.4 DATA DEVELOPMENT - VALUATION

Guidance for Corps of Engineers economic analyses defines asset value in terms of depreciated replacement value, which is defined as the cost of replacing an item today with an item of identical effective age (i.e., not a brand new item, unless the item being replaced is brand new). As the term implies, the concept is to identify the replacement cost of the item and then depreciate this value according to the item's condition and age. This concept of value is applied to values for all structures, whether residential or non-residential, as well as major production or office equipment and vehicles. Inventories of businesses, including raw materials, work in progress, and finished goods, are valued in terms of replacement value.

The economic expression of values for each property category also must include uncertainty factors to be used in the risk analysis. Most economic variables in flood risk management studies are believed to be distributed normally, so the uncertainty around a median value is expressed as a standard deviation. In cases where the samples available for estimating variables are very small and the distribution of the variable is unknown, uncertainty may instead be expressed as a triangular distribution with most likely, maximum, and minimum value estimates.

4.4.1 Residential Structures Valuation. For this analysis, appraised values of homes were initially taken from the 2003 Shawnee County property tax data as an approximation of depreciated replacement values. (The appraised values ultimately were updated to 2006 values for use in the alternatives analysis.) The appraised values are based on sales data for comparable properties, and sale prices generally provide a fair approximation of depreciated replacement value, with two provisos: overall property value must be stripped of land value (which had been done by the county prior to receipt of the data by the Corps), and appraisals must be updated regularly. Kansas state law, enforced by audits, requires county appraisers to keep statistics indicating how well appraised values reflect actual sales prices data, and appraised values are required to be within 10% of actual sale prices. The Shawnee County appraiser's office, based on data for the most recent 12-month period, estimated that residential property appraisals have been within 3% of actual sales. The field survey also allowed a reality check on the reasonableness of appraised values since each property could be visually inspected in light of its appraised value, and severe mismatches between estimated value and reality could be identified. Generally, however, the field survey confirmed the reasonableness of the appraised values for Topeka homes.

The appraised values were only used as a starting point, however. A detailed Marshall and Swift analysis of depreciated replacement value was performed on a sample of homes, with the intention of ultimately using the results to adjust the appraised values of the entire population of residences. The sample size was selected by calculating mean values and a standard deviation for the entire population of appraised values and then entering them into a standard statistical formula along with specified confidence factors and deviations from the mean. The sample was stratified by study reaches and included only single family, non-manufactured homes. (Mobile homes and apartments, which form much smaller groups within the population, were dealt with separately but using a parallel methodology.) Given our specification of a 90% confidence factor and an allowable deviation of 10% from the mean value, the minimum sample size was estimated to be 31 for Auburndale, 62 for Oakland/South Topeka, and 214 for North Topeka, for a total of 307 homes.

We obtained detailed data from the county tax database on each of the homes in the sample, including square footage, construction type, number of stories, wall type, basements, garages, porches, heating and air conditioning types, floor coverings and interior walls, and lump sum adjustments such as fireplaces. The Marshall and Swift database provides values associated with each of these characteristics and allows computation of detailed replacement values for each home. Additional data from the tax database on age and condition were then used in conjunction with the Marshall and Swift material to estimate depreciation and calculate a depreciated replacement value. Upon completion of the sample, the resulting depreciated replacement values for each of the 307 homes was compared to the 2007 appraised value to determine the percentage change. Finally, the percentage changes for the sample were averaged and the average increase of 21.8% was applied to the remainder of the population.

Structure value uncertainty in this analysis generally is related to uncertainty in either the assessment of residential construction quality or depreciation estimates. The standard deviation for residential structure value in this analysis is assumed to be normally distributed and is characterized by a standard deviation of 0.19. This standard deviation is based on the typical differences in value between successive categories of construction quality in the Marshall and Swift residential data.

4.4.2 Residential Contents Valuation. Residential content values are normally expressed in terms of a contents-to-structure value ratio (CSVR). For example, if a home appraised at $100,000 has a CSVR of 0.5, the home is assumed to have contents valued at $50,000. The CSVR is a standard technique used in the insurance industry for estimating contents values in the absence of detailed data. Due to the nature of the residential depth-damage relationships (developed by the Institute for Water Resources and described further in section 4.4.1 below) used in this analysis, a nominal residential CSVR of 1.0 is used in the risk analysis, following the guidance accompanying the IWR functions. The IWR functions are formulated so that no CSVR is actually used to compute content values in the analysis (the function of the nominal CSVR of 1.0 is only to ensure that the depth-damage functions result in corrrect calculations in the risk analysis). For purely informational purposes of estimating investment values in the study area, residential contents value is assumed to equal 50% of structure value.

The IWR functions are used for all 1, 1 1/2, and 2-story homes, with or without basement. Mobile homes and apartments are not included in the IWR functions, and CSVRs are used to value contents for these two residential categories. For apartments, a CSVR of 0.23 was used, based on New Orleans District data summarized in the next section below. For mobile homes, a CSVR of .636 was used, based on Table 6-4 in EM 1110-2-1619, "Risk Based Analysis for Flood Damage Reduction Studies," 1 August 1996.

Autos are included in the residential data by assuming that there are two vehicles associated with each home, based on data from the Bureau of Labor Statistics indicating an average of 2.2 cars per household in this region. We assume that in the event of evacuation, one vehicle would be left behind and would be subject to damage. In order to account for autos, as well as landscaping and other outdoor features nor included in the contents category, all residences are assumed to have an "other"-to-structure value ratio of 20%. In support of this ratio, we determined that the average used car sale value in 2007 is approximately $8,500 (Maryland Motor Vehicle Administration, 2007). The $8,500 would be slightly more than 15% of the average home value in this study of $55,600, and since the $8,500 does not account for those who have new cars (triple the cost of used vehicles, on average) and does not include landscaping, 20% of structure value appears to be a reasonable assumption for this category of damages.

Uncertainties in residential contents valuation are not specified in this analysis for those homes affected by the IWR functions, following the guidance for the functions warning against the use of any uncertainty factors because of how the functions are constructed and used in the risk analysis. That approach has been followed in this analysis. For mobile homes, the source for the CSVR (EM 1110-2-1619, Table 6-4) also specifies a standard deviation of 0.378. The New Orleans data which includes the CSVR for apartments also specifies a standard deviation of 0.13. For the "other" category, which includes autos, a standard deviation of 0.05 is assumed.

4.4.3 Commercial and Public Structures Valuation. The values of commercial and public structures in this analysis are estimated using information from the county tax database in conjunction with Marshall and Swift's commercial valuation reference products. Characteristics for each building taken from the tax database included occupancy type (e.g., garage, church, retail store, office building, etc.), construction class, construction quality, and square footage. These characteristics were the basis for calculation of replacement values for each structure using the Marshall and Swift reference data. The next step involved obtaining data on age, typical building life, and condition for each structure from the tax database and using these characteristics to develop an effective age and a corresponding depreciation factor. Application of the depreciation factor to the replacement value resulted in a depreciated replacement value for each building. These methods are similar to the process used for residential structure valuation, but unlike the residential computations which used a sample to adjust a large population of residences, all non-residential building values were evaluated individually without a sample.

Uncertainty in the valuation of commercial and public structures is assumed to be normally distributed and is characterized in this analysis by a standard deviation of 0.21 for all properties. Like the structure value uncertainty for residential properties, this standard deviation assumes that assessment of construction types and qualities is a key source of value uncertainty and reflects the typical differences between successive categories of construction types in Marshall and Swift commercial data.

4.4.4 Commercial and Public Contents Valuation. Commercial and public contents include assets such as office equipment, major production equipment, and rolling stock, as well as inventories items including raw materials, work in progress, and finished goods. All properties in this analysis were assigned content values in terms of a contents-to-structure-value ratio (CSVR). For firms and facilities that provided more detailed data to us via discussions, this ratio was developed indirectly from data on asset and inventory values obtained from the companies. It should be stressed that in these cases, the structure and content values were developed first, then the CSVRs were derived from those values. Although computation of CSVRs was an additional step not required for valuation of these businesses and facilities, the CSVRs were developed in order to treat all data in the database consistently (the majority of businesses derive content values from CSVRs) and facilitate simpler data handling for the risk analysis.

The first-hand, company-specific data yielded CSVRs ranging from 0.28 for a railroad company to 80.17 for a food warehouse. Since the companies and facilities providing these data accounted for about 65% of the estimated total study area non-residential contents value, it can be seen that non-residential contents valuation in this analysis is primarily based on first-hand information from the companies. Since obtaining first-hand data from all 800 companies in the study area would not be realistic, content values for the majority of businesses and facilities must be derived from something other than company-specific data. For contents valuation of these firms, this analysis primarily utilizes CSVRs developed by the New Orleans District Corps of Engineers, which has accomplished a great deal of analysis over several major studies concerning typical content values and depth-damage functions for both structures and contents in a broad range of industries. The data used in this analysis were published in the report "Depth-Damage Relationships for Structures, Contents, and Vehicles and Content-to-Structure Value Ratios in Support of the Lower Atchafalaya Reevaluation and Morganza to the Gulf, Louisiana Feasibility Studies," dated May 1997. This source was recommended by Corps subject experts for use in NWK flood risk management economic analyses. The New Orleans report, which includes two sets of CSVRs for various business types, is probably the most methodical available attempt to develop CSVRs. One set of CSVRs was based on estimates by expert panels, while the other set was based on interviews with business owners or operators in the Baton Rouge area. The informative expert panel data from the report is limited somewhat by its use of only one prototypical business as a basis for estimating CSVRs in each broad industry category. We instead chose to use CSVRs from the New Orleans owner/operator data. These data were based on post-flood surveys conducted in the aftermath of an urban, freshwater, main stem (long duration) flood event in Louisiana - characteristics that transfer well to the Topeka context of flooding. The owner/operators interviewed represented many of the same types of businesses and facilities as are found in the Topeka structure inventory. Seven broad business categories are included: restaurants, grocers, retail and services, professional offices, repairs and home use businesses, warehouses and contractors, and public facilities. Development of the owner/ operator data for each of these categories included interviews with 10 businesses, usually representing several specific types of business within each broad category.

Additional CSVRs for churches and service stations were taken from IWR Report 96-R-12, "Analysis of Nonresidential Content Value and Depth-Damage Data for Flood Damage Reduction Studies," May 1996. This report evaluated post-flood data from the Wyoming Valley area of the Susquehanna River basin in northeastern Pennsylvania. The context of the data is again long-term, freshwater, main stem river flooding in an urbanized area, which is similar to the flooding context of the present analysis. Finally, non-residential properties for which available information was insufficient to determine an occupancy type were assigned a CSVR of 1.0. Vacant properties were assigned a CSVR of 0.05, since many vacant properties have minor contents or are used for storage; moreover, properties that are currently vacant would not necessarily remain vacant over the 50-year period of analysis. Table D-9 summarizes the CSVRs used in this analysis.

In contrast to residential valuation, values were not added to commercial and public contents as an "other" category to account for vehicles and landscaping. Each home is assumed to have vehicles, and many residents of the study area also work there. Therefore, the addition of vehicles at places of business would entail considerable double counting. Landscaping is not included since no generalized data are available relating to business structure values.

Uncertainty in contents valuation for firms we did not contact and speak to is assumed to be subject to a normal distribution and is characterized by standard deviations accompanying the CSVRs in the New Orleans data, as seen in Table D-9. To take an example using the second category listed, a grocery store with a structure value of $100,000 would have contents valued at $128,000 ($100,000 X 1.28). The data indicate a standard deviation of 0.76, which would amount to $97,280 ($128,000 X 0.76) for one standard deviation and $194,560 for two standard deviations. Consequently, the sampled contents value could range from $0 on the low end ($128,000 - $194,560 < $0; negative values would not be sampled) to $322,560 at the high end ($128,000 + $194,560).

TABLE D-9

CONTENT TO STRUCTURE VALUE RATIOS

Category	CSVR	Standard deviation
1. Eating & recreation places	3.06	1.62
2. Groceries & gas stations	1.28	0.76
3. Professional businesses	0.78	0.58
4. Repairs & home use businesses	2.51	0.86
5. Retail & personal service businesses	1.48	0.79
6. Warehouses & contractor services	3.72	1 45
7. Public & semi-public enterprises	0.82	1.39
8. Churches	0.34	0.82
9. Service stations	1 22	1.57
10. Multi-family housing	0.23	0.13
11. Mobile homes	0.64	0.38

Sources "Depth-Damage Relationships for Structures, Contents, and Vehicles and Content-to-Structure Value Ratios (CSVR) in Support of the Lower Atchafalaya Reevaluation and Morganza to the Gulf, Louisiana Feasibility Stuides," Gulf Engineers & Consultants, May 1997, prepared for New Orleans District COE (#1-7, 10), IWR Report 96-R-12, "Analysis of Nonresidential Content Value and Depth-Damage Data for Flood Damage Reduction Studies," Planning and Management Consultants Ltd , May 1996, prepared for the Institute for Water Resouces (#8-9), EM 1110-2-1619, Table 6-4 (#11)

4.4.5 Roads and Streets Valuation. Length in miles of city streets, highways, and railroad track was computed for each protected area based on GIS data provided by the city. Identification of construction costs for each segment of each street or road, along with appropriate depreciation factors, is not practical for an analysis of this nature. For this reason, the valuation of roads and streets is based on typical construction costs per mile, which are applied to the length in miles for each type of road. Typical construction costs are based on data from various sources, including several state departments of transportation, cities in the Kansas City District, railroad companies, the USACE Transportation Systems Center in Omaha, and previous Corps studies. Values for the urban railroad tracks include switching. For conversion of these replacement values per mile to depreciated replacement values, the costs were discounted by 35% as an average life-cycle rate of depreciation. The resulting depreciated replacement values per mile for various road categories are listed below:

Railroad track	$1,314,000
Highways	$2,290,000
City arterials	$2,752,000
City secondary streets	$1,502,000
City residential streets	$1,127,000
County roads	$751,000

Uncertainty in valuation of roads and streets was computed as a triangular distribution. Low and high values around the median were computed by changing assumptions for replacement cost per mile (based on the different sources listed above) and depreciation percentage. Based on these hypothetical adjustments in data, railroad values are allowed to range from 19.2% to 182.7% of the most likely value. For streets, roads and highways, the allowable range in values is from 34.6% to 182.7%.

Also included in this category is damage to rail cars sitting idle in the rail yards of South Topeka, Oakland and North Topeka. Locomotives would likely be evacuated in the event of a flood warning, but most boxcars could not be removed on short notice due to lack of sufficient locomotive power. For those boxcars stranded in the floodplain, damage would mainly consist of damage to wheel assemblies, along with more minor damage to the cars themselves. But any commodities stored on the cars would be subject to total loss, although the containers would incur little damage. Based on information obtained from railroad representatives interviewed for the Kansas Cities Seven Levees study, we assumed a cost of $80,000 per car for replacement of wheel assemblies, plus an average cost per car of $22,000 in commodities based on the types of commodities commonly routed through Topeka. We estimated that on average, at least 3,000 rail cars would be found in study area rail yards on any given day. Of these, we assumed that a flood warning would lead to the evacuation of all locomotives and 25% of boxcars. Of the remaining boxcars stranded in the area, many would be located at the BNSF shops in South Topeka, where cars are sent for repair, and most of these cars presumably would not be carrying commodities. Therefore, we assumed that only one-third of the 3,000 cars would carry commodities.

4.4.6 Agricultural Valuation. Crop damages in the analysis are expressed as a value per representative acre. A value per acre was prepared for Shawnee County using a weighted average that accounts for a number of factors. Initially, a typical crop pattern or distribution is established for river bottoms in the relevant area. Standard, widely available county and district crop data are not useful for this purpose since they reflect all farms, not just those in river bottom areas, and crop patterns and yields in river bottom areas usually differ significantly from other farms. Instead, Farm Service Agency county staff and Natural Resource Conservation Service state staffs are consulted for their estimates of local crop patterns and yields in floodplain areas. Virtually all river bottom farming in the study area involves corn and soybeans, with a very small amount of wheat and bean double-cropping in Kansas counties. Crop budgets available from state university extension offices are used to determine annual production costs per acre for each crop, including planting costs per input and harvest costs. Crop calendars for each crop are used to determine the typical monthly schedule for planting, growing and harvesting. Yields per acre for each crop are obtained from the FSA and NRCS sources. For prices per bushel, Corps economic analyses are required to use normalized prices updated each year by the U.S. Department of Agriculture for all basic crops.

These data inputs are integrated to determine on a monthly basis the extent to which each crop is in the ground, mature, and harvested. These calculations in turn determine the value per acre that can be lost to flooding at any given time during the year. Potential monthly losses for each crop are then integrated with monthly flooding probabilities to determine actual losses. Finally, the losses for each crop are combined with crop distribution data to determine the overall crop value lost per acre in a flood. The damage per acre assumed in this analysis is $149.

To determine an uncertainty factor for these values, the FSA staff consulted on local crop distribution and yields were asked to estimate yields per acre in an average year, a very good year, and a poor year. The value per acre computations that had been done using the yields per average year were repeated for the very good and poor years. These computations established a maximum and minimum value. The maximum was 14 to 16% greater than the average, while the minimum was 14 to 17% less than the average. The value uncertainty for crops is therefore expressed using a triangular distribution, with a minimum of 85% and a maximum of 116%.

4.4.7 Emergency and Disaster Relief Costs Valuation. In addition to the tangible damages to businesses, homes, and other physical property items caused by flood inundation or exposure, the costs of flooding include emergency costs and disaster relief costs. Emergency cost savings can encompass savings related to a wide range of flooding impacts, including emergency personnel costs, flood fighting costs (sandbagging, for example), avoidance costs (raising or evacuation of property), temporary food and housing, debris cleanup, and damage to infrastructure items not otherwise included in the damage analysis such as sewer lines. The city of Topeka was contacted to obtain available historical data on emergency costs incurred during previous flood events. However, no serious Kansas River events have occurred since 1951, with the result that there is a dearth of empirical data, and we were unable to obtain enough reliable data to estimate this category of impacts based on direct or first-hand data. Yet emergency flood fighting costs are a recognized and significant category of economic impacts from flooding, and accuracy is not served by their absence from the economic analysis.

As an alternative, we consulted several reports published by the Corps pertaining to the 1993

Missouri River basin flood in order to estimate typical emergency costs for a large flood in an urban setting. (The 1993 event was rated as equal to or approximating a 0.2%-chance event in most locations along the Missouri.) These reports included the 1993 Interagency Floodplain Management Review Committee Report (Galloway Report); Impacts of the Great Flood of 1993 (CELMV, May 1996); and the Flood Plain Management Assessment of the Upper Mississippi River and Lower Missouri Rivers and Tributaries (USACE, June 1995). We compared 1993 flood damage estimates for damage centers detailed in these reports with 1993 agency emergency costs as reported in these documents. Based on these data, emergency costs as a percentage of total physical flood damages ranged from a low of 12.4% to a high of 15%, with an average of 13.4% for all states impacted by the 1993 flood. In addition, we also consulted a white paper by a former HQUSACE reviewer who surveyed planning reports submitted to HQUSACE by Corps districts across the nation in recent years. This analysis found that emergency costs claimed in approved Corps reports averaged about 9% of total EAD reduced. Based on the information contained in these sources, we assumed that emergency costs are equivalent to a maximum of 9% of physical flood damages in the largest events and to smaller percentages in lesser events. Preliminary HEC-FDA runs were executed to obtain estimates of total physical damages for the 0.2%-chance event in each study reach, and these totals were entered into HEC-FDA.

Also included in the data we reviewed from prior studies were estimates of disaster relief costs. However, these costs appeared to overlap with the emergency cost estimates in the same studies, presenting a potential for double-counting damages, and we instead elected to obtain data from the Region VII FEMA office. Their data included typical costs for disaster housing assistance and grant assistance to individuals and families following recent Missouri floods, including the 1993 Missouri River flood. Relocation and reoccupation costs for non-residential occupants were not estimated and were not included in the analysis. The data indicated that residential emergency assistance averaged about $7,500 per home. We multiplied this average household amount by the estimated number of homes damaged in a 0.2%-chance flood, again using preliminary HEC-FDA runs. This total was entered into the HEC-FDA study file for each levee unit area as the maximum emergency costs that could be incurred.

4.4.8 Lost Production Valuation -- Major flood events often cause economic impacts to businesses beyond physical flood damages, including the value of production lost during the operational interruption. Most such production losses can be made up later by the affected company or by other businesses and, consequently, are local or regional impacts to the company but not to the nation's economy. But discussions with several large businesses in the study area indicated some potential for NED impacts from business interruptions. In these cases, a particular plant may be one of only a few producers of a product, and any production losses during a lengthy shutdown could not be made up elsewhere in the short term, if at all. NED losses were delineated and separated from non-NED impacts in each case based on estimates of production activity obtained from each business operator. These estimates usually were based on annual figures and were converted to losses per day for this analysis.

The financial data obtained from companies and used for this category of damages are considered very sensitive by most companies. For this reason, the data must be summarized in fairly general terms. The following breakdown indicates the industrial breakdown of the production losses included in the analysis using 2-digit NAICS (North American Industrial Classification System) codes: manufacturing (31-32), 44%; wholesale trade (42), 5%; transportation and warehousing (48-49), 14%; information (51), 6%; leisure and hospitality (71), 30%; other services (81), 1%.

4.5 DATA DEVELOPMENT - DEPTH-DAMAGE FUNCTIONS

The goal of this portion of the analysis is the production of depth-damage relationships or functions for each type of item susceptible to inundation. An item that has experienced prolonged submersion might be a total loss, or badly damaged but salvageable, or even relatively unaffected in some cases. Depth-damage functions give estimated percentages of value affected by each foot of flooding; e.g., 2 feet of inundation might be associated with damage amounting to 20% of total property value. The relationships are developed for each type of occupancy within each economic category and are usually broken down by structure and contents. Uncertainty in the depth-damage percentages must also be specified in terms of either a standard deviation or minimum and maximum values for each foot of flooding. A selection of depth-damage functions used in this analysis is presented in Table D-10 and discussed below.

4.5.1 Residential Depth-Damages. Residential damages for most homes in this analysis are based on depth-damage percentages released in Economic Guidance Memorandum 04-01, "Generic Depth-Damage Relationships for Residential Structures With Basements," dated 10 October 2003. This EGM summarized data developed by the Institute for Water Resources (IWR) using post-flood residential damage claim records provided by the Federal Emergency Management Agency (FEMA). The functions account for both structural and content damage to homes. Based as they are on post-flood damage claims data, the functions should also account for any emergency flood avoidance actions taken by residents such as evacuation or flood proofing. Of the eight residential occupancy types selected for this analysis, the IWR functions pertain to six: 1-story with and without basement, 1 1/2-story with and without basement, and 2-story with and without basement. Although the IWR functions begin as low as 8 feet below the first floor for homes with basements, all homes in this analysis have been assigned beginning damage stages of minus 2 feet. This prevents the software from beginning to read the functions until a depth of minus 2 feet is attained, and then only for homes with basements.

The other two residential occupancy types, mobile homes and apartments/multi-family housing, are not included in the IWR data. However, the IWR function for 1-story homes with no basement was chosen to compute damages for apartments without basements. For mobile homes, a depth-damage relationship from the New Orleans District data was used.

4.5.2 Commercial and Public Depth-Damages. A customized individual occupancy type for use in the risk analysis was developed for companies and facilities that provided specific information on values, elevations and damage potential in our discussions with them. Each major asset or inventory item was valued and assigned a depth-damage function with uncertainty (usually expressed as a triangular distribution with minimum and maximum values) indexed to a given elevation within the plant (usually the floor of the main building). Companies with more than one building were asked to split their overall estimates of investment into values per building and to identify types of equipment and inventory in each building. Often, Corps personnel made these determinations during on-site inspections of each building. Ultimately, a spreadsheet program was used to develop a single contents depth-damage function for the company based on a weighted average of all the individual item depth-damage functions, with each item weighted by its value as a percentage of total contents value for the company. For example, if office equipment was valued at $10,000 for a given facility, and total equipment and inventory for the facility were valued at $200,000, the depth-damage relationship for office equipment would get 5% of the weight in determining the total contents depth-damage function.

Most businesses and facilities in a large urban floodplain inventory cannot be characterized by company-specific data, and the treatment of depth-damage relationships for these businesses is similar to the contents valuation process for the same businesses described above in section 4.4.4. The New Orleans District report discussed there is also the source for many of the depth-damage functions used in this analysis and is considered relevant to the study area for the same reasons. The functions are based on a wide range of expertise, including panels made up of experienced subject experts on construction and post-flood cleanup, owner/operators of businesses, and FEMA post-flood depth-damage functions for the same region. The New Orleans owner/operator estimates used for Topeka were based on post-flood surveys conducted in the aftermath of an urban, freshwater, main stem (long duration) flooding event in Louisiana. The owner/operators interviewed represented many of the same types of businesses and facilities as those included in the Topeka structure inventory. These are the factors making the data relevant for Topeka. Depth-damage functions are included in the New Orleans District report for each of three types of non-residential structure (masonry, steel, and wood) and seven types of non-residential contents (restaurants, grocers, retail and services, professional offices, warehouses and contractors, repair and home use establishments, and public facilities). The New Orleans functions include median, maximum, and minimum values that serve as the basis for triangular damage uncertainty distributions in the risk analysis. Additional depth-damage functions for churches and service stations came from a published IWR report evaluating data from the Wyoming Valley in Pennsylvania. These depth-damage curves included only median values and had to be augmented by assumed uncertainty bounds. In cases where no generalized depth-damage function for similar businesses was available or not enough information existed concerning the nature of the business, one of three generalized functions was used based on high, medium or low damage potential (see #26-28 in Table D-10).

It will be noted that some of the functions assume that damage occurs at an elevation of zero. One reason for this is that surface flows do, in fact, damage some items. Examples include finished good inventories stored on the floor (particularly items such as food or drugs), inventories that are very sensitive to humidity even if not directly touching the water, or equipment with electrical wiring in the floor. Another reason is that depth-damage functions typically are structured in depth increments of a half-foot, if not a foot. If damage occurs with depths of only two or three inches (as it usually would), these depths would more readily round to zero than to one foot or one half foot. Damage percentages paired with an elevation of zero, therefore, might in actuality be accounting for very shallow flows of greater than zero depth.

The availability of flood avoidance measures such as evacuation, raising, or flood proofing was taken into consideration in formulating depth-damage relationships where appropriate. The company-specific information we obtained, covering key facilities throughout the study area accounting for a large portion of total investment, included discussion of avoidance measures and emergency plans that could be employed in a major flood event. However, most of the large plants or warehouses evaluated in this study would be unable to relocate more than a small portion of their massive inventories in the warning time provided, and most of the facilities would be unable to move or raise their equipment regardless of warning time. One exception is aircraft, which are assumed to be evacuated from the airport in advance of a flood event.

4.5.3 Road and Street Depth-Damages. Depth-damage functions used for roads in this analysis were formulated by obtaining typical costs per mile for minor maintenance such as regrading and resurfacing as well as for more major reconstruction to compare against the costs of new construction. In general, it is assumed that lower levels of inundation will result in relatively minor damage requiring repairs amounting to regrading and/or resurfacing, while more severe inundation levels will require much more expensive repairs that would be comparable to reconstruction. The resurfacing and reconstruction costs per mile obtained were divided by the new construction costs per mile to produce the depth-damage percentages.

4.5.4 Agricultural Depth-Damages. Based on our interviews with farmers following many previous flood events, the depth-damage function used for crop damages simply assumes that one foot of water ruins a crop. A surface flow is assumed to result in about 5% of total damage, based primarily on contamination rather than physical crop destruction.

4.5.5 Emergency Cost, Disaster Relief, and Lost Production Depth-Damages. The depth-damage functions constructed for these categories of non-physical costs were developed in conjunction with preliminary runs of the HEC-FDA program that estimated single-event damages for the 0.2%-chance event and other large events. The emergency costs function was structured so that a 0.2%-chance flood would result in damages for this category equal to about 9% of total physical damages. Percentages for smaller events were estimated as proportions of the 9% damage based on comparing typical flood depths in each event.

For the disaster relief category, we estimated total costs in the 1%, 0.4%, and 0.2%-chance events based on the estimated number of homes flooded in each event and the per home cost of $7,500. The depth-damage function was then structured so that it produced nominal damages at each flood event roughly approximate to these amounts.

For production losses during operational shutdowns, potential losses were delineated for each company and computed as average losses per day of shutdown. Hydrographs from the 1951 and 1993 floods were then used to estimate the days of operational interruptions and the resulting losses for each flood event analyzed. For example, a 1%-chance event was estimated to result in a closure of 8 days for those companies affected, while a 0.2%-chance event would be expected to result in a closure of 18 days. The damage-frequency data were paired with stages using the water surface profiles at each index point, with the result serving as a basis for a generalized depth-damage relationship for use in HEC-FDA.

TABLE D-10

SELECTED DEPTH-DAMAGE FUNCTIONS

Abbreviations: NB = no basement; WB = with basement, std dev = standard deviation

RESIDENTIAL

TYPES	DEPTH IN FEET	0	1	2	3	4	6	8	10	12	16
1 1 story no basement homes	Struc damage %	13.4	23.3	32.1	40.1	47.1	58.6	67.2	73.2	77.2	80.7
	Struc damage % std dev	2.0	1.6	1.6	1.8	1.9	2.1	2.3	2.7	3.3	4.9
	Cont damage %	8.1	13.3	17.9	22.0	25.7	31.5	35.7	38.4	39.7	40.0
	Cont damage % std dev	1.5	1.2	1.2	1.4	1.5	1.6	1.8	2.1	2.6	3.8
2 1 1/2 story no basement homes	Struc damage %	11.4	19.3	26.5	33.2	39.3	49.7	58.0	64.5	69.3	75.0
	Struc damage % std dev	2.7	2.3	2.2	2.4	2.6	2.9	3.2	3.5	3.8	5.0
	Cont damage %	6.6	11.0	15.1	18.8	22.1	27.7	32.1	35.2	37.2	38.6
	Cont damage % std dev	2.2	1.9	1.9	2.0	2.1	2.4	2.6	2.8	3.1	4.0
3 2 story no basement homes	Struc damage %	9.3	15.2	20.9	26.3	31.4	40.7	48.8	55.7	61.4	69.2
	Struc damage % std dev	3.4	3.0	2.8	2.9	3.2	3.7	4.0	4.2	4.2	5.0
	Cont damage %	5.0	8.7	12.2	15.5	18.5	23.9	28.4	32.0	34.7	37.2
	Cont damage % std dev	2.9	2.6	2.5	2.5	2.7	3.2	3.4	3.5	3.5	4.2
4 1 story with basement homes	Struc damage %	25.5	32.0	38.7	45.5	52.2	64.5	74.2	80.1	81.1	81.1
	Struc damage % std dev	0.9	1.0	1.1	1.4	1.6	2.1	2.5	2.8	2.9	2.9
	Cont damage %	16.0	18.9	21.8	24.7	27.4	32.4	36.3	38.6	39.1	39.1
	Cont damage % std dev	0.7	0.8	1.0	1.2	1.4	1.8	2.1	2.4	2.5	2.5
5 1 1/2 story with basement homes	Struc damage %	21.7	27.2	32.9	38.7	44.6	55.7	65.3	72.5	76.3	78.8
	Struc damage % std dev	1.1	1.2	1.3	1.6	1.8	2.4	2.8	3.2	4.0	7.6
	Cont damage %	14.0	16.4	18.8	21.2	23.6	28.4	32.7	36.5	39.6	45.9
	Cont damage % std dev	0.9	1.0	1.1	1.3	1.5	2.0	2.3	2.7	3.3	6.3
6 2 story with basement homes	Struc damage %	17.9	22.3	27.0	31.9	36.9	46.9	56.4	64.8	71.4	76.4
	Struc damage % std dev	1.3	1.4	1.5	1.8	2.0	2.6	3.1	3.7	5.0	12.4
	Cont damage %	11.9	13.8	15.7	17.7	19.8	24.3	29.1	34.4	40.0	52.6
	Cont damage % std dev	1.1	1.1	1.2	1.4	1.7	2.2	2.6	3.0	4.1	10.2
7 Apartments & multi-family	Struc damage %	13.4	23.3	32.1	40.1	47.1	58.6	67.2	73.2	77.2	80.7
	Struc damage % std dev	2.0	1.6	1.6	1.8	1.9	2.1	2.3	2.7	3.3	4.9
	Cont damage %	8.1	13.3	17.9	22.0	25.7	31.5	35.7	38.4	39.7	40.0
	Cont damage % std dev	1.5	1.2	1.2	1.4	1.5	1.6	1.8	2.1	2.6	3.8
8 Mobile homes	Struc damage %	9.9	44.7	45.7	96.5	96.5	96.5	96.5	96.5	96.5	96.5
	Struc damage % min	9.4	42.5	43.4	91.6	91.6	91.6	91.6	91.6	91.6	91.6
	Struc damage % max	12.9	58.1	59.4	100.0	100.0	100.0	100.0	100.0	100.0	100.0
	Cont damage %	0.0	85.0	95.0	99.0	99.0	99.0	99.0	99.0	99.0	99.0
	Cont damage % min	0.0	80.0	95.0	95.0	95.0	95.0	95.0	95.0	95.0	95.0
	Cont damage % max	0.0	95.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
9 Automobiles	Damage %	0.0	3.7	46.7	100.0	100.0	100.0	100.0	100.0	100.0	100.0
	Damage min %	0.0	2.3	44.7	100.0	100.0	100.0	100.0	100.0	100.0	100.0
	Damage max %	0.0	4.7	46.7	100.0	100.0	100.0	100.0	100.0	100.0	100.0

NON-RESIDENTIAL

TYPES	DEPTH IN FEET	0	1	2	3	4	6	8	10	12	16
10 Structure - masonry	Damage %	0.0	13.7	25.9	33.4	40.5	53.4	64.8	72.4	75.7	78.1
	Damage % min	0.0	0.0	0.0	0.0	2.0	2.0	2.0	2.0	2.0	2.0
	Damage % max	0.0	35.0	75.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
11 Structure - metal	Damage %	0.0	10.1	18.6	21.0	27.4	47.1	53.1	58.9	60.4	61.6
	Damage % min	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Damage % max	0.0	50.0	50.0	50.0	90.0	100.0	100.0	100.0	100.0	100.0
12 Structure - wood	Damage %	0.0	18.3	31.0	38.1	43.1	57.0	69.2	75.5	83.7	91.3
	Damage % min	0.0	4.0	5.0	6.0	10.0	15.0	15.0	15.0	50.0	50.0
	Damage % max	0.0	85.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
13 Contents - warehouse	Damage %	0.0	27.5	45.3	54.6	62.3	77.5	87.0	93.0	95.5	95.5
	Damage % min	0.0	0.0	20.0	25.0	25.0	55.0	55.0	55.0	55.0	55.0
	Damage % max	0.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
14 Contents - retail & services	Damage %	0.0	29.6	54.9	64.5	77.0	95.5	96.5	96.5	96.5	100.0
	Damage % min	0.0	10.0	19.0	25.0	50.0	65.0	65.0	65.0	65.0	100.0
	Damage % max	0.0	65.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
15 Contents - repair & home supply	Damage %	0.0	30.0	40.9	51.6	65.3	90.6	93.3	99.0	100.0	100.0
	Damage % min	0.0	1.0	3.0	8.0	28.0	43.0	43.0	90.0	100.0	100.0
	Damage % max	0.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

TABLE D-10 -- SELECTED DEPTH-DAMAGE RELATIONSHIPS (continued)

TYPES	DEPTH IN FEET	0	1	2	3	4	6	8	10	12	16
16 Contents - grocers	Damage %	0.0	39.0	54.0	65.9	78.5	97.0	99.5	99.5	100.0	100.0
	Damage % min	0.0	0.0	0.0	29.0	50.0	80.0	95.0	95.0	100.0	100.0
	Damage % max	0.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
17. Contents - professional offices	Damage %	0.0	31.2	52.4	65.2	72.7	82.0	85.9	89.4	91.5	97.5
	Damage % min	0.0	0.0	10.0	15.0	20.0	30.0	34.0	34.0	50.0	75.0
	Damage % max	0.0	79.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
18 Contents - public facilities	Damage %	0.0	25.1	55.0	69.0	79.0	84.5	85.0	89.7	90.2	94.0
	Damage % min	0.0	0.0	5.0	15.0	35.0	50.0	50.0	50.0	50.0	50.0
	Damage % max	0.0	92.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
19 Contents - restaurants	Damage %	0.0	26.0	54.0	67.5	83.0	95.0	98.0	99.0	100.0	100.0
	Damage % min	0.0	0.0	0.0	20.0	30.0	80.0	90.0	90.0	100.0	100.0
	Damage % max	50.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
20 Contents - service stations & auto dealers	Damage %	0.0	14.4	25.6	34.2	40.9	50.0	55.5	58.8	60.8	62.6
	Damage % min	0.0	5.0	15.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0
	Damage % max	0.0	20.0	40.0	60.0	80.0	100.0	100.0	100.0	100.0	100.0
21 Contents - churches, 1 story with basement	Damage %	8.6	31.5	47.5	58.7	66.5	75.8	80.4	82.6	83.6	84.4
	Damage % min	5.0	20.0	35.0	45.0	50.0	60.0	65.0	70.0	70.0	70.0
	Damage % max	15.0	40.0	65.0	75.0	80.0	90.0	95.0	100.0	100.0	100.0
22 Contents - churches, 2 story with basement	Damage %	6.6	44.9	64.7	75.0	80.2	84.4	85.5	85.8	85.9	85.9
	Damage % min	3.0	20.0	40.0	50.0	55.0	65.0	65.0	65.0	65.0	65.0
	Damage % max	15.0	60.0	80.0	90.0	100.0	100.0	100.0	100.0	100.0	100.0
23 Contents - churches, 1 story no basement	Damage %	0.0	25.5	43.3	55.8	64.5	74.8	79.9	82.3	83.5	84.4
	Damage % min	0.0	15.0	30.0	40.0	50.0	55.0	65.0	70.0	70.0	70.0
	Damage % max	5.0	35.0	55.0	65.0	75.0	100.0	100.0	100.0	100.0	100.0
24 Contents - churches, 2 story no basement	Damage %	0.0	41.5	63.0	74.0	79.8	84.3	85.5	85.8	85.9	85.9
	Damage % min	0.0	25.0	35.0	45.0	55.0	70.0	70.0	70.0	70.0	70.0
	Damage % max	5.0	50.0	70.0	80.0	80.0	100.0	100.0	100.0	100.0	100.0
25 Contents - motels	Damage %	8.1	13.3	17.9	22.0	25.7	31.5	35.7	38.4	40.0	40.0
	Damage % std dev	1.5	1.2	1.2	1.4	1.5	1.6	1.8	2.1	3.2	3.8
26 Contents - miscellaneous - medium damage	Damage %	1.0	10.0	20.0	30.0	40.0	60.0	80.0	100.0	100.0	100.0
	Damage % min	0.0	5.0	10.0	15.0	25.0	40.0	60.0	80.0	80.0	80.0
	Damage % max	5.0	25.0	50.0	65.0	85.0	100.0	100.0	100.0	100.0	100.0
27 Contents - miscellaneous - light damage	Damage %	0.0	3.0	7.0	11.0	15.0	23.0	25.0	25.0	25.0	25.0
	Damage % min	0.0	1.0	3.0	5.0	7.0	11.0	15.0	15.0	15.0	15.0
	Damage % max	1.0	5.0	15.0	20.0	25.0	35.0	40.0	40.0	40.0	40.0
28 Contents - miscellaneous - heavy damage	Damage %	3.0	25.0	50.0	80.0	100.0	100.0	100.0	100.0	100.0	100.0
	Damage % min	1.0	15.0	30.0	45.0	60.0	95.0	100.0	100.0	100.0	100.0
	Damage % max	5.0	35.0	65.0	95.0	100.0	100.0	100.0	100.0	100.0	100.0
29 Contents - vacancy	Damage %	4.0	26.9	42.4	52.3	58.9	66.5	70.3	72.3	73.4	74.3
	Damage % min	8.5	13.3	12.9	12.1	11.4	10.4	10.0	10.0	10.1	10.3
	Damage % max	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
30 General structure & contents	Struc dmg %	5.6	13.6	21.3	28.1	34.1	44.3	52.6	59.3	64.9	73.4
	Struc dmg % std dev	9.5	9.3	9.1	9.1	9.1	8.7	8.0	7.3	6.9	6.9
	Cont dmg %	4.0	26.9	42.4	52.3	58.9	66.5	70.3	72.3	73.4	74.3
	Cont dmg % std dev	8.5	13.3	12.9	12.1	11.4	10.4	10.0	10.0	10.1	10.3
ROADS											
31 Streets & roads	Damage %	0.6	2.0	4.0	6.0	8.0	15.0	22.5	32.5	42.5	62.5
	Damage % std dev	0.6	1.4	1.4	1.4	1.4	2.8	3.5	3.5	3.5	3.5
32 Railroad track	Damage %	1.0	3.1	7.0	10.0	15.0	22.0	26.0	30.0	34.0	42.0
	Damage % std dev	1.0	1.0	2.0	2.0	4.0	6.0	6.0	6.0	7.0	12.0
CROPS											
TYPES	**DEPTH IN FEET**	0	1	2	3	4	6	8	10	12	16
33 Crops	Damage %	5.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
	Damage % min	0.0	35.0	80.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
	Damage % max	50.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Source IWR residential functions (#1-7, 25); New Orleans District (#8-20), IWR Wyoming Valley data (#21-24); Kansas City District file data (#26-31)

4.6 COSTS OF FLOODING NOT INCLUDED IN ANALYSIS

Although the accounting of flood losses for this analysis is fairly comprehensive, certain costs of flooding are not included in this economic analysis. Usually this is because of one or a combination of the following reasons: (a) difficulty of monetizing the damages; (b) difficulty of estimating the scale of damage and relating it to specific flood events for use in a function; or (c) uncertainty that improvements in the Federal project would significantly affect the costs involved. Costs not included in the analysis include:

- Damages to some utilities - Damages to sewer systems and underground utility lines would occur in each reach, with damages likely in the millions of dollars, and cleanup costs would add to the total. But much of this damage probably would still occur in any large flood event, even with a stronger or higher levee.

- Damage to levee units - The levee units that are the subjects of this study would themselves sustain at least minor damages in large flood events, and damages easily could reach the tens of millions of dollars. But here again, much of this damage might still occur even with augmented levees.

- Traffic interruption costs - Flood-related detours result in extra vehicular operating expenses as well as the opportunity costs of lost time, and the costs can be substantial when busy routes or lengthy detours are involved. But most of these traffic interruptions would occur whenever there is a serious flood threat, even if no flooding actually occurs, so Federal project improvements probably would not prevent most of these losses

4.7 RISK ANALYSIS PREPARATION

The comprehensive structure inventory for the study area – including elevations, values, and depth-damage functions for each property – was entered into the HEC-FDA risk analysis program for damage computations. HEC-FDA refers to the Flood Damage Analysis software developed by the Hydrologic Engineering Center for use by the Corps of Engineers. The basic assumption underlying use of a risk analysis program is that the field data in flood control studies are based on imperfect knowledge and that key variables for which median or most likely values are specified could, in reality, take on a range of values above and below the specified values. The economic structure inventory is loaded into HEC-FDA and integrated with hydraulic and hydrologic data characterizing flood potential as well as geotechnical and structural data characterizing the levee units. All engineering and economic data are entered into the program in terms of median or most likely values and accompanied by appropriate uncertainty parameters specifying the range of possible values for each variable. The subsequent risk analysis simulates tens of thousands of theoretical flood events, synthetically extending the period of record to thousands of years and thereby producing results that embody uncertainties in assumptions and the dynamic interaction of variables over time. For each event, the program samples the range of possible values for each variable and determines (a) whether the flood event results in damage, and (b) how much damage occurs.

Damages are initially expressed as a stage-damage relationship; i.e., each foot of potential flooding at an index point is associated with an estimated amount of "primary damage." But the ultimate goal is expression of damages in an annualized equivalent form. The calculation of average annual damages conceptually involves a weighted average in which the primary damages for each event are multiplied by the incremental probability of that event and the product is summed. This total represents an estimate of the average damages that could be expected in any given year over the long term. The average annual damage total can then be compared on an equal basis to an annualized cost for the planned project to obtain a benefit-cost ratio.

An additional result of the risk analysis is a set of statistics characterizing project performance in terms of reliability or non-exceedance probability. The program estimates the probability that a levee unit will successfully contain certain specified flood events of interest such as the 1% chance event (i.e., the event magnitude with a 1% chance of occurring in any year).

4.7.1 Hydrologic and Hydraulic Data. Water surface profiles relating Kansas River and Soldier Creek stages to frequencies or probabilities of occurrence throughout the study area were provided for each of eight events, including the 10%, 2%, 1%, 0.5%, 0.2%, 0.133%, 0.1% and 0.4% chance events. The profiles are referenced to 2004 conditions, although it should be noted that no increases in these stages are forecasted through the period of analysis and the same profiles are used for existing, base year, and future conditions. Table D-11 displays the elevations and discharges associated with each of eight selected flood events on the Kansas River. The table also includes major historical flood events placed in the context of the current stage-discharge-frequency relationships. The data are relative to the index points of each of the Kansas River reaches and also include the official USGS gauge. Table D-12 displays similar data for Soldier Creek.

The exceedance-probability relationship for the Kansas River was evaluated using the graphical method, which involves specifying a discharge-probability relationship (including a discharge for the 0.999 probability event) for each index point along with the equivalent record length (82 years) for the stream. For Soldier Creek, the exceedance-probability relationship was based on the analytic method, which computes synthetic statistics given discharges associated with the 50%, 10% and 1% chance events along with the equivalent record length of 70 years. A stage-discharge relationship also was entered for each reach along with the associated standard deviations of 0.85 feet for Kansas River stages and 1.68 feet for Soldier Creek stages.

The risk-based economic analysis is based on each levee's lowest point. The low point for each unit is identified by developing a water surface profile that corresponds to the overtopping discharge and then comparing the water surface profile to the top of levee elevation profile to find the location at which the top of levee falls below the water surface profile. The initial overtopping elevation in each area is adjusted to the economic index point for that reach. The resulting adjusted initial overtopping elevation at the index point essentially serves as the top of levee elevation for that reach, although it will not necessarily be the same as the actual top of levee elevation at the index point.

4.7.2 Geotechnical and Structural Data. Geotechnical and structural evaluations of each levee unit were carried out, resulting in identification of the locations with the most critical deficiencies. For each unit with deficiencies, a probability of failure function was developed for each critical section or location. The functions were developed in accordance with the procedures for evaluating reliability of existing levees prescribed in Appendix E of ER 1105-2-100 as well as guidance in other geotechnical engineering regulations. Each function extends from the elevation at which probability of failure begins to the top of levee elevation at that location. Among other points specified in each function are the probable failure point (PFP), the stage associated with an 85% chance of failure, and the probable non-failure point (PNP), the stage associated with an 85% chance of non-failure. The elevations specified in the function at each location were then adjusted to the appropriate index points.

A potential problem in modeling some reaches was presented by a HEC-FDA limitation. HEC-FDA allows the specification of only one probability of failure function for each reach, yet several reaches have more than one location with geotechnical or structural concerns. This limitation in modeling was dealt with by devising combined probability of failure functions for each reach with more than one deficiency. For any elevation at the index point where x_1, x_2, and x_3 represent the probabilities of failure at each of three locations within the same reach, the combined probability of failure at each elevation is given by the formula

$$1-((1-x_1)*(1-x_2)*(1-x_3))$$

Combined probability of failure functions were entered into HEC-FDA for North Topeka and South Topeka/Oakland.

TABLE D-11

ELEVATIONS AND DISCHARGES FOR SELECTED KANSAS RIVER FLOOD EVENTS

event	event frequency	discharge (thousands of cfs)	elevations						
			USGS GAUGE (RM 83.1)		WW	AUB	N TOP	S TOP	OAK
			stage	elevation	RM 87.0	RM 86.1	RM 85.6	RM 84.8	RM 82.3
10 year	10 00%	93.6	28 6	875 3	879.2	878 1	877 4	876 8	874 6
1993 flood discharge >	2 30%	170 0	---	---	---	---	---	---	---
50 year	2 00%	173 0	34.5	881 2	886 6	885 3	884 4	883 5	880 4
1993 flood stage >	1 85%	n a	34 9	881 6	---	---	---	---	---
100 year	1.00%	217.0	37 0	883 7	889 7	888 4	887 5	886 3	882 7
1903 flood (est cfs) >	0 60%	253 0	37 7	884 4	n.a	n a	n a	n.a	n a.
250 year	0 40%	268 0	39 3	886.0	892 8	891 4	890 4	889 0	885 0
1951 flood discharge (est with full regulation) >	0 35%	288 0	40.1	---	---	---	---	---	---
1951 flood stage >	0 31%	---	40 8	887.5	---	---	---	---	---
Design discharge >	0 29%	314 0	41 2	---	---	---	---	---	---
500 year	0 20%	348 0	42 6	889.3	900.4	899.5	898 7	897 3	888 1
750 year	0 13%	387 0	44.0	890.7	901 1	900 1	899 2	897.5	889 5
1000 year	0 10%	410 0	44 8	891 5	902 6	901 5	900 6	898 9	890.3
1951 flood discharge (actual) >	0 06%	469 0	---	---	---	---	---	---	---
2500 year	0 04%	500.0	47.8	894 5	907 7	906 7	905.8	903 8	893.1

Note on historical floods The 469,000 cfs discharge was the actual discharge of the 1951 event. However, only one of today's five upstream reservoirs - and neither of the two biggest lakes - was in operation in 1951, so the historical discharge does not fit smoothly into the current regulated rating curve It is estimated that if the conditions that produced the 1951 peak occurred today with much greater upstream regulation, the discharge would instead be about 288,000 cfs Stages cannot be identified for 1951 in the context of this table since the stage-discharge relationship has changed since 1951 The same considerations apply to the 1903 event

TABLE D-12

ELEVATIONS AND DISCHARGES FOR SELECTED SOLDIER CREEK EVENTS

event	frequency	USGS GAUGE (RM 6.0)			URBAN RIGHT BANK (RM 4.2)	
		discharge (thousands of cfs)	stage	elevation	discharge (thousands of cfs)	elevation
2 year	50.00%	6.5	13.2	876.2	7.1	871.8
5 year	20.00%	11.8	18.5	881.5	12 9	877.4
10 year	10 00%	16.3	22 0	885.0	17 8	881.0
20 year	5 00%	21 5	25 1	888.1	23 4	884.0
1981 flood >	3 67%	25 0	25.9	888 9	---	---
1982 flood stage >	---	---	27.4	890 4	---	---
50 year	2.00%	29 4	28 6	891 6	32 0	887 4
1982 flood discharge >	1.86%	30.4	---	---	---	---
100 year	1 00%	36.4	31.1	894.1	39.7	890.2
200 year	0.50%	44.3	33 7	896.7	48.3	892 8
2005 flood >	0 41%	47 8	34.5	--	--	--
500 year	0.20%	56 4	40.2	903.2	61 5	897.2

4.7.3 Treatment of South Topeka and Oakland. The areas protected by the South Topeka and Oakland units are treated as a single study reach in the analysis of damages and benefits. Despite the longstanding practice in older reports of treating the two units as separate and independent, we have determined upon further inspection that they are not hydraulically independent. Overland flows from any flood event not contained by the South Topeka levee can also enter and flood the Oakland area immediately downstream. Therefore, the performance of the South Topeka levee has impacts in the Oakland area as well as the South Topeka area. Damages in Oakland can be caused by the performance of either the Oakland levee or the South Topeka levee. Any effort to allocate Oakland damage potential to the two relevant levees would face virtually insurmountable analytical complexities, including the probability of double-counting. Such issues are circumvented and the deficiencies of the levee system under existing conditions are fully accounted for by considering the Oakland and South Topeka areas as one joint reach for purposes of computing damages, benefits, and benefit-cost ratios. On the other hand, investment is shown in terms of the two separate areas, even though allocation of properties to one reach or the other is somewhat arbitrary since there is no clear physical division between the reaches, In addition, engineering performance and costs in this report are computed in terms of the two separate areas rather than the combined reach.

For the damage analysis of the Oakland area, a combined probability of failure function is used in HEC-FDA to account for the effects of all five critical sections on the Oakland and South Topeka levee units. The lowest overtopping point for the two units, adjusted to the Oakland index point, serves as the top of levee elevation. On the other hand, properties in the South Topeka area must be delineated since flooding emanating from the Oakland area cannot flow uphill and back up into the South Topeka area. South Topeka area properties are coded in the risk simulations so that they are affected only in damaging floods resulting from performance of the South Topeka unit.

4.7.4 Treatment of North Topeka. The North Topeka Kansas River unit and the main section of the Soldier Creek unit each protect essentially the same urban area of North Topeka. Separate analyses evaluate the damages attributable to each unit - i.e., the model contains no assumptions or data linking stages and discharges on Soldier Creek with corresponding data for the Kansas River. The economic structure inventory used is identical for both streams. Damages for the two units are therefore not additive. Double counting would result from any summation of North Topeka and Soldier Creek urban damages. Damage totals for the North Topeka area cited in this analysis will reflect damages attributable to the Kansas River unit unless otherwise stated.

The foregoing discussion applies only to the Soldier Creek urban subunit. The other six subunits, collectively identified in this appendix as "Soldier Creek rural," protect small rural areas, primarily on the left bank, that are distinct from the urban area and are therefore additive.

5.0 DAMAGE ANALYSIS RESULTS

Preliminarily, it should be emphasized that the damages summarized in this section are risk-based, and the results obtained in the risk analysis can appear to be at odds with nominal data that do not reflect the uncertainties involved. As an example, it might be stated that a given Kansas River unit in existing conditions would successfully contain a 1%-chance flood, inasmuch as the current top of levee elevation for that unit exceeds the nominal or most likely 1%-chance flood elevation by one foot. It might also be stated elsewhere that a 1%-chance flood event would result in damages of $5 million within that same unit. These two statements are not contradictory. Although the nominal 1%-chance flood elevation might be lower than the top of levee, a Monte Carlo-based risk analysis would produce a number of possible estimates for the 1%-chance flood event elevation. Within the risk analysis, the standard-deviation of 0.85 feet for the Kansas River stage-frequency relationship under existing conditions means that the elevation attained by a 1%-chance event could be 1.7 feet above or below the nominal 1% elevation at two standard deviations from the mean. The 1%-chance flood elevation, in other words, could assume a value anywhere within a range of about 3.4 feet. As such, although the top of levee might exceed the nominal 1%-chance flood elevation by a foot, with uncertainty thrown into the mix the risk-based 1%-chance flood elevation could reach a height that would overtop the levee by as much as 0.7 feet. The levee that is said to contain a 1%-chance event therefore would also show substantial damages for a 1%-chance event.

An additional factor distinguishing damage potential in the risk context from data based on nominal top of levee and flood event elevations is that the risk model assumes that a flood can occur from geotechnical or structural failure as well as by overtopping. Geotechnical and structural deficiencies are by far the main existing issues with units of the Topeka levee system.

5.1 KEY FLOOD EVENTS

Two flood events of particular interest in defining an area's flood damage potential are the 1% and 0.2%-chance events. Among other things, these events are particularly relevant in defining floodplains for purposes of determining flood insurance requirements. The HEC-FDA results for these events take into account the effects of existing flood protection measures, but are not annualized. The estimated damage potential of these events, as well as the 0.4%-chance event, is summarized in Table D-13. Production losses due to operational shutdowns are not included.

5.1.1 The 1%-Chance Flood. A 1%-chance flood event in the existing condition would cause catastrophic damage in Topeka. The main points are summarized below:

- Estimated total damages of $768.4 million would be expected in Topeka. North Topeka and Oakland would be the affected areas; the other units would not flood.

- A total of 5,046 homes and 571 businesses and facilities would be damaged, along with about 50 acres of crops. Average damage per home would amount to about $40,000. For businesses and facilities, damages would average about $857,000.

- North Topeka estimated damages would total $585.9 million, accounting for 76% of the total. Depths would average 5 feet and would reach depths of 20 feet in some places.

- Oakland damages would be an estimated $182.5 million. Water depths would average 1 foot and reach 13 feet.

The centrality of geotechnical and structural issues is clear from the perspective of this flood event. All levees in the study area are at least three feet higher than the 1%-chance flood elevation, and all units except Oakland are at least six feet higher. Yet two units do not contain the 1%-chance event due to their geotechnical/structural deficiencies and suffer serious flooding.

5.1.2 The 0.4%-Chance Flood. Effects of a 0.4%-chance flood event in Topeka would include the following:

- Total damages would be nearly $1.42 billion. All study reaches except Auburndale would be flooded.
- A total of 5,637 homes and 697 businesses and facilities would be damaged, along with about 740 acres of crops. Average losses per home would amount to $60,000.
- North Topeka again would suffer the worst impact with an estimated $940.5 million in damages, 66% of the total. Depths in North Topeka would average 7.5 feet and would reach 22 feet in some areas.
- Oakland damages would be an estimated $306.3 million, about 22% of the total. Depths would average 2 feet and would reach as much as 11.5 feet.
- South Topeka would account for most of the remaining damage, an estimated $137.3 million, with average depths of 2 feet and maximum depths of about 11.5 feet.
- Waterworks damages would reach an estimated $32.2 million, and the average depth would be about 3 feet. Water supply operations for the entire city of Topeka and surrounding communities would be interrupted for several days.
- Soldier Creek rural reaches would suffer about $1.9 million in damage from a 0.4%-chance flood on Soldier Creek. The urban Soldier Creek subunit also would flood in such an event, resulting in $212.6 million in estimated damages in North Topeka.

TABLE D-13

DAMAGES FOR KEY EVENTS (EXISTING CONDITIONS)

October 2008 prices, $1,000s

1% CHANCE EVENT - EXISTING CONDITIONS

UNITS	Total Damage	% of Total	Residential			Non-Residential			Crops		Streets & Roads	Disaster	Emergency	Depths (feet) **	
			Homes	Damage	Avg Dmg	Businesses	Damage	Avg Dmg	Acres	Damage	Damage	Relief	Costs	Avg	Max
WW	$0.0	0.0%	0	$0.0	$0.0	0	$0.0	$0.0	0	$0.0	$0.0	$0.0	$0.0	0.0	0.0
AUB	$0.0	0.0%	0	$0.0	$0.0	0	$0.0	$0.0	0	$0.0	$0.0	$0.0	$0.0	0.0	0.0
S TOP	$0.0	0.0%	0	$0.0	$0.0	0	$0.0	$0.0	0	$0.0	$0.0	$0.0	$0.0	0.0	0.0
OAK	$182,504.0	23.8%	2,535	$99,319.3	$39.2	69	$58,938.2	$854.2	44	$1.8	$5,693.9	$8,322.5	$10,228.4	1.0	13.0
N TOP	$585,917.4	76.2%	2,511	$105,159.9	$41.9	502	$430,328.5	$857.2	7	$1.6	$17,691.1	$5,378.8	$27,357.5	5.0	20.0
SOLD CK RURAL	$0.0	0.0%	0	$0.0	$0.0	0	$0.0	$0.0	0	$0.0	$0.0	$0.0	$0.0	0.0	0.0
SOLD CK URBAN*	$0.0	--	0	$0.0	$0.0	0	$0.0	$0.0	0	$0.0	$0.0	$0.0	$0.0	0.0	0.0
TOTAL	$768,421.4	100.0%	5,046	$204,479.2	$40.5	571	$489,266.7	$856.9	51	$3.4	$23,385.0	$13,701.3	$37,585.9		

0.4% CHANCE EVENT - EXISTING CONDITIONS

UNITS	Total Damage	% of Total	Residential			Non-Residential			Crops		Streets & Roads	Disaster	Emergency	Depths (feet) **	
			Homes	Damage	Avg Dmg	Businesses	Damage	Avg Dmg	Acres	Damage	Damage	Relief	Costs	Avg	Max
WW	$32,193.6	2.3%	0	$0.0	$0.0	1	$28,164.3	$0.0	0	$0.0	$0.0	$0.0	$4,029.3	3.0	3.0
AUB	$0.0	0.0%	0	$0.0	$0.0	0	$0.0	$0.0	0	$0.0	$0.0	$0.0	$0.0	0.0	0.0
S TOP	$137,285.5	9.7%	52	$1,233.8	$23.7	86	$119,610.3	$0.0	0	$0.0	$3,262.1	$424.1	$12,755.2	2.0	11.5
OAK	$306,335.3	21.6%	2,776	$166,708.6	$60.1	82	$98,928.5	$1,206.4	74	$3.0	$9,557.2	$13,969.4	$17,168.5	3.0	14.5
N TOP	$940,528.9	66.3%	2,748	$168,805.2	$61.4	528	$690,773.7	$1,308.3	11	$2.6	$28,398.2	$8,634.2	$43,914.9	7.5	22.0
SOLD CK RURAL	$1,868.1	0.1%	61	$1,416.4	$23.2	0	$0.0	$0.0	652	$105.1	$109.6	$107.0	$130.0	0.5	23.5
SOLD CK URBAN*	$212,613.4	--	2,745	$27,139.1	$9.9	369	$167,159.7	$0.0	11	$0.1	$2,564.0	$6,712.9	$9,037.6	8.5	23.5
TOTAL	$1,418,211.3	100.0%	5,637	$338,164.0	$60.0	697	$937,476.8	$1,345.0	737	$110.6	$41,327.2	$23,134.7	$77,997.9		

0.2% CHANCE EVENT - EXISTING CONDITIONS

UNITS	Total Damage	% of Total	Residential			Non-Residential			Crops		Streets & Roads	Disaster	Emergency	Depths (feet) **	
			Homes	Damage	Avg Dmg	Businesses	Damage	Avg Dmg	Acres	Damage	Damage	Relief	Costs	Avg	Max
WW	$54,536.5	2.8%	0	$0.0	$0.0	1	$47,657.4	$0.0	0	$0.0	$62.3	$0.0	$6,816.8	10.5	10.5
AUB	$55,088.0	2.8%	529	$34,061.4	$64.4	11	$10,800.7	$0.0	0	$0.0	$2,501.8	$3,943.9	$3,780.2	3.0	19.5
S TOP	$221,427.3	11.4%	71	$1,989.9	$28.0	115	$192,919.0	$0.0	0	$0.0	$5,261.5	$684.0	$20,572.9	5.0	16.5
OAK	$374,456.5	19.2%	2,917	$203,780.4	$69.9	88	$120,927.7	$1,374.2	90	$3.7	$11,682.5	$17,075.9	$20,986.3	5.5	17.5
N TOP	$1,231,906.9	63.2%	2,752	$221,101.5	$80.3	538	$904,777.1	$1,681.7	15	$3.4	$37,196.0	$11,309.1	$57,519.9	13.5	28.0
SOLD CK RURAL	$11,757.8	0.6%	95	$9,753.6	$102.7	1	$48.7	$0.0	700	$112.7	$256.0	$714.9	$871.8	3.5	27.0
SOLD CK URBAN*	$250,677.6	--	2,747	$31,997.8	$11.6	373	$197,086.3	$0.0	15	$0.2	$3,023.0	$7,914.7	$10,655.5	12.5	26.5
TOTAL	$1,949,173.0	100.0%	6,364	$470,686.8	$74.0	754	$1,277,130.6	$1,693.8	805	$119.8	$56,960.1	$33,727.8	$110,547.9		

* Soldier Creek urban damages are not included in total since they are for the same area as the North Topeka levee

** Depths cited refer to average and maximum depths affecting those homes and businesses in the study reach that flood in that event

5.1.3 The 0.2%-Chance Flood. A 0.2%-chance flood event would result in catastrophic damage throughout the entire study area.

- Damages would total over $1.95 billon in the study area, and all protected areas would flood.
- A total of 6,364 homes, 754 businesses and facilities, and over 800 acres of crops would be damaged. Average residential damages would be about $74,000.
- North Topeka damages would reach an estimated $1.23 billion, about 63% of the total, with depths averaging 13.5 feet and maximum depths of about 28 feet.
- Oakland's damage total of $374.5 million would comprise about 19% of total study area damages. Depths would average 5.5 feet, and depths would reach 17.5 feet in some locations.

- South Topeka damages would total an estimated $221.4 million, 11% of the total, with average depths of 5 feet and maximum depths of about 16.5 feet.

- Waterworks and Auburndale would suffer estimated damages of $54.5 million and $55 million, respectively, less than 3% of the total in each case. Depths at Waterworks would be about 10.5 feet. Auburndale depths would average about 3 feet but would be nearly 20 feet in some areas.

- A Soldier Creek flood of 0.2%-chance magnitude would result in estimated damages of $250.7 million in North Topeka and $11.8 million in the rural areas.

5.2 RESULTS BY REACH - EXISTING CONDITIONS

As computed in the HEC-FDA risk analysis model, equivalent annual damages (EAD) total $22,865,900 for the study area. The distribution of EAD among the individual protected areas is summarized in Table D-15. Table D-14 gives the benefits of the levees in their existing conditions - how much damage hypothetically would occur annually if the levees did not exist. These benefits are compared to the EAD totals in Table D-15. For example, the table indicates that North Topeka's annualized damages amount to $15.1 million in the context of that levee's currently less-than-optimal condition (see section 5.3.5 below), but would be expected to reach $25.1 million if the levee did not exist at all. D-16 summarizes the engineering performance statistics emerging from the risk analysis. Both aspects of the results are discussed below for each study reach.

In general, the analysis produces two conclusions regarding the engineering performance of the Topeka levee system:

- Hydraulically, all of the Kansas River units at Topeka are sufficiently high to offer protection against all but the most extreme events.

- However, significant geotechnical and structural concerns are compromising the performance of the three largest units - North Topeka, Oakland, and South Topeka. There also are significant but lesser concerns at Waterworks, while Auburndale and Soldier Creek have no identified problem areas.

TABLE D-14 BENEFITS OF EXISTING LEVEES			
Oct 2008 prices, 4.625% interest rate; $1,000s			
Levee Unit	**EAD without existing levees**	**EAD with existing levees**	**Benefits**
KANSAS RIVER			
Waterworks	$597.0	$211.0	$386.0
Auburndale	$515.0	$194.3	$320 7
South Topeka	$2,818 1	$1,017.8	$1,800.3
Oakland	$5,384 0	$4,852.0	$532.0
North Topeka	$25,069.1	$15,126.6	$9,942.5
Kansas River total	$34,383.2	$21,401.7	$12,981 5
SOLDIER CREEK			
Urban (North Topeka)	$22,858.4	$1,521.1	$21,337.3
Rural	$731.8	$48.7	$683.1
Soldier Creek total	$23,590.2	$1,443.6	$22,146 7
TOTAL	**$35,115.1**	**$21,450.4**	**$13,664.6**

TABLE D-15 EQUIVALENT ANNUAL DAMAGES - EXISTING CONDITIONS									
Oct 2008 prices, 4 625% interest rate; $1,000s									
Levee Unit	**Non-Residential**	**Residential**	**Roads**	**Ag**	**Emergency**	**Disaster Relief**	**Lost Production**	**Total**	**% of Total**
KANSAS RIVER									
WATERWORKS	$193 1	$0.0	$0 3	$0.0	$28 5	$0 0	$0 0	$221 8	1 0%
AUBURNDALE	$39 9	$125 7	$9 2	$0 0	$14 2	$14.7	$0 0	$203 7	0.9%
SOUTH TOPEKA/OAKLAND	$2,579 6	$2,786.3	$184 6	$0 1	$506 8	$247 3	$52 9	$6,357 6	27 8%
NORTH TOPEKA	$11,694 8	$2,857 8	$480 8	$0 1	$737.0	$149.3	$111 9	$16,031 7	70.1%
TOTAL KANSAS RIVER	$14,507 3	$5,769 8	$674 9	$0 1	$1,286 5	$411 3	$164 9	$22,814 8	99 8%
SOLDIER CREEK									
Urban (North Topeka)	$1,258 4	$202 2	$19 3	$0 0	$324 5	$55 3	$12 3	$1,872 0	
Rural	$0.2	$42 3	$1.3	$0 9	$3 6	$2 9	$0 0	$51 1	0 2%
TOTAL SOLDIER CREEK	$1,258 6	$244 5	$20 6	$0 9	$328 0	$58 2	$12 3	$1,923 1	
TOTAL	**$14,507.5**	**$5,812.1**	**$676.1**	**$1.0**	**$1,290.1**	**$414.3**	**$164.9**	**$22,865.9**	100 0%

Soldier Creek urban damages are for the same area covered by the North Topeka unit and are not counted in the study area total

Oakland totals reflect combined probabilities of failure for both Oakland and South Topeka The Oakland totals represent all damage that would occur in Oakland without regard to the source of the flooding, which can be either the Oakland unit or the South Topeka unit South Topeka totals include only damage occurring in South Topeka and do not include damages in Oakland attributable to the South Topeka unit

TABLE D-16

ENGINEERING PERFORMANCE - EXISTING CONDITIONS

	WW	AUB	S TOP	OAK	N TOP	SOLD CRK URBAN
ANNUAL EXCEEDANCE PROBABILITY (median)	0.003	0.003	0.004	0.057	0.024	0.006
Return interval (years)	333	333	250	18	42	167
LONG-TERM RISK (chance of exceedance during indicated period)						
over 10 years	1 in 25	1 in 32	1 in 23	1 in 2	1 in 4	1 in 13
over 25 years	1 in 10	1 in 13	1 in 9	1 in 1.3	1 in 2	1 in 5
over 50 years	1 in 5	1 in 7	1 in 5	1 in 1	1 in 1.4	1 in 3
PERFORMANCE VS. 1% FLOOD						
Initial overtopping elevation margin (feet) over nominal 1% flood elevation	5.9	8.2	6.5	3.7	6.6	1.7
Conditional exceedance probabilty - overtopping or failure	0.072	0.032	0.158	0.971	0.860	0.332
Conditional exceedance probabilty - overtopping only	0.067	0.032	0.054	0.058	0.054	0.332
OTHER FLOOD EVENTS - EXCEEDANCE						
10.0%	0.000	0.000	0.000	0.165	0.004	0.000
4.0%	0.000	0.000	0.003	0.589	0.180	0.002
2.0%	0.003	0.032	0.031	0.857	0.554	0.094
0.4%	0.331	0.213	0.436	0.995	0.970	0.661
0.2%	0.758	0.644	0.806	1.000	0.998	0.817

Annual exceedance probability is the chance of experiencing any flood event - of whatever magnitude - within any year.
Conditional exceedance probability is the probability that a specified flood event would overtop or breach the levee

5.2.1 Waterworks Unit

5.2.1.1 Waterworks Economic Performance Without Project. Equivalent annual damages total $221,800 for Waterworks, about 1% of the total study area EAD. Over 99% of this total is accounted for by the water plant, while roads account for a tiny percentage. The risk-based outputs from the model show that a 0.4%-chance event would be required to cause damage (whether overtopping or failure) in Waterworks.

5.2.1.2 Waterworks Engineering Performance Without Project. At the economic index point, RM 87.0, the adjusted top of levee elevation of 895.6 exceeds the nominal 1%-chance event elevation of 889.7 by 5.9 feet. There is an overtopping exceedance probability of 0.045 in a 1%-chance flood, and this would be the overall 1%-chance event exceedance probability for the levee if there were no were no geotechnical or structural issues. The median annual exceedance probability is 0.003; this is the percentage chance in any year that a flood event will occur that is of a large enough magnitude to result in economic damages.

But even in the context of geotechnical and structural deficiencies, the overall exceedance probability for Waterworks in the context of any 1%-chance event is 0.07. The levee's only significant deficiency is a floodwall sliding threat at about RM 87.3. This threat occurs only in large flood events when water approaches the top of the floodwall. At this location, the PNP (probable non-failure point) at which there is an 85% chance of nonexceedance is 2.4 feet below the top of levee, and probability of failure reaches 89.6% at the top of the wall. However, the levee would overtop at its lowest point before water reaches the top of levee at the location of the floodwall concern. Probability of failure reaches only 27.6% at the initial overtopping elevation. Table D-17 summarizes the probability of failure function used in the HEC-FDA analysis for the Waterworks unit.

TABLE D-17 WATERWORKS UNIT PROBABILITY OF FAILURE FUNCTION - EXISTING CONDITIONS			
p(F) = probability of failure, WSE = water surface elevation; TOL = top of levee			
FLOODWALL SLIDING THREAT			
sta. 0+78 to 7+00 & 10+00 to 16+50			
Kansas River mile 87.3			
WSE @ index point RM 87.0		p(F)	key elevations
900 4			
897.5	0.0	0.8960	TOL
895.6	1.9	0.2763	Initial overtopping point at index point
895.1	2 4	0.1500	PNP
893.9	3 6	0 0000	
892.8	4.7		0.5% chance (200 year) flood
889 7	7.8		1% chance (100 year) flood
886.6	10 9		2% chance (50 year) flood

5.2.2 Auburndale Unit

5.2.2.1 Auburndale Economic Performance Without Project. Equivalent annual damages in Auburndale total $203,700, which is less than 1% of the total study area EAD. About 62% of this total is residential damages and 20% is business and public facilities. The remaining 20% is roads and streets, disaster relief and emergency costs. As with the Waterworks unit immediately upstream, a flood event of greater than a 0.004 magnitude is required to result in economic damage in Auburndale.

5.2.2.2 Auburndale Engineering Performance Without Project. The Auburndale top of levee elevation of 896.6 exceeds the 1%-chance event elevation of 888.4 by 8.2 feet at the index point (RM 82.1). This levee unit has no significant geotechnical or structural deficiencies, so the PFP would be equal to the top of levee as specified in Corps guidance. The overall nonexceedance probability is the same as the overtopping nonexceedance probability. The Auburndale unit has an exceedance probability of 0.032 in a 1%-chance flood event. The median annual exceedance probability is 0.003.

5.2.3 South Topeka/Oakland Unit

5.2.3.1 South Topeka/Oakland Economic Performance Without Project. The total equivalent annual damages for the combined South Topeka and Oakland reach are $6,357,600. This is 27.8% of the total EAD for the study area. Businesses and public facilities account for $2,579,600, or 41% of total EAD, and residential properties and streets account for $2,786,300, or 44%. Streets and roads account for 3%, and non-physical costs account for the remaining 12%. A relatively small flood event of approximately a 5%-chance magnitude would result in economic damages at Oakland, according to the HEC-FDA results, although damages in the South Topeka area would occur only in events exceeding the 0.075%-chance event.

5.2.3.2 South Topeka/Oakland Engineering Performance Without Project. Identified deficiencies in the combined reach include three sections along the South Topeka levee and two on the Oakland levee. The first South Topeka section, near RM 84.4, has been identified as a potential underseepage problem area. The PFP (probable failure point), at which probability of failure reaches 85%, occurs at this site only 0.2 feet below top of levee, although the levee would overtop elsewhere before this elevation is reached by water. But the PNP (probable non-failure point) at which the probability of failure reaches 15%, is 8.8 feet below the top of levee at that location. The second South Topeka section is near the downstream end of the unit at RM 83.9 and involves a critical floodwall foundational weakness. This deficiency raises the possibility of a very dangerous floodwall blow-out in large flood events. Probability of failure at top of levee reaches only 44.7%, so the PFP essentially occurs at or just below top of levee, but the PNP at this site is 4.9 feet below adjusted top of levee. Also in the same area is the third critical South Topeka site at the Kansas Avenue pumping plant, where there is a strength deficiency issue. The probability of failure at this site reaches 31% at top of levee, and the PNP is located 4.1 feet below top of levee. The pump station section is less critical to the combined probability of failure section for the levee than the floodwall and underseepage problem areas.

Table D-18 and Figure D-2 summarize the probability of failure functions for South Topeka. Figure 2 is a bar chart showing the three individual probability of failure functions and the combined function for the reach. Each function is portrayed as a bar with a clear section from the ground up to the PNP elevation, a hatched area between the PNP and the PFP, and a blacked-out area above the PFP. The chart is not to scale and is not a substitute for the numerical functions detailed in Table D-18, but it is intended to complement the rather complex functions with a starker view of the unit's geotechnical/structural deficiencies in terms of the positioning of key reference points (PFP and PNP) relative to top of levee and ground elevations. The combined PNP of -8.9 feet indicates that a significant probability of failure begins well before water approaches the top of the South Topeka levee.

(Note that the PFPs and PNPs in Figure D-2 appear to differ from those in Table D-18. For example, the PNP for the floodwall at site 2, is shown as -1.1 feet in the table and as -3.3 feet in the figure. The difference is explained by different reference points. Figure 2 portrays the PNP relative to the top of levee at that location, while Table D-18 adjusts the elevations at the three sites to a common index point for the reach and uses the lowest overtopping point in the reach, adjusted to the index point, as the top of levee elevation. This adjusted initial overtopping elevation generally will not be the same as the top of levee elevation at most locations along the levee. The key elevations need to be understood in both contexts to fully understand the problem, and sections 5.2.4 and 5.2.5 below also will present the critical points in both contexts.)

Hydraulically, the South Topeka levee's overtopping elevation exceeds the 1%-chance event elevation of 886.3 by 6.5 feet at the index point. The levee would have an exceedance probability in overtopping 1%-chance events of 0.054. But the overall exceedance probability from either overtopping or failure in a 1%-chance flood is 0.158. The median annual exceedance probability is 0.004.

The Oakland levee has two critical sections with deficiencies. The first, at RM 82.3, is a potential underseepage location. The PFP and PNP at this location are 7.3 and 12.9 feet below top of levee. The second Oakland section is the East Oakland pump station, several miles downstream at RM 77.3, where the potential for uplift has resulted in a PFP and PNP of 10.7 and 11.4 feet below top of levee. The individual and combined probability of failure functions are summarized in Table 19 and Figure 3, which show significant probabilities of failure at both locations long before water reaches the top of the levee. The combined PFP and PNP for the levee occurs 11.4 and 16.6 feet below top of levee.

The Oakland levee's initial overtopping elevation at the index point of RM 82.3 is 886.4, which is 3.7 feet above the 1%-chance event elevation. If all 1%-chance events were overtopping events, Oakland's exceedance probability would be 0.057. But in the context of all possible 1%-chance events, the exceedance probability is 0.971. Even when the frame of reference is switched to smaller events, the levee has an exceedance probability of 0.857 in a 2%-chance event and 0.589 in a 4%-chance event.

TABLE D-18 SOUTH TOPEKA UNIT PROBABILITY OF FAILURE FUNCTIONS - EXISTING CONDITIONS						
WSE ** @ index point	p(F) site 1 UNDERSEEPAGE	p(F) site 2 FLOODWALL FOUNDATION WEAKNESS	p(F) site 3 KANSAS AVENUE PUMP STATION	p(F) combined	key elevations (adjusted to index point)	
	sta. 22+00 to 48+00	sta. 74+41 to 93+86	sta. 75+84			
RM 84.8	RM 84.4	RM 84.0	RM 83.9			
897.3					4.6	0.2% chance (500 year) event
896.5	0.8569	0.4467	0.3100	0.9454	3.7	TOL underseepage site
896.3	0.8500	0.4467	0.3100	0.9427	3.5	PFP underseepage site
895.5	0.7785	0.4467	0.3100	0.9154	2.7	TOL pump station site
894.9	0.7348	0.4467	0.2840	0.8949	2.2	TOL floodwall site
894.8	0.7238	0.4344	0.2775	0.8872	2.0	
894.3				0.8500	1.6	approximate combined PFP
893.3	0.5827	0.2880	0.2000	0.7623	0.5	
892.8	0.5370	0.2460	0.1755	0.7122	**0.0**	**Initial overtopping***
892.5	0.5079	0.2195	0.1600	0.6774	-0.3	
892.4	0.5033	0.2152	0.1500	0.6692	-0.4	PNP pump station
891.6	0.4321	0.1500	0.0236	0.5287	-1.1	PNP floodwall site
889.9	0.3048	0.0498	0.0000	0.3394	-2.9	
889.0					-3.8	0.5% chance (200 year) event
887.7	0.1500	0.0065	0.0000	0.1555	-5.1	PNP underseepage site; approximate combined PNP
886.3					-6.5	1% chance (100 year) event
883.5					-9.3	2% chance (50 year) event
883.4	0.0009	0.0000	0.0000	0.0009	-9.4	
881.3	0.0000	0.0000	0.0000	0.0000	-11.5	

* Initial overtopping point is the lowest point on the top of levee profile within the reach, adjusted to the index point. It is not necessarily located at any of the sites listed.

** p(F) = probability of failure; WSE = water surface elevation; TOL = top of levee; PFP = probable failure point (elevation at which there is an 85% chance of failure); PNP = probable non-failure point (elevation at which there is an 85% chance of non-failure)

Figure D-2 - South Topeka Existing Condition Probability of Failure Functions

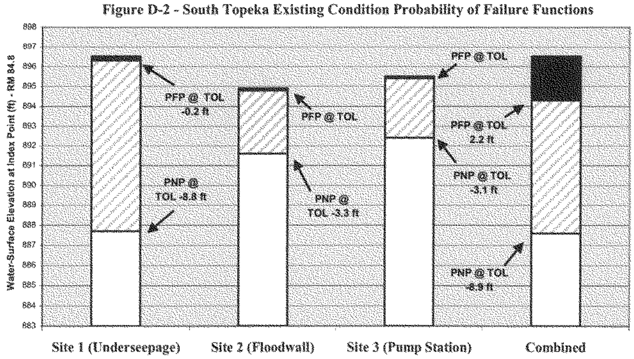


TABLE D-19

OAKLAND UNIT

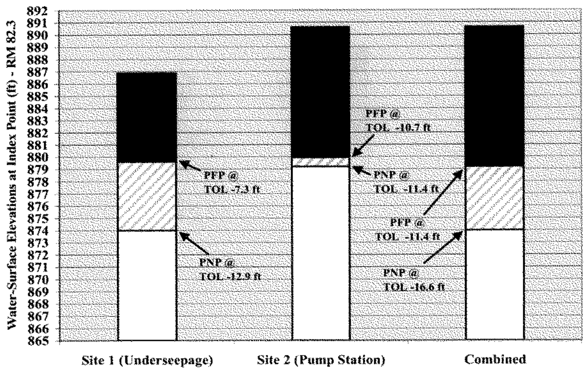
PROBABILITY OF FAILURE FUNCTIONS - EXISTING CONDITIONS

WSE @ index point RM 82.3	p(F) site 1 UNDERSEEPAGE	p(F) site 2 EAST OAKLAND PUMP STATION UPLIFT	p(F) combined	key elevations (adjusted to index point)	
	sta. 64+00 to 88+00	sta. 228+00			
	RM 82.3	RM 77.3			
890.6	1.0000	1.0000	1.0000	4.2	TOL East Oakland pump station
888.1				1.7	0.2% chance (500 year) event
887.6	1.0000	1.0000	1.0000	1.2	
886.9	1.0000	1.0000	1.0000	0.4	TOL underseepage site
886.4	1.0000	1.0000	1.0000	**0.0**	**initial overtopping point**
885.0				-1.4	0.5% chance (200 year) event
882.7	0.9999	1.0000	1.0000	-3.7	1% chance (100 year) event
881.5	0.9882	1.0000	1.0000	-5.0	
880.7	0.9813	0.9886	0.9998	-5.7	
880.4				-6.1	2% chance (50 year) event
880.0	0.8854	0.8500	0.9828	-6.5	PFP East Oakland pump station
879.6	0.8500	0.5513	0.9327	-6.8	PFP underseepage site
879.3			0.8500	-7.2	approximate combined PFP
879.2	0.8007	0.1500	0.8306	-7.2	PNP East Oakland pump station
878.7	0.7479	0.0000	0.7479	-7.7	
875.8	0.2639	0.0000	0.2639	-10.7	
874.0	0.1500	0.0000	0.1500	-12.4	PNP underseepage site / approximate combined PFP
871.8	0.0065	0.0000	0.0065	-14.7	
871.5	0.0000	0.0000	0.0000	-14.9	

*** Initial overtopping point is the lowest point on the top of levee profile within the reach, adjusted to the index point It is not necessarily located at any of the sites listed**

**** p(F) = probability of failure; WSE = water surface elevation; TOL = top of levee; PFP = probable failure point (elevation at which there is an 85% chance of failure); PNP = probable non-failure point (elevation at which there is an 85% chance of non-failure)**

Figure D-3 - Oakland Existing Condition Probability of Failure Functions



5.2.5 North Topeka Unit

5.2.5.1 North Topeka Economic Performance Without Project. North Topeka equivalent annual damages are an estimated $16,031,700, accounting for 70.5% of the total study area EAD. Businesses and facilities account for 73% of EAD, while residential comprises 18% and roads 3%. The remaining 6% comes from crop acreage and non-physical costs. A moderate flood event of about 2.5%-chance magnitude would cause damages at North Topeka.

5.2.5.2 North Topeka Engineering Performance Without Project. North Topeka has three sites with significant deficiencies. The probability of failure functions for the three sites and the combined function for the reach are summarized in Table D-20 and Figure D-4. Site 1 is a levee section with underseepage potential at RM 86.9 near the North Topeka treatment plant. The probability of failure function at this site includes a PFP that is 7.1 feet below the top of levee, and the PNP is 13.9 feet below top of levee. Site 2 is an additional underseepage threat near Buchanan Street at RM 85.6. Here, the PFP and PNP are 5.8 and 10.6 feet below top of levee. Site 3 is the Fairchild pump station at RM 83.1, where there are potential uplift issues. The PFP and PNP here are 7.1 and 7.8 feet below top of levee.

The 1%-chance flood elevation of 887.5 at the index point, RM 85.6, is 6.6 feet below the initial overtopping elevation of 894.1. As with other Kansas River units in the Topeka system, the height of the North Topeka levee is more than adequate in preventing 1%-chance overtopping floods, and the exceedance probability in such events is 0.054. But geotechnical and structural issues increase the overall exceedance probability in a 1%-chance event to 0.86. Exceedance probability in a smaller 2%-chance event would be 0.554. The median annual exceedance probability is 0.024.

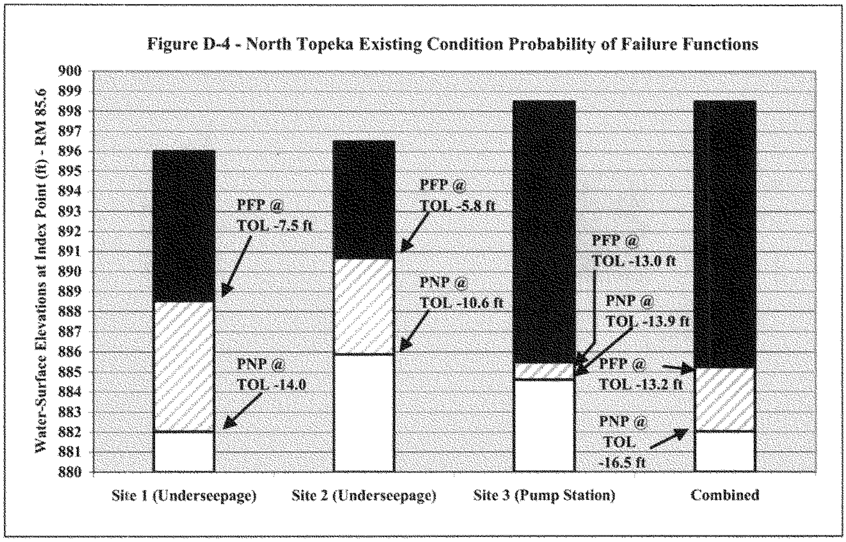


Figure D-4 - North Topeka Existing Condition Probability of Failure Functions
Water-Surface Elevations at Index Point (ft) - RM 85.6
900
899
898
897
896
895
894
893
892
891
890
889
888
887
886
885
884
883
882
881
880
PFP @
TOL -7.5 ft
PNP @
TOL -14.0
PFP @
TOL -5.8 ft
PNP @
TOL -10.6 ft
PFP @
TOL -13.0 ft
PNP @
TOL -13.9 ft
PFP @
TOL -13.2 ft
PNP @
TOL
-16.5 ft
Site 1 (Underseepage)
Site 2 (Underseepage)
Site 3 (Pump Station)
Combined

TABLE D-20
NORTH TOPEKA UNIT
PROBABILITY OF FAILURE FUNCTIONS - EXISTING CONDITIONS

WSE @ index point RM 85.6	p(F) site 1	p(F) site 2	p(F) site 3	p(F) combined	key elevations (adjusted to index point)	
	UNDERSEEPAGE	UNDERSEEPAGE	FAIRCHILD PUMP STATION			
	sta. 165+00 to 189+00	sta. 246+00 to 250+00	sta. 364+40			
	RM 86.9	RM 85.6	RM 83.1			
898.7						0.2% chance (500 year) event
898.5	0.9919	0.9952	1.0000	1.0000	4.4	TOL Fairchild pump station
896.5	0.9919	0.9952	1.0000	1.0000	2.4	TOL underseepage site 2
896.0	0.9919	0.9952	1.0000	1.0000	1.9	TOL underseepage site 1
895.5	0.9886	0.9893	1.0000	1.0000	1.4	
894.1	0.9795	0.9726	1.0000	1.0000	**0.0**	**Initial overtopping point**
893.0	0.9724	0.9597	1.0000	1.0000	-1.1	
891.0	0.9407	0.8787	1.0000	1.0000	-3.1	
890.7	0.9355	0.8500	1.0000	1.0000	-3.4	Underseepage site 2 PFP
890.5	0.9327	0.8328	1.0000	1.0000	-3.6	
890.4					-3.7	0.5% chance (200 year) event
888.6	0.8506	0.5855	1.0000	1.0000	-5.5	
888.5	0.8500	0.5779	1.0000	1.0000	-5.6	Underseepage site 1 PFP
887.5					-6.6	1% chance (100 year) event
886.9	0.7235	0.2752	1.0000	1.0000	-7.2	
885.9	0.6118	0.1500	0.9835	0.9946	-8.2	Underseepage site 2 PNP
885.5	0.5650	0.1009	0.8500	0.9413	-8.6	Fairchild pump station PFP
885.3				0.8500	-8.8	approximate combined PFP
885.0	0.5089	0.0419	0.4682	0.7497	-9.1	
884.6	0.4588	0.0336	0.1500	0.5554	-9.5	Fairchild pump station PNP
884.4	0.4319	0.0294	0.0000	0.4486	-9.7	2% chance (50 year) event
882.0	0.1500	0.0000	0.0000	0.1500	-12.1	Underseepage site 1 PNP / approximate combined PNP
877.1	0.0000	0.0000	0.0000	0.0000	-17.0	

* Initial overtopping point is the lowest point on the top of levee profile within the reach, adjusted to the index point. It is not necessarily located at any of the sites listed

** p(F) = probability of failure, WSE = water surface elevation, TOL = top of levee, PFP = probable failure point (elevation at which there is an 85% chance of failure), PNP = probable non-failure point (elevation at which there is an 85% chance of non-failure)

5.2.6 Soldier Creek Unit Performance

5.2.6.1 Soldier Creek Economic Performance Without Project. The Soldier Creek Unit's urban North Topeka subunit is charged with equivalent annual damages of $1,872,000. This total is not included in the overall study area total because the same area is the basis for the North Topeka unit's totals. Approximately 78% of the EAD is non-residential and 18% is residential, while roads make up 3% of the total. Floods of a magnitude of at least 0.075%-chance (133- year) are required to produce economic damages from Soldier Creek in North Topeka.

The rural reaches of Soldier Creek account for $51,100 in EAD. Of this total, 82% is residential, and the remainder is streets, crops, emergency costs and disaster relief costs. A flood of at least

0.075%-chance scale is also required to produce flood damage in these rural reaches.

5.2.6.2 Soldier Creek Engineering Performance Without Project. The Soldier Creek Unit's urban North Topeka subunit has an initial overtopping elevation of 892.0 at the index point of RM 4.4. This is higher than the 1%-chance flood elevation of 890.8 at the same location by 1.7 feet. The urban subunit's exceedance probability in a 1%-chance flood is 0.332, and the rural subunits have similar exceedance probabilities in the 1%-chance event. The median annual exceedance probability for the urban subunit is 0.006, while the rural subunits have individual annual exceedance probabilities ranging from 0.001 to 0.007. The exceedance probabilities are based solely on hydraulics, as there are no significant structural or geotechnical concerns related to this unit.

5.3. FUTURE WITHOUT-PROJECT CONDITION - SUMMARY OF EVALUATION ACCOUNTS

Continuing neglect of the deficiencies in the Topeka levee system eventually would result in catastrophic flood losses affecting large urban neighborhoods and industrial areas, as can be seen from the summary in Table D-21. There is at least a 1 in 2 chance that the two largest units, Oakland and North Topeka, will experience at least one flood in the next 25 years. A "no action" condition would have negative impacts on the national economic development (NED), regional economic development (RED), and other social effects (OSE) accounts, as discussed below.

5.3.1 NED Effects of No Action. Losses to national economic output can be quantified to a considerable extent by reference to the equivalent annual damages (EAD) estimated for this study. EAD is the average damage expected annually over the long term if existing conditions are maintained - i.e., if the levee system remains in its current condition. EAD totals an estimated $22.87 million in the study area. This is an average annual total; little or no damage might occur in some years, while other years would bring flood events causing as much as $2 billion in damages. Listed below are several aspects of these losses.

- **Residential** - Many residents in the study area would sustain heavy personal losses from flooding. A 0.2%-chance flood would be expected to damage more than 6,300 homes in Topeka. Even a smaller 1%-chance flood would damage more than 5,000 homes.

- **Businesses** - Many businesses and public facilities, large and small, would be seriously damaged by flooding and possibly driven out of business. A 0.2%-chance flood could damage more than 750 businesses in the city, and a smaller 1%-chance flood could damage nearly 600 businesses. Production losses at some study area companies probably could not be made up by other companies or other branches of the same company, at least not quickly enough to meet consumer needs.

- **Public sector** - Public sector losses would be catastrophic: (a) sewage treatment facilities in the North Topeka and Oakland areas would be subject to relatively frequent damage and their operations would be interrupted periodically; (b) the Waterworks plant supplying the city's water also would face marginally greater periodic damage to its facilities; (c) highways and streets would require very costly repairs. (d) police and fire-fighting services employed in flood fights, along with other emergency personnel and their equipment and temporary offices, would cost the city millions of dollars in significant floods; (e) relocation and reoccupation assistance would be required for thousands of residents at an average of $7,500 per home.

Additional effects that are likely NED losses, but are not included in the EAD cited above because they were not calculated for this study (see section 4.6), include the following:

- **Water supply** - The Topeka region's water supply plant behind the Waterworks levee unit would suffer periodic operational interruptions or damage, affecting water supply delivery to 160,000 people and likely resulting in net income losses due to the need to implement alternative water supply arrangements.

- **Traffic interruptions** - Periodic closures during flooding (threatened flooding as well as actual) would interrupt traffic and commerce along key transportation arteries such as U.S. Highways 24 and 75, Kansas Route 4, and the two railroad lines in the area. Lengthy closures could lead to long detours and time-consuming delays on these routes.

5.3.2 RED Effects of No Action. Regional economic development considerations are factors affecting the Topeka regional economy while not necessarily affecting national economic outputs. Several such effects in this study would be in connection with the danger that one or more Federal levee units in the Topeka system could be decertified. This action would loom large in the area's business climate. RED effects resulting from this and other factors would include the following:

TABLE D-21
FUTURE WITHOUT-PROJECT CONDITION SUMMARY

	Equiv annual damages	Expected damages in 1%-chance flood	Expected damages in 0 2%-chance flood	Affected population	Affected homes	Affected businesses and facilities	Annual exceedance probability	1%-chance event nonexceedance probability	Chance of failure or overtopping over 25 years
Waterworks	$221.8	$0.0	$54,536.5	0	0	1	0.003	0.928	1 in 10
Auburndale	$203 7	$0 0	$55,088 0	1,468	616	18	0 003	0.968	1 in 13
South Topeka/ Oakland	$6,357 6	$182,504.0	$595,883.8	7,241	3,022	231			
South Topeka							0 004	0 842	1 in 9
Oakland							0 057	0 029	1 in 1 3
North Topeka	$16,031 7	$585,917 4	$1,231,906 9	6,725	2,752	539	0 024	0.141	1 in 2
Soldier Creek									
Urban	$1,872.0	$0 0	$250,677 6	(6,725)	(2,752)	(539)	0 006	0 669	1 in 5
Rural	$51 1	$0 0	$11,757 8	664	97	1	0 005	0 162	1 in 6
Total	$22,865 9	$768,421 4	$1,949,173 0	16,098	6,487	790			

Soldier Creek urban damages are not included in overall total because North Topeka damages covering the same area are included

- **Residential flood insurance premium costs** *(probable adverse income impact)* - Residents would face onerous new flood insurance requirements in the event of levee decertification.

- **Threats to existing local/regional businesses** *(probable adverse income and jobs impacts)* - Topeka businesses in and around the study area would be threatened by multiple factors related to flood risk, including (a) catastrophic periodic flood damage; (b) frequent business closures or scalebacks; (c) employee safety during flood events; (d) the cost of new flood insurance requirements in the event of levee decertification; (e) stiffer building codes, also in the event of levee decertification, that would work against firms needing to expand in the floodplain. Large employers in the study area such as BNSF Railroad, Goodyear, Hallmark, Del Monte, Hill's and others could decide to relocate from the city and region. Particularly affected would be manufacturing jobs which are declining nationally but have been a strong part of the Topeka jobs base, and which are concentrated in floodplain locations.

- **Threats to economic development prospects** *(probable adverse income and jobs impacts)* - The same considerations listed just above would affect existing jobs in the city also would discourage new development and growth in the form of businesses migrating into the city or region or the development of new areas. Large companies considering moving into the study area, bringing job concentrations with them, probably would not do so in a flood-prone area with a decertified levee and the attendant regulatory environment. In addition, many of the city's most attractive developable parcels are located in Oakland and North Topeka, which are the two units with by far the highest flood risk. Land uses would in many cases be downgraded from higher valued commercial and residential uses to greenways and possibly agriculture, resulting in income losses.

- **Threats to riverfront redevelopment** *(possible adverse income impacts)* - Topeka's emerging strategy to rehabilitate and revive its riverfront, which has resulted in the recent redevelopment of the old Union Pacific depot in North Topeka and is likely to spawn hiking and biking trails and other amenities in the future, could be stymied by periodic flood damage, resulting in impacts to recreation and tourism revenues.

5.3.3 Other Social Effects of No Action

- **Public safety** *(probable adverse impacts on human life)* - The chance of a major flood in the next 10 years is 1 in 4 in North Topeka and 1 in 2 in Oakland. At risk are more than 13,700 residents and more than 5,700 homes in these two areas, in addition to daytime populations of workers in the thousands in North Topeka. Warning times would be expected to be relatively short, since the overwhelmingly likely failure mode would be structural or geotechnical failure rather than overtopping. Danger would take the form of drownings, electrocution, and illness from exposure to contaminated flood waters. South Topeka is also a potential concern; although the chance of failure is only 1 in 23 over the next 10 years, any failure that did occur due to rupture of the floodwall would leave very little chance for residents and workers to escape inundation.

- **Low income residents suffer greatest flood risk** *(probable adverse socioeconomic impacts)* - The South Topeka, Oakland, and North Topeka neighborhoods collectively had a 2000 poverty rate of 18.4%. This rate was 48% greater than the Topeka city and national rates of 12.4% and was 92% greater than the Shawnee County rate of 9.6%. In some portions of these areas, poverty rates exceeded 40%. The 2000 unemployment rate of 8.1% in these three areas was 69% greater than the city rate, 93% greater than the Kansas rate, and 103% greater than the county rate, and some block groups reached rates as high as 19%. Per capita income for these areas in 2000 was $14,403, which was only three-quarters of the Topeka per capita income, about seven-tenths of Shawnee County, and two-thirds of the national figure. (See sections 2.1.2, 2.4.2, 2.5.2, and 2.6.2 as well as Table D-4.)

- **Minority residents suffer greater flood risk** *(probable adverse socioeconomic impacts)* - Hispanics account for 20.4% of South Topeka's population and 27.1% of Oakland's residents. These percentages are approximately twice the national percentage of 12.5%, two to three times the Topeka percentage of 8.9%, and three to four times the state percentage of 7.0%. In about half of the Oakland and South Topeka block groups, Hispanics account for more than 25% of the population, and a few areas have majority Hispanic populations. (Again, see sections 2.1.2, 2.4.2, and 2.5.2 as well as Table D-4.)

- **Threats to center city redevelopment** *(probable adverse cultural impacts)* - Topeka's long-term efforts to maintain and rebuild center city areas would be dealt a crippling blow. The floodplain areas of North Topeka, Oakland and South Topeka comprise a substantial portion of the center city. Population losses from the center city would occur as residents flee the likelihood of flood damage and react to the shrinkage in area job opportunities. High vacancy rates would characterize commercial properties and the housing stock.

- **Threats to riverfront redevelopment** *(possible adverse cultural, historical and aesthetic impacts)* - Also touched on above under R.E.D. impacts; if redevelopment is indeed hampered, it would negatively affect aesthetic values (removal of blight followed by orderly, planned redevelopment) and historical values (the riverfront is where the city began).

- **Untreated sewage releases** *(adverse health and environmental impacts)* - The city sewage treatment plants in Oakland and North Topeka would likely be subject to frequent short-term operational interruptions, and the interruptions would be much longer term in flood events causing physical damages at the facilities. Service interruptions would result in large releases of unprocessed sewage into the Kansas River, adversely affecting public health (potentially) and environmental values (certainly).

6.0 ALTERNATIVES SCREENING

6.1 OVERVIEW OF EVALUATION PROCEDURES

Economic costs and benefits resulting from a project are evaluated in terms of their impacts on national wealth, without regard to where in the United States the impacts may occur. National Economic Development (NED) benefits must result directly from a project and must represent net increases in the economic value of goods and services to the national economy, not simply to a locality. For example, if a flood interrupts auto production at a plant in one community, that community suffers a loss. But if the affected company replaces the interrupted production at another plant in another city, the community's loss does not represent a net loss to the national economy, and the prevention of such a loss cannot be claimed as a NED benefit.

NED costs represent the costs of diverting resources from other uses in implementing the project, as well as the costs of uncompensated economic losses resulting from detrimental effects of the project. NED benefits, the benefit-cost ratio, and the net NED benefits are calculated during the evaluation process. Net benefits represent the amount by which the NED benefits exceed NED costs, thereby defining the plan's contribution to the nation's economic output. The plan with the highest net benefits is considered the recommended plan, assuming technical feasibility, environmental soundness, and public acceptability. Note that the plan with highest net benefits is not necessarily the plan with the highest benefit-cost ratio. The benefit-cost ratio helps identify which plans have likely economic feasibility and can be carried forward for further analysis, but is not decisive in identifying the NED plan from among those plans that are economically feasible.

6.2 GENERAL DESCRIPTION OF ALTERNATIVES

While a number of alternatives were evaluated at some level of detail, there were seven alternatives showing enough promise to justify preparation of costs and benefits. None of the alternatives involve levee raises; all are related to the structural and geotechnical probability of failure characterizing the existing levees. The Waterworks unit has one alternative while the North Topeka, Oakland and South Topeka units each have a similar pair of alternatives. The pair of alternatives for each of the latter three units includes a fix for the structural deficiency affecting that unit (floodwall or pump station) along with a geotechnical fix. In each pair of alternatives, the geotechnical fix is an underseepage berm in the first alternative and a relief wells system (with or without collector system) in the second alternative.

The alternatives are listed below:

- Waterworks 1 - Stability berm.

- South Topeka 1 - Underseepage berm at site 1, floodwall replacement at site 2, wall stiffener at pump plant, miscellaneous heel extensions.

- South Topeka 2 - Same as South Topeka 1 except substitute relief wells for underseepage berm.

- Oakland 1 - Underseepage berm, East Oakland pump station heel extension, small stability berm on Shunganunga Creek tieback, miscellaneous heel extensions.

- Oakland 2 - Same as Oakland 1 except substitute relief wells for underseepage berm.

- North Topeka 1 - Underseepage berm at site 1, relief wells and collector system at site 2, abandonment of Fairchild pump station.

- North Topeka 2 - Same as North Topeka 1 except substitute relief wells at site 1 for underseepage berm.

6.3 SCREENING BENEFITS DETERMINATION

6.3.1. Benefits Computation. To determine the economic justification of the array of alternatives, each alternative was entered into the HEC-FDA risk analysis model. The Monte Carlo analysis in HEC-FDA was then employed to determine residual damages – i.e., damages that would continue to occur in the with-project condition even with implementation of that alternative. The residual damages that would continue to occur in the with-project condition were expressed as equivalent annual damages that account for both the base year condition and the discounted present-worth of the future year condition. The difference between the without-condition EAD and the residual EAD for each alternative represents the damages reduced or benefits for the alternative. The Topeka alternatives analysis involved no modifications to the existing condition economic structure inventory and occupancy type data.

Screening benefits in this analysis were based on physical inundation reduction to homes, businesses, public facilities, roads, and crops, as well as emergency costs and relocation/ reoccupation costs. Not included were induced damages, which should be insignificant if not nonexistent in any case since no levee raises are being considered.

6.3.2 Engineering Data Considerations. Like the economic data, top of levee elevations and hydraulic and hydrologic data also were unchanged from the existing conditions. Given the structural and geotechnical character of all identified deficiencies in the Topeka levee system, the most important variable in determining the performance of alternatives in this analysis was the probability of failure function. As described above in section 4.4.2, each reach has a single probability of failure function accounting for the multiple locations of concern within the reach by combining them at the index point. For the alternatives analysis, the probability of failure function for the existing condition at each problem site is modified to reflect the repair by specifying a probability of failure of 0.002 at top of levee and a zero probability of failure at three feet below top of levee and all points below. (The risk program interpolates probabilities between these two points.) The modified individual functions then go into a revised combined probability of failure function at the index point, and the risk simulation is repeated to determine residual damages with the project in place and damages reduced (i.e., benefits).

6.3.3 Treatment of South Topeka and Oakland. Because there are two alternatives for the South Topeka levee and an additional two alternatives for the Oakland levee, it was necessary to treat the area as two separate reaches for the screening analysis and allocate a portion of Oakland damages to the South Topeka levee. To do this, a computation of Oakland damages was prepared which assumed that the Oakland levee's two deficient sections were fixed. All damage potential in the Oakland area therefore was assumed to be due to the performance of the South Topeka levee. The resulting screening-level benefits total for the South Topeka alternatives comprises a portion of the overall potential damage reduction in Oakland as well as benefits from South Topeka. For the Oakland unit, damages are based on the combined effects of all five critical sections of both the South Topeka and Oakland units, while the benefits are based on repair of the two Oakland sections. This treatment of Oakland damages results in considerable double-counting of damages, but this does not matter for purposes of the screening analysis since both Oakland alternatives have identical benefits, as do both South Topeka alternatives. The alternatives ranking for each unit is not affected by allocation of Oakland damages.

6.4 SCREENING COST ESTIMATES

Screening-level costs are summarized in Table D-22. Costs were prepared by cost engineering staff for each of the seven alternatives. All costs include interest during construction computations which assume project completion in mid-2013. All screening costs reflect an October 2005 price level, and the annualized totals reflect the current Federal interest rate of 4.875% as well as a 50-year period of analysis.

(Note on price levels: The screening damages, benefits, and costs in this section reflect a price level of October 2005, unlike the existing condition damage computations in section 5 and the NED plan benefits and costs in section 7, both of which are in October 2008 prices. The screening cost estimates were completed late in FY 2006 (October 2005 price level) and were subsequently revisited only for the selected plan. In order to put the screening-level economic costs on the same basis as the benefits, the benefits were deflated to October 2005 prices using the ENR Building Cost Index. The price level has no effect on the screening-level evaluation and plan selection since all alternatives reflect the same price level. But the economic screening data summarized below in Tables D-22 and D-26 cannot be compared directly with the existing condition damages in Table D-14 or the NED plan benefits and costs in Tables D-29 through D-32 without taking account of the different price levels, and there are also other differences touched on below.)

Annual costs for operations and maintenance were included only for the alternatives that would produce additional O&M costs over and above current without-project levels. The three alternatives with net additional O&M costs are the alternatives that include relief wells. For these alternatives, the life-cycle cost analysis for each alternative assumed that each pump would require servicing every four years at $5,000 per pump. There are 22 wells for the Oakland relief

TABLE D-22

SCREENING COSTS SUMMARY

October 2005 prices, 4 875% interest rate, 50 year period of analysis, $1,000s

ITEM	PED	LERRD	CONSTR	S&A	TOTAL FIRST COST	IDC	O&M	TOTAL ANNUAL COSTS
WATERWORKS ALT 1								
Stability berm	$3 7	$1.5	$37 1	$2 4	$44 7	$2 6	$0.0	$2.5
SOUTH TOPEKA ALT 1								
Underseepage berm	$81 7	$849 0	$457 5	$53 1	$1,441.3	$82 9	$0 0	$81 9
Floodwall replacement	$1,001 6	$27 5	$10,015 7	$650 0	$11,694 8	$672 4	$0.0	$664.4
Kansas Avenue pump plant wall stiffener	$0 5	$0.0	$5 5	$0 4	$6 4	$0 4	$0 0	$0 4
Miscellaneous heel extensions	$39 0	$0 0	$390 3	$25 3	$454.6	$26 1	$0 0	$25 8
Total	$1,122 9	$876 5	$10,868 9	$728 8	**$13,597.0**	$781.8	$0 0	**$772.5**
SOUTH TOPEKA ALT 2								
Relief wells	$115 6	$0 0	$1,155 6	$75 0	$1,346 2	$77 4	$51 0	$127 5
Floodwall replacement	$1.001 6	$27 5	$10,015 7	$650 0	$11,694.8	$672 4	$0 0	$664 4
Kansas Avenue pump plant wall stiffener	$0 5	$0 0	$5 5	$0 4	$6 4	$0 4	$0 0	$0 4
Miscellaneous heel extensions	$39 0	$0 0	$390 3	$25 3	$454 6	$26 1	$0 0	$25 8
Total	$1,156 7	$27 5	$11,567 1	$750 7	**$13,502.0**	$776 4	$51 0	**$818.1**
OAKLAND ALT 1								
Underseepage berm	$94 2	$215 3	$942 3	$61 2	$1,313 1	$75 5	$0 0	$74 6
East Oakland pump station heel extension	$19 0	$0 0	$189 9	$12 3	$221 2	$12 7	$0 0	$12 6
Stability berm on Shunganunga tieback	$2 0	$14 8	$19 6	$1.3	$37 6	$2 2	$0 0	$2 1
Miscellaneous heel extensions	$1 1	$0 0	$11 3	$0 7	$13 2	$0 8	$0 0	$0 8
Total	$116 3	$230 2	$1,163 2	$75 5	**$1,585.1**	$91 1	$0 0	**$90.1**
OAKLAND ALT 2								
Relief wells	$73 4	$0 0	$733 8	$47 6	$854.8	$49 1	$31.3	$79 9
East Oakland pump station heel extension	$19 0	$0 0	$189 9	$12 3	$221 2	$12 7	$0 0	$12 6
Stability berm on Shunganunga tieback	$2 0	$14 8	$19 6	$1 3	$37 6	$2 2	$0 0	$2 1
Miscellaneous heel extensions	$1 1	$0.0	$11 3	$0 7	$13 2	$0 8	$0 0	$0 8
Total	$95 5	$14 8	$954 6	$62.0	**$1,126.8**	$64 8	$31 3	**$95.3**
NORTH TOPEKA ALT 1								
Underseepage berm (site 1)	$153 5	$181 2	$1,534 5	$99 6	$1,968.8	$113 2	$0 0	$111 8
Relief wells & collector system (site 2)	$39 8	$0 0	$398 1	$25 8	$463 7	$26 7	$10 7	$37 0
Fairchild pump station abandonment	$4 0	$0 0	$40 2	$2 6	$46.8	$2 7	$0 0	$2 7
Total	$197 3	$181 2	$1,972 8	$128 0	**$2,479.3**	$142 6	$10 7	**$151.6**
NORTH TOPEKA ALT 2								
Relief wells (site 1)	$105 8	$110 3	$1,057 6	$68 6	$1,342.3	$77.2	$46 7	$122 9
Relief wells & collector system (site 2)	$39 8	$0 0	$398 1	$25 8	$463 7	$26 7	$10 7	$37 0
Fairchild pump station abandonment	$4 0	$0 0	$40 2	$2 6	$46 8	$2 7	$0.0	$2.7
Total	$149 6	$110 3	$1,495 8	$97 1	**$1,852.8**	$106 5	$57 4	**$162.6**

Interest during construction (IDC) assumes following project schedule. PED, Jan 08 thru Jan 11, LERRD, Jan 11 thru Oct 11, construction, Oct 11 thru Jul 13

Total first costs = PED + LERRD + construction + S&A
Annual costs = ((Total first costs + IDC) X interest & amortization factor of 0 053722) + O&M
Annual O&M costs include only additional or net costs over and above comparable existing costs

wells alternative, 35 for South Topeka, and 38 for North Topeka. Complete replacement of the wells was assumed to be required after 40 years at a cost equal to the current construction cost for the wells in each alternative plus 17% to account for E&D and S&A. In addition to the relief wells, the North Topeka alternative also includes underground collector systems and a temporary pumping component. O&M costs for the collector systems assume that flushing and cleaning would be required every 25 years and would cost $10,900 in each instance. This total includes 3 days of labor by a 2-man crew as well as equipment costs. The temporary pumping plan would be needed when the water surface elevation comes within 3 feet of top of levee, which would require an event of about a 0.5% magnitude. We assumed that the pumping capability would be needed three times over the 50-year period of analysis. Each event would require one pump rental for one week costing $700, which includes installation, use, removal and return.

6.5 SCREENING RESULTS BY REACH

Economic and engineering performance results for each of the alternatives screened are detailed in Table D-26 and D-27 at the end of this section and in the discussions of each reach below.

6.5.1 Waterworks Alternative. To address the floodwall sliding threat, a stability berm was evaluated as the most likely cost-effective solution. Replacement of the floodwall section or modification of the wall's foundation probably would be much more expensive than the berm, which would require less than 1,000 cubic yards of material. The first cost for the stability berm is $44,700, and the annualized total cost is $2,500. Annual benefits total $4,900, and the benefit-cost ratio is 1.9 with net benefits of $2,400. The benefits total is based solely on physical flood risk management and does not include benefits related to preventing interruptions of the city's water supply, so these benefits are very conservative. Residual damages associated with this alternative are $193,500, meaning that 98% of the equivalent annual damages at Waterworks would continue to occur even with the project in place, but the residual damages would be associated with very large and infrequent events. Project implementation would marginally improve the levee's exceedance probability in a 1%-chance event from 0.072 to 0.067.

6.5.2 South Topeka Alternatives

6.5.2.1 South Topeka Alternatives - Economic Performance. Alternative 1 at South Topeka includes an underseepage berm at site 1 (first cost of $1,441,300) and a floodwall replacement at site 2 ($11,694,800). Also included are two smaller features at or near the floodwall site: a wall stiffener at the Kansas Avenue pump plant ($6,400), and small heel extensions at several manholes ($454,600). A separate probability of failure function was not developed for the heel extensions. Their proximity to the deficient floodwall section, which is the major deficiency at that section of the levee, would make it difficult or impossible to accurately determine a separate probability of failure for each feature, and the costs are minor in the context of the overall alternative (about 3% of total costs for alternative 1). Alternative 1 has first costs of $13,597,000. No net annual O&M costs are included in the annualized total cost of $772,500.

Alternative 2 at South Topeka is the same as Alternative 1, except that the site 1 fix is a system of 35 relief wells rather than the underseepage berm. As discussed above in section 6.3, annual operation and maintenance costs for relief well systems are significant. Alternative 2 has first costs of $13,502,000. Net annual O&M costs are $51,000, and the total annual cost is $818,100.

Annual benefits, which account for damage reduction in both South Topeka and Oakland, total $932,300 for both alternatives (October 2005 prices). Alternative 1 annual costs are $772,500, resulting in a benefit-cost ratio of 1.2 and net benefits of $159,800. Alternative 2 annual costs are $818,100, which yields a benefit-cost ratio of 1.1 and net benefits of $114,200. Both South Topeka alternatives are economically justified, and Alternative 1, which includes the underseepage berm at site 1, is the NED alternative with the greatest net benefits.

Significant annual residual damages of $1,834,000 would continue to occur in the with-project condition. The overall damage reduction relative to the existing condition EAD of $2,766,300 would be 34%. However, the 66% of EAD that remains in the with-product condition would occur primarily in large and infrequent flood events.

6.5.2.2 South Topeka Alternatives - Engineering Performance. Implementation of either South Topeka alternative would improve the unit's exceedance probability in a 1%-chance flood event from 0.158 to 0.054. The median annual exceedance probability, which is 0.004 under existing conditions, would increase to 0.003. The chance of flooding over a 50-year period would be 1 in 6, improved from the existing conditions chance of 1 in 4. (Refer to Table D-24 for additional statistics.)

Table D-23 shows the combined probability of failure function for existing conditions, fixing each of the three sites separately, fixing any two of the three sites, and fixing all three sites as in the formulated alternatives. It will be seen that all of the partial repairs fail to reduce probability of failure to an acceptable minimum. Only by repairing all three sites can probability of failure for the unit be reduced to a level appropriate to public safety in a densely populated urban area.

TABLE D-23

SOUTH TOPEKA - PROBABILITY OF FAILURE FUNCTIONS WITH-PROJECT

p(F) = probability of failure

Elevation @ index point	Existing condition	Fix of underseepage only	Fix of floodwall only	Fix of pump station only	Fix underseepage & floodwall, not pump station	Fix underseepage & pump station, not floodwall	Fix floodwall & pump station, not underseepage	Combined fix of all 3 sections
892.8	0.7122	0.3784	0.6182	0.6509	0.1755	0.2460	0.5370	0.0020
892.6	0.6923	0.3587	0.6000	0.6308	0.1665	0.2306	0.5201	0.0011
891.6	0.5141	0.1542	0.4323	0.5083	0.5141	0.1441	0.4255	0.0007
889.9	0.3394	0.0498	0.3048	0.3394	0.0000	0.0498	0.3048	0.0000
888.2	0.1974	0.0127	0.1871	0.1974	0.0000	0.0127	0.1871	0.0000
887.7	0.1555	0.0065	0.1500	0.1555	0.0000	0.0065	0.1500	0.0000
885.4	0.0277	0.0000	0.0275	0.0277	0.0000	0.0002	0.0275	0.0000
883.4	0.0009	0.0000	0.0009	0.0009	0.0000	0.0000	0.0009	0.0000
881.3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

6.5.3 Oakland Alternatives

6.5.3.1 Oakland Alternatives - Economic Performance. Alternative 1 for Oakland includes an underseepage berm at the Oakland wastewater plant (first cost of $1,313,100) and a heel extension at the East Oakland pump station ($221,200). Also included are two smaller, inexpensive repairs that are not separately evaluated in this analysis: a small stability berm on the unit's Shunganunga Creek tieback ($37,600) and heel extensions at several manholes

($13,200). The total first cost for alternative 1 is $1,585,100. The annualized total cost, which does not include any net annual O&M costs, is $90,100.

Alternative 2 includes the same features as alternative 1, except that a system of 22 relief wells ($854,800) is substituted for the underseepage berm at the treatment plant. The first cost of $1,126,800 is lower than the first cost for alternative 1, but alternative 2 also has significant annual O&M costs of $31,300 that result in a higher annualized cost. The annual cost for alternative 2 is $95,300.

Both alternatives have annual benefits of $2,558,500, and the difference in net benefits is quite small. The NED plan is alternative 1, with a benefit-cost ratio of 28.4 and net benefits of $2,468,400. Alternative 2 also would have strong economic justification with a benefit-cost ratio of 26.8 and net benefits of $2,463,100. The project would reduce 56% of existing condition EAD, leaving residual damages of $2,005,300.

6.5.3.2 Oakland Alternatives - Engineering Performance. Table D-24 presents the probability of failure functions for existing conditions, as well as the combined with-project reliabilities for separate underseepage berm or relief wells system, separate heel extension at the East Oakland pump station, and the two repairs combined. The functions for the two separate with-project conditions once again show very little significant improvement over the existing condition; only the combined repair creates the conditions for regaining an acceptable level of engineering wells and collector system at site 2. The total annual cost for alternative 2 is $162,600.

TABLE D-24

OAKLAND - PROBABILITY OF FAILURE FUNCTIONS WITH-PROJECT

Elevation @ index point	Existing condition	Underseepage fix	Pump station fix	Combined fix of both sections
887 5	1 0000	1 0000	1 0000	0 0020
886.9	1 0000	1 0000	1 0000	0 0016
886.4	1 0000	1 0000	1 0000	0 0014
883.7	1 0000	1 0000	1 0000	0 0000
882 7	1 0000	1 0000	0 9999	0 0000
881.5	1.0000	1 0000	0.9882	0 0000
880 7	0 9998	0 9886	0 9813	0 0000
880.0	0 9828	0 8500	0 8854	0 0000
879 6	0 9327	0 5513	0 8500	0 0000
879 2	0 8306	0 1500	0 8007	0 0000
878 7	0 7479	0 0000	0 7479	0 0000
875.8	0 2639	0 0000	0 2639	0 0000
874 0	0 1500	0 0000	0 1500	0 0000
871 8	0 0000	0 0000	0 0000	0 0000

Benefits are $10,118,000 for both alternatives. The NED plan for North Topeka is alternative 1, performance. The extremely high exceedance probability of 0.97 in a 1%-chance event that currently characterizes the Oakland unit would be improved only marginally by fixing only the underseepage section (0.903 with project) or only the pump station (0.958 with project). But implementation of either of the formulated alternatives which include improvements at both critical sections would reduce the 1%-chance event exceedance probability to 0.058. The chance of a damaging flood over a 50-year period would be reduced from 1 in 1.05 to 1 in 6, and the median annual exceedance probability with the project in place would be 0.003, compared to the current probability of 0.057.

6.5.4 North Topeka Alternatives

6.5.4.1 North Topeka Alternatives - Economic Performance. Alternative 1 for North Topeka includes an underseepage berm at site 1 ($1,968,800), a relief wells and collector system at site 2 ($463,700), and abandonment of the old Fairchild pump station ($46,800). The total first cost of the alternative is $2,479,300. The total annual costs of $151,600 also include $10,700 of O&M costs associated with the site 2 relief wells & collector system.

Alternative 2 is identical to alternative 1 except that the underseepage berm at site 1 is replaced by a system of 32 relief wells ($1,342,300). The total alternative cost is $1,852,800. Annual O&M costs are $57,400, including $46,700 for the relief wells at site 1 and $10,700 for the relief which has a benefit-cost ratio of 66.8 and net benefits of $9,966,500. Alternative 2 also has strong economic justification with a benefit-cost ratio of 62.2 and net benefits of $9,955,400. Either alternative would reduce existing condition EAD by 71%, but would also be characterized by significant residual damages of $4,110,100.

6.5.4.2 North Topeka Alternatives - Engineering Performance. Probability of failure functions are shown in Table D-25 for the three North Topeka critical sections, individually and combined, under existing conditions. Also shown are the with-project functions that result from repairing each section separately, as well as the functions associated with the repair of any two sites out of three. The last column shows the function that results from repairing all three sites. Only the latter function displays any significant improvement over the existing condition. Even the functions for repair of two out of three sites continue to show PFPs several feet below top of levee and PNPs near the bottom of the levee. The existing condition exceedance probability of 0.859 against a 1%-chance flood event improves to 0.054 with implementation of improvements at all three deficient sections. The chance of a damaging flood over 50 years drops from 1 in 1.4 in the existing condition to 1 in 6 with implementation of either formulated alternative. The median annual exceedance probability improves from 0.024 to 0.003.

TABLE D-25
NORTH TOPEKA - PROBABILITY OF FAILURE FUNCTIONS WITH-PROJECT

p(F) = probability of failure

Elevation @ index point	Existing condition	Fix underseepage site 1	Fix underseepage site 2	Fix pump station (site 3)	Fix sites 1 & 2	Fix sites 1 & 3	Fix sites 2 & 3	Combined p(F) for repair of all 3 sections
894.1	1.0000	1.0000	1.0000	0.9999	1.0000	0.9893	0.9886	0.0020
893.5	1.0000	1.0000	1.0000	0.9992	1.0000	0.9655	0.9756	0.0005
893.0	1.0000	1.0000	1.0000	0.9989	1.0000	0.9597	0.9724	0.0002
892.7	1.0000	1.0000	1.0000	0.9985	1.0000	0.9480	0.9705	0.0000
890.7	1.0000	1.0000	1.0000	0.9903	1.0000	0.8500	0.9355	0.0000
889.0	1.0000	1.0000	1.0000	0.9566	1.0000	0.6671	0.8697	0.0000
887.0	1.0000	1.0000	1.0000	0.8086	1.0000	0.2875	0.7313	0.0000
886.7	0.9993	0.9977	0.9991	0.7822	0.9969	0.2519	0.7088	0.0000
885.5	0.9413	0.8651	0.9347	0.6089	0.8500	0.1009	0.5650	0.0000
885.3	0.8500	0.8500	0.8500	0.5294	0.4682	0.0419	0.5089	0.0000
885.0	0.7497	0.4905	0.7388	0.5037	0.3011	0.0375	0.4843	0.0000
884.8	0.6531	0.3274	0.6396	0.4769	0.1500	0.0336	0.4588	0.0000
884.6	0.5554	0.1785	0.5400	0.4486	0.0000	0.0294	0.4319	0.0000
884.4	0.4486	0.0294	0.4319	0.2438	0.0000	0.0003	0.2436	0.0000
883.0	0.2438	0.0003	0.2436	0.2275	0.0000	0.0000	0.2275	0.0000
882.0	0.1500	0.0000	0.1500	0.0512	0.0000	0.0000	0.0512	0.0000
879.1	0.0024	0.0000	0.0024	0.0000	0.0000	0.0000	0.0000	0.0000
877.1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

6.6 SELECTION OF NED PLAN

Based on the screening data summarized above, the NED plan consists of the single Waterworks alternative along with Alternative 1 (berm rather than relief wells) in South Topeka, Oakland and North Topeka. All alternatives exhibit economic feasibility (i.e., net benefits), but these alternatives have the highest net benefits, as can be seen in Table D-26. Engineering performance statistics for the alternatives can be found in Table D-27. The next section will fully describe the NED plan.

While the Waterworks unit does not have serious engineering deficiencies at present and already has a high level of reliability, the stability berm is very inexpensive and is economically justified even without consideration of the substantial benefits of preventing interruption of water supply to a relatively large urban area. Additionally, existing deficiencies in a levee, even if small at present, probably will only become worse with time, threatening the city water supply.

TABLE D-26

SCREENING ALTERNATIVES - BENEFITS & COSTS SUMMARY

October 2005 prices, 50 year period of analysis, 4 875% interest rate

Unit	WATERWORKS	SOUTH TOPEKA				OAKLAND		NORTH TOPEKA	
Alternative	**Alt 1**	**EAD in S Top**	**EAD in Oak**	**Alt 1**	**Alt 2**	**Alt 1**	**Alt 2**	**Alt 1**	**Alt 2**
DAMAGES & BENEFITS									
EAD without project	$198 4	$957 3	$1,809 0	$2,766 3		$4,563 8		$14,228 1	
EAD residual	$193 5	$775 3	$1,058 7	$1,834 0		$2,005 3		$4,110 1	
Residual as % of without project	97 5%	81 0%	58 5%	66 3%		43 9%		28 9%	
EAD reduction									
Mean	$4 9	$182 0	$750 3	$932 3		$2,558 5		$10,118 0	
Probabilistic estimates*									
0.75	$3 9	$81 6	$395 2	$476 8		$1,516 9		$5,829 4	
0.5	$4 6	$139 1	$612 2	$751 3		$2,379 9		$9,070 0	
0.25	$6 1	$270 6	$1,164 0	$1,434 6		$3,362 3		$13,635 0	
Annual benefits - screening level	**$4.9**	$182 0	$750 3	**$932.3**		**$2,558.5**		**$10,118.0**	
COSTS									
First costs	$44 7	--	--	$13,597 0	$13,502 0	$1,585 1	$1,126 8	$2,479 3	$1,852 8
Annual costs - screening level	**$2.5**	--	--	**$772.5**	**$818.1**	**$90.1**	**$95.3**	**$151.6**	**$162.6**
BENEFIT-COST RATIO	**1.9**			**1.2**	**1.14**	**28.4**	**26.8**	**66.8**	**62.2**
NET BENEFITS	**$2.4**			**$159.8**	**$114.2**	**$2,468.4**	**$2,463.1**	**$9,966.5**	**$9,955.4**

* Probabilistic EAD reduction shows the minimum level of benefits expected at the indicated probability, resulting in a range of possible benefit values rather than a single value For example, North Topeka benefits, expressed as a mean value, equal $10,118 0, but there is 75% confidence that benefits are at least $5,829,4 and 25% confidence that they exceed $13,635 0

Alternatives within each reach have identical benefits since they accomplish the same project purposes The economic performance of the alternatives differs only in costs Screening BCR data will not match the BCR data for the selected plan in Table D-26 This table includes a portion of Oakland damages and damages reduced that is double-counted in both Oakland and South Topeka benefits for screening purposes Moreover, the price level for the screening BCR data is different from other sections of the report, and the NED plan benefits also include additional categories of benefits not considered in the screening analysis

TABLE D-27

SCREENING ALTERNATIVES - ENGINEERING PERFORMANCE

Alternative	Annual exceedance probability (median)		Long-term risk (chance of exceedance during indicated period)			Exceedance probability per flood event		
	Probability	Return interval (years)	10 years	25 years	50 years	2.0%	1.0%	0.2%
WATERWORKS - ALT 1								
Without project	0.003	333	1 in 25	1 in 10	1 in 5	0.003	0.072	0.758
With project	0.003	333	1 in 26	1 in 11	1 in 6	0.003	0.067	0.750
SOUTH TOPEKA - ALT 1 OR 2								
Without project	0.004	250	1 in 23	1 in 9	1 in 5	0.031	0.158	0.806
With project	0.003	333	1 in 27	1 in 11	1 in 6	0.002	0.054	0.721
OAKLAND - ALT 1 OR 2								
Without project	0.057	18	1 in 2	1 in 1.3	1 in 1.05	0.856	0.971	1.000
With project	0.003	333	1 in 27	1 in 11	1 in 6	0.003	0.058	0.700
NORTH TOPEKA - ALT 1 OR 2								
Without project	0.024	42	1 in 4	1 in 2	1 in 1.4	0.180	0.860	0.998
With project	0.003	333	1 in 27	1 in 11	1 in 6	0.002	0.054	0.715

7.0 THE NED PLAN

7.1 DESCRIPTION OF THE NED PLAN

The plan for the Topeka levee system emerging from the screening analysis consists of the single Waterworks alternative, South Topeka alternative 1, Oakland alternative 1, and North Topeka alternative 1. These are the NED alternatives in each unit. Specifically, the plan consists of the following elements:

1. At Waterworks, a stability berm would be constructed to eliminate the sliding threat between stations 0+00 and 16+50. Only 958 cubic yards of fill would be required for the berm.

2. At South Topeka's underseepage section (stations 22+00 to 48+00), an underseepage berm would be built using 48,150 cubic yards of fill.

3. At South Topeka's weakened floodwall section (stations 74+41 to 93+86), the deficient sections of the floodwall would be replaced.

4. In the same area, a strength deficiency at the Kansas Avenue pump station (station 75+84) would be remedied by wall stiffener, and uplift concerns at several nearby sites would be dealt with by small heel extensions.

5. At Oakland's underseepage section (stations 64+00 to 80+00, near the Oakland treatment plant), an underseepage berm would be constructed, using 84,500 cubic yards of fill. A small

heel extension would be done in the same area at a manhole where uplift concerns exist.

6. At Oakland's East Oakland pump station (station 220+00), a heel extension would be built to alleviate uplift concerns.

7. On the Shunganunga Creek tieback of the Oakland unit (stations 485+86 to 491+01), a sliding threat would be addressed by a small stability berm. 388 cubic yards of fill would be required.

8. At the upstream North Topeka underseepage site (stations 165+00 to 189+00), an underseepage berm would be constructed, using 122,250 cubic yards of fill.

9. At the downstream North Topeka underseepage section (sections 246+00 to 250+00), a system of 6 relief wells and an underground collector system would be built. A temporary pumping plan also would need to be implemented periodically.

10. Near the downstream end of the North Topeka unit, the old Fairchild pump station would be abandoned in order to end the uplift threat at that location. (It is no longer an active portion of the Topeka local protection system and would not need to be replaced functionally.)

7.2 ENGINEERING PERFORMANCE OF NED PLAN

Table D-28 compares without and with-project condition reliability statistics for the NED plan. The key results of implementing the NED plan would be as follows:

- The median annual exceedance probability -- currently as much as 0.057 for Oakland, 0.024 for North Topeka, and 0.004 for South Topeka -- would improve to 0.003 for the system. In other words, there would be a 0.3% chance of a damaging flood in any year following project implementation.

- In a 1%-chance flood event, all Kansas River units would have between a 5% and 7% chance of experiencing damage. Currently, Oakland has a 97.1% chance of a damaging flood in an event of that magnitude, North Topeka an 85.9% chance, and South Topeka a 15.8% chance. The Waterworks nonexceedance probability would increase marginally to 0.933, and the performance of other Kansas River units would be substantially improved.

- The long-term risk of a damaging flood in any of the Kansas River units over a 50-year period would be approximately 1 in 6, compared to a current 50-year risk exceeding 1 in 2 for the Oakland and North Topeka units. The with-project risk over 25 years would be 1 in 11; over 10 years, it would be 1 in 27.

- Probability of failure (PFP) elevations, defined as the elevation at which the probability of failure reaches 85%, would not occur until the top of levee elevation is almost reached.

7.3 COSTS OF NED PLAN

Costs for the NED plan are summarized in Table D-29. The first cost of the NED plan is $21,157,000. The total annual cost is $1,168,100. The South Topeka/Oakland combined unit accounts for almost 86% of the total, North Topeka 14%, and Waterworks less than 1%. An interest rate of 4.625% is used in the computations with a 50-year period of analysis. The price level is October 2008. A completion date of April 2015 is assumed for the project.

Annual costs include $12,800 in net OMRR&R costs associated with the North Topeka relief walls/collector system and temporary pumping plan. (Total annual OMRR&R costs in the existing condition are estimated at $299,000, including $199,000 for North Topeka and $100,000 for the right bank levees. The total annual OMRR&R cost with implementation of the NED plan would be $311,800.)

The City of Topeka would be the non-Federal sponsor for the Kansas River right bank improvements. These improvements affect Waterworks, South Topeka and Oakland and consist of the first seven elements of the NED plan listed above. The total cost for this portion of the NED plan sponsored by the City of Topeka would be $18,290,000, which is 86% of the total NED plan costs. The city's non-Federal share currently is estimated at $6,401,500. North Topeka improvements, consisting of NED plan elements 8 through 10 above, would cost

TABLE D-28
ENGINEERING PERFORMANCE FOR NED PLAN - WITH vs. WITHOUT CONDITIONS

	WATERWORKS		AUBURNDALE		SOUTH TOPEKA		OAKLAND		NORTH TOPEKA		SOLDIER CREEK	
	WITHOUT	WITH	WITHOUT	WITH	WITHOUT	WITH	WITHOUT	WITH	WITHOUT	WITH	WITHOUT	WITH
ANNUAL EXCEEDANCE PROBABILITY*												
Median	0.003	0.003	0.003	no change	0.004	0.003	0.057	0.003	0.024	0.003	0.006	no change
Return interval (years)	333	333	333		250	333	18	333	42	333	167	
LONG-TERM RISK (chance of flooding during period)												
over 10 years	1 in 25	1 in 26	1 in 32	no change	1 in 23	1 in 27	1 in 2	1 in 27	1 in 4	1 in 27	1 in 13	no change
over 25 years	1 in 10	1 in 11	1 in 13		1 in 9	1 in 11	1 in 1.3	1 in 11	1 in 2	1 in 11	1 in 5	
over 50 years	1 in 5	1 in 6	1 in 7		1 in 5	1 in 6	1 in 1	1 in 6	1 in 1.4	1 in 6	1 in 3	
PERFORMANCE VS. 1%-CHANCE FLOOD												
Top of levee margin (feet) over flood elevation**	5.9		8.2	no change	6.5		3.7		6.6		1.7	no change
Conditional nonexceedance probability	0.928	0.933	0.968		0.842	0.946	0.029	0.942	0.141	0.946	0.668	
Conditional exceedance probability	0.072	0.067	0.032		0.158	0.054	0.971	0.058	0.860	0.054	0.332	
OTHER FLOOD EVENTS - EXCEEDANCE PROBABILITY												
10.0%	0.000	0.000	0.000	no change	0.000	0.000	0.165	0.000	0.004	0.000	0.000	no change
4.0%	0.000	0.000	0.000		0.003	0.000	0.589	0.000	0.180	0.000	0.002	
1951 flood (3.5%)***	0.001	0.015	0.008		0.010	0.001	0.656	0.001	0.273	0.001	0.025	
2.0%	0.003	0.003	0.032		0.031	0.002	0.857	0.003	0.554	0.002	0.094	
0.4%	0.331	0.321	0.213		0.436	0.285	0.995	0.280	0.970	0.285	0.661	
0.2%	0.758	0.750	0.644		0.806	0.721	1.000	0.700	0.998	0.721	0.817	

* Annual exceedance probability is the chance of a damaging flood in any year. The statistic implies nothing about the magnitude of the flood except that it would be large enough to exceed the system's capacity.

** Top of levee here means initial overtopping margin, i.e., the low point on the levee profile in the reach. The 1%-chance flood elevation refers to the nominal value of the elevation and is not risk-based.

*** 1951 flood statistics are interpolated between the nearest events evaluated in HEC-FDA (the 4% and 2% events).

TABLE D-29
NED PLAN COST SUMMARY

Oct 2008 prices, 4.625% interest rate, 50 year period of analysis, $1,000s

ITEM	PED	LERRD	Constr	S&A	Total First Costs	IDC	I&A	O&M	Total Annual Costs	% of total
WATERWORKS UNIT										
(Sponsor City of Topeka)										
Stability berm	$4.4	$1.5	$42.3	$2.8	$51.0	$2.8	$2.8	$0.0	$2.8	0.2%
SOUTH TOPEKA / OAKLAND UNIT										
(Sponsor City of Topeka)										
Underseepage berm (ST)	$142.6	$879.5	$547.3	$59.9	$1,629.4					
New Gatewells (ST)	$103.3	$0.0	$1,024.0	$67.0	$1,194.3					
New Madison Street pump station (ST)	$0.0	$0.0	$0.0	$0.0	$0.0					
Kansas Avenue pump plant wall stiffener (ST)	$0.7	$0.0	$7.2	$0.5	$8.5					
Floodwall replacement (ST)	$1,124.4	$46.0	$11,104.2	$727.0	$13,001.6					
Miscellaneous heel extensions (ST)	$45.9	$0.0	$454.9	$29.8	$530.6					
South Topeka subtotal	*$1,416.9*	*$925.5*	*$13,137.7*	*$884.3*	*$16,364.4*	*$944.5*	*$893.7*	*$0.0*	*$893.7*	
Underseepage berm (OAK)	$134.6	$220.1	$1,117.7	$73.2	$1,545.7					
East Oakland pump station heel extension (OAK)	$23.2	$0.0	$229.4	$15.0	$267.6					
Miscellaneous heel extensions (OAK)	$1.5	$0.0	$15.4	$1.0	$18.0					
Stability berm on Shunganunga tieback (OAK)	$3.8	$15.3	$22.8	$1.4	$43.4					
Oakland subtotal	*$163.1*	*$235.5*	*$1,385.3*	*$90.7*	*$1,874.6*	*$108.2*	*$102.4*	*$0.0*	*$102.4*	
Total	$1,580.0	$1,161.0	$14,523.0	$975.0	$18,239.0	$1,052.7	$996.1	$0.0	$996.1	85.3%
NORTH TOPEKA UNIT										
(Sponsor North Topeka Drainage District)										
Underseepage berm	$193.5	$117.0	$1,806.4	$118.5	$2,235.3					
Relief wells & collector system	$48.7	$0.0	$483.1	$31.7	$563.5					
Fairchild pump station abandonment	$5.9	$0.0	$58.5	$3.8	$68.2					
Total	$248.0	$117.0	$2,348.0	$154.0	$2,867.0	$161.9	$156.4	$12.8	$169.2	14.5%
TOTAL NED PLAN	**$1,832.4**	**$1,279.5**	**$16,913.3**	**$1,131.8**	**$21,157.0**	**$1,217.4**	**$1,155.3**	**$12.8**	**$1,168.1**	100.0%
Estimated Federal share					**$13,752.0**					
Estimated Non-Federal share					**$7,404.9**					
City of Topeka projects					***$6,401.5***					
North Topeka D.D. projects					***$1,003.5***					

Interest during construction (IDC) assume, following project schedule PED, Oct 2009 thru Sep 2012, LERRD, Oct 2012 thru Jun 2013, construction, Jul 2013 thru Apr 2015

Annual O&M costs include only additional or net costs over and above comparable existing costs

$2,867,000 and would be sponsored by the North Topeka Drainage District, which would be charged with an estimated non-Federal cost share of $1,003,500. The total non-Federal share for the project would be S7,405,000.

7.4 ECONOMIC PERFORMANCE AND JUSTIFICATION OF NED PLAN

7.4.1 Benefit-Cost Ratio And Net Benefits. The NED plan has total annual benefits of $15,427,600 for the Topeka levee system and annual costs of $1,168,100. The plan exhibits very strong economic justification with a benefit-cost ratio of 13.2. With net benefits of $14,259,500, the project represents a strong contribution to national economic outputs.

Benefits and costs reflect a price level of October 2008 and the current Federal interest rate of 4.625%. The data for each unit of the Topeka system as well as for the overall system are summarized in Table D-30.

TABLE D-30 TOTAL NED PROJECT BENEFITS & COSTS					
October 2008 prices; 4.625% interest rate; $1,000s					
Unit	Annual Benefits	First Costs	Annual Costs	**BCR**	**Net Benefits**
NORTH TOPEKA UNIT	$11,408.2	$2,867.0	$169.2	**67.4**	**$11,239.0**
WATERWORKS UNIT	$5.5	$51.0	$2.8	**2.0**	**$2.7**
SOUTH TOPEKA / OAKLAND UNIT	$4,013.9	$18,239.0	$996.1	**4.0**	**$3,017.8**
TOTAL	**$15,427.6**	**$21,157.0**	**$1,168.1**	13.2	**$14,259.5**

7.4.2 Benefits Breakdowns. The total project benefits of $15,427,600 and the individual unit totals are broken down by category in Table D-31, which also includes probabilistic outputs. North Topeka accounts for 74% of total benefits and South Topeka/Oakland 26%, while Waterworks benefits make up less than 1% of the total.

About 63.7% of the total benefits are based on damage reduction to businesses and facilities. Another 27.2% of the benefits come from residential damage prevention. Roads and streets account for 2.5%, reduction in emergency costs for 4.6%, reduced disaster relief costs for 1.5%, and reduced production losses for 0.6%. Only negligible crop benefits are provided by the project.

A more probabilistic assessment of damage reduction by the NED plan also is shown in Table D-31. The mean value of damages reduced as produced by the risk analysis is $15,427,600. The table shows that there is a 75% probability that the true benefits exceed $8,769,700, a 50% probability that they exceed $13,738,400, and a 25% probability that they exceed $20,875,200.

TABLE D-31 NED PLAN BENEFITS SUMMARY							
October 2008 prices, 4 625% interest rate, $1,000s							
	NORTH TOPEKA UNIT	WATERWORKS UNIT	AUBURNDALE UNIT	SOUTH TOPEKA/ OAKLAND UNIT	SOLDIER CREEK (RURAL)	TOTAL	
Total EAD (equivalent annual damages)							**% of EAD**
Without project damages	$16,031 7	$221 9	$203 7	$6,357 6	$51 1	$22,865 9	
Residual damages (with project)	$4,623 5	$216 4	$203 7	$2,343 7	$51 1	$7,438 4	32 5%
Damages reduced (benefits)	$11,408 2	$5 5	$0 0	$4,013 9	$0 0	$15,427 6	67 5%
Unit benefits as % of total	73 9%	0 0%	0 0%	26 0%	0 0%	100 0%	
Benefits by category							**% of total**
Non-Residential	$8,407 2	$4 4	$0 0	$1,415 1	$0 0	$9,826 8	63 7%
Residential	$2,191 1	$0 0	$0 0	$2,000 0	$0 0	$4,191 1	27 2%
Roads & Streets	$284 8	$0 0	$0 0	$97 3	$0 0	$382 1	2 5%
Crops	$0 0	$0 0	$0 0	$0 0	$0 0	$0 1	0 0%
Disaster Relief	$67 4	$0 0	$0 0	$165 1	$0 0	$232 5	1 5%
Emergency Costs	$379 4	$1 1	$0 0	$323 7	$0 0	$704 2	4 6%
Lost Production	$78 2	$0 0	$0 0	$12 7	$0 0	$90 9	0 6%
Total	$11,408 2	$5 5	$0 0	$4,013 9	$0 0	$15,427 6	100 0%
Probabilistic benefit estimates - value that benefits exceed with indicated probability							
0 75	$6,570 1	$4 1	$0 0	$2,195 5	$0 0	$8,769 7	
0 50	$10,218 7	$4 9	$0 0	$3,514 9	$0 0	$13,738 4	
0 25	$15,361 8	$6 5	$0 0	$5,506 9	$0 0	$20,875 2	
Mean	$11,408 2	$5 5	$0 0	$4,013 9	$0 0	$15,427 6	

7.4.3 Economic Justification of Individual Units. It will be seen from Table D-30 that in addition to the strong benefit-cost ratio for the system-wide project, each unit of the Topeka system also is individually justified. The combined South Topeka/Oakland portion of the total project has a benefit-cost ratio of 4.0, while the North Topeka unit's benefit-cost ratio is 67.4 and the Waterworks portion stands at 2.0.

While the South Topeka/Oakland economic justification is strong, a further question may arise concerning separable justification of the two units. As has already been discussed, there were insurmountable analytical difficulties in separating the economic performance of the South Topeka and Oakland units in relation to Oakland damages, leading to the decision to treat the two areas as one combined reach in the economic analysis. This is the most accurate method for evaluating damages and benefits in this study. However, costs and engineering performance statistics for this analysis, as opposed to damages and benefits, have been computed for the two units individually. Therefore, an incremental benefit-cost analysis for the two units also has been prepared to approximate total economic outputs for each unit.

The incremental calculations assume the positioning of the South Topeka unit as the first-added unit. This assumption reflected the strong consensus of the product development team that, of the two units in question, South Topeka would be repaired first. The main reason for this priority is that flooding in South Topeka can run downhill into Oakland, while flooding in Oakland cannot back up into South Topeka. Since Oakland flooding has dual sources, it would make little sense to fix the Oakland levee first while leaving the area vulnerable to flooding via the unrepaired South Topeka unit, rendering the Oakland repair useless and a waste of money. In addition, the design overtopping discharge for South Topeka is marginally less than for Oakland.

The incremental calculations are summarized by means of a flowchart approach in Table D-32 and are discussed step by step below:

1. First, damages in Oakland were computed relative to all sources of flooding (e.g., both the South Topeka and Oakland levee units). The probability of failure function used in this set of computations combined the five individual functions - both Oakland critical sections and all three South Topeka critical sections. The total equivalent annual damages for Oakland from all sources was estimated to be $5,228,600. This total was considered to be the overall baseline for Oakland damages.

2. A with-project condition, which assumed the repair of all five critical sections for both units, determined that total damage reduction in Oakland from all sources would be $3,795,500. Residual damages would total $1,433,100. The total Oakland damage reduction of $3,795,500 represented the total to be allocated to the Oakland and South Topeka units in the first and second-added computations.

3. First-added benefits to the South Topeka unit were determined utilizing a second HEC-FDA analysis that evaluated Oakland damages relative to the South Topeka unit. It was assumed that all Oakland levee deficiencies were already repaired and that South Topeka levee deficiencies represented the only flood threat to the Oakland area. The second analysis therefore was based on a low overtopping point on the South Topeka unit and a combined probability of failure function for the three South Topeka critical sections, all adjusted to the Oakland index point. Oakland without-project damages attributable to the South Topeka unit were estimated to total $2,058,000, and total damage reduction was estimated at $855,500. The latter total represented the first-added benefits for the South Topeka unit.

4. In addition to the $855,500 in first-added benefits from damage reduction in Oakland, benefits for the South Topeka levee also include $218,400 in damage reduction in South Topeka. Total benefits for the South Topeka unit were determined to be $1,074,000.

5. Deducting the $855,500 in first-added benefits from the baseline Oakland damage total of $5,228,600, the residual Oakland damages following first-added calculations were $4,373,000.

6. It was previously determined that the total damage reduction in Oakland resulting from implementation of the entire project was $3,795,500 (see step 2 above). Deducting the $855,500 in first-added benefits, the second-added benefits total of $2,940,000 was credited to the Oakland unit.

7. Residual damages following the second-added calculations were $1,433,100 ($4,373,000 in residual damages following the first-added calculations minus the $2,940,000 in Oakland second-added benefits). Therefore, $1,433,100 in residual damages would remain after implementation of the entire project - the same total calculated in step 2.

8. Total benefits for the two units are therefore as follows: South Topeka unit, $1,074,000; Oakland unit, $2,940,000. Note that these incrementally-based benefit totals for the two units differ from those in Table D-26 summarizing results of the screening analysis.

Based on these results, the South Topeka unit incremental benefits of $1,074,000 can be set against the South Topeka annual costs of $893,700 (first costs of $16,364,400), with a resulting benefit-cost ratio of 1.2. The Oakland incremental benefits of $2,940,000 also can be set against Oakland unit annual costs of $102,400 (based on first costs of $1,874,600). The Oakland unit's benefit-cost ratio would be 28.7. The incremental analysis demonstrates that the South Topeka/Oakland portion of the project, which has a strong benefit-cost ratio of 4.0, also is economically justified if the two units are separated.

TABLE D-32

COMPUTATION OF NED PLAN INCREMENTAL BENEFITS FOR SOUTH TOPEKA AND OAKLAND UNITS

	1. OVERALL OAKLAND DAMAGES	2. 1ST-ADDED BENEFITS TO SOUTH TOPEKA UNIT FROM OAKLAND *	3. RESIDUAL / REMAINING OAKLAND DAMAGES AFTER 1ST-ADDED SOUTH TOPEKA UNIT FIX	4. 2ND-ADDED BENEFITS FOR OAKLAND	5. RESIDUAL OR REMAINING OAKLAND DAMAGES AFTER 2ND-ADDED OAKLAND UNIT PROJECT	6. TOTAL SOUTH TOPEKA BENEFITS	7. TOTAL OAKLAND & SOUTH TOPEKA INCREMENTAL BENEFITS
TOTAL DAMAGES IN OAKLAND resulting from combined performance of existing Oakland and South Topeka units **	$5,228.6		$5,228 6				
RESIDUAL DAMAGES continuing after implementation of Oakland fix	$1,433.1				$1,433.1		
TOTAL DAMAGE REDUCTION IN OAKLAND from entire project	$3,795.5			$3,795 5			
DAMAGES IN OAKLAND charged to SOUTH TOPEKA UNIT PERFORMANCE ***		$2,058.0					
RESIDUAL DAMAGES IN OAKLAND (charged to South Topeka unit) that continue after SOUTH TOPEKA PROJECT IMPLEMENTATION		$1,202.5					
DAMAGE REDUCTION from Oakland area CREDITED TO SOUTH TOPEKA UNIT		$855.5	$855 5	$855 5		$855 5	
RESIDUAL OAKLAND DAMAGES FROM ALL SOURCES continuing after South Topeka fix			$4,373.0		$4,373 0		
OAKLAND UNIT BENEFITS				$2,940.0	$2,940 0		$2,940.0
DAMAGE REDUCTION FROM SOUTH TOPEKA AREA						$218 4	
TOTAL SOUTH TOPEKA UNIT BENEFITS						$1,074.0	$1,074.0

* Incremental analysis assumes South Topeka unit would be fixed first, Oakland unit second For reasoning supporting this assumption, see section 7 4 1

** These totals represent damages in the Oakland area from the combined performance of both sources of flooding - the Oakland unit and the South Topeka unit Project performance is based on the combined performance of both levees, considering all five problem sites in Oakland and South Topeka, and on the initial overtopping elevation for the Oakland levee

*** Assumes South Topeka unit controls all damage in Oakland area (as though there were no problems related to the Oakland levee) and that it would be fixed first, prior to the Oakland unit Project performance is based on probabilities of failure for the 3 South Topeka problem sites and on the initial overtopping elevation for the South Topeka levee translated to the Oakland index point

7.4.4 Induced Damages. The proposed project is not be expected to cause additional damages upstream, downstream or across the river from the study area. No new levees would be constructed, and no existing levees would be raised. All project elements involve only the strengthening of the existing levee system to meet expected design levels of performance rather than enhancement of performance to new levels.

7.5 FUTURE WITH-PROJECT CONDITION SUMMARY

A recently reinvigorated emphasis on collaborative planning within the Corps of Engineers has set the stage for greater consideration of the full range of Federal interest in water resources projects. This includes not only tangible NED effects of the project, but also non-NED economic impacts, social impacts, and environmental impacts on the city and region. Environmental aspects are discussed in Appendix E, while this section discusses some of the major economic and social considerations.

7.5.1 NED Effects of NED Plan. The overall NED contribution to the national economy is about $14.3 million, which is the total net benefits of the project. The project would reduce the existing condition EAD of $22.9 million by more than two-thirds to $7.4 million in residual EAD. The chances of experiencing floods that could result in losses of up to $2 billion would be greatly reduced (although not eliminated completely). Most of the adverse impacts described in section 5.3 would be headed off, including the following:

- **Residential** - Residents would be spared most of the heavy personal losses they would face from flood damage if no action was taken.

- **Businesses** - Business owners likewise would be spared most of their potential flood losses in buildings, equipment and inventories. This includes physical flood damages as well as income losses from shutdowns.

- **Public sector** - Public sector repair costs would be greatly reduced at public facilities such as parks, community centers, Billard Airport, and the Oakland and North Topeka sewage treatment plants. Costly repairs to city streets and roads would be reduced. Expenditures on flood-fighting by emergency personnel, as well as relocation and reoccupation assistance, would also be reduced.

- **Water supply** - Water supply delivery to 160,000 customers in and around Topeka would be protected by reducing the chances of operational disruptions from flooding at the Waterworks plant. The city's major sewage treatment plants in North Topeka and Oakland, both of which would have been subject to frequent flood damage or operational interruptions in the without-project condition, would be subject to much less frequent damage, and their operations also would be interrupted more infrequently.

- **Transportation networks** - The risk of frequent flood-related closings and detours on heavily traveled routes would be greatly reduced along highways, city streets and railroads. Drivers would be favorably affected in avoiding lost time opportunity costs and increased vehicular operating costs. Costly flood-related physical damages to roads and railroad track also would be greatly reduced.

- **Flood control works operation and maintenance costs** *(probable minor adverse impact on income)* - The project would add net annual O&M costs of about $12,800 to the North Topeka unit.

7.5.2 RED Effects of NED Plan. Regional economic development factors associated with project implementation - mostly positive - include the following:

- **Existing local jobs, income and tax base** *(probable positive impacts on income and jobs)* - The planning horizon for existing companies in and around the study area would include a much reduced degree of flood risk. Discouraging factors in the business climate such as the potential of ruinous flood damage and income losses from shutdowns would be reduced, while the potential for flood insurance requirements and stiffer building codes would be removed. The risk of relocation from the city and region by large regional employers such as BNSF Railroad, Goodyear, Hallmark, Del Monte, Hill's and others would be sharply reduced. Population losses, likely to occur in the context of a serious and ongoing flood risk, would be far less likely. The threat of large-scale job losses from relocations as well as reductions of the city's tax base would be sharply reduced.

- **Economic growth** *(probable positive impacts on income and jobs)* - The project would greatly alleviate potential obstacles presented by high flood risk for attracting new businesses with new jobs. Certification of the Federal levees would not be called into question, meaning that the looming threats of new costs for flood insurance and stiffer construction codes could be removed from the planning horizon. This would at the very least forestall adverse impacts to local jobs and income by improving the regulatory climate for those businesses wishing to expand, build, or move into the market from the outside. Key areas targeted for future business growth in North Topeka and Oakland - among the few significant sites the city has available for significant business development - would gain a high enough degree of protection to minimize flood damage impacts and remove flood-related regulatory burdens. Commercial operations at Billard Airport would not face the prospect of frequent shutdowns and flood damage.

- **Riverfront redevelopment** *(possible positive impact on income)* - Topeka's planned redevelopment of the riverfront in the center city could proceed absent the likelihood of increasing blight from frequent flood damage. Successful redevelopment would be expected to bring tourism and recreation revenues into the city and the study area.

- **Project construction impacts** *(miscellaneous possible minor impacts, both positive and* *adverse, to jobs and income)* - (a) No businesses or homes are slated for acquisition or relocation due to the project. (b) The region would temporarily gain some jobs during construction of the project. (c) The temporary presence of construction workers may bring a temporary increase in demand for some local services, but also a temporary increase in volume, profits, and sales tax receipts at local retail and service businesses. (d) Modest transitory population increases could occur in the study area in connection with project construction. (e) Minor traffic disruption near the levees could occur during construction, although based on the best available information at this time, no roads are anticipated to be blocked or closed for extended periods. Most of the project area would be accessed from the levee road and should not interfere with the normal flow of traffic.

7.5.3 Other Social Effects of NED Plan

- **Public safety** (*probable positive impacts to human life)* - Serious public safety concerns, particularly in Oakland, South Topeka, and North Topeka, would be minimized by a large reduction in flood risk. The chance of project exceedance (i.e., a damaging flood event) over a 25-year period, which currently is greater than 1 in 2 for Oakland and North Topeka, would improve to 1 in 11 (see Table D-28). Moreover, any floods that did occur in extreme circumstances likely would be overtopping rather than breaching events, which would imply a greater warning time.

- **Effects on minority and low-income residents** *(probable positive socioeconomic impacts)* Topeka residents in lower-income areas and minority neighborhoods would be disproportionately affected by ongoing flood risk; refer to the detailed demographics in section 5.3.3 as well as section 2.2. Thus, the same groups in South Topeka, Oakland and North Topeka also would benefit disproportionately from the project.

- **Threats to center city redevelopment** *(probable positive cultural impacts)* - Local efforts to revitalize center city areas would avoid a substantial obstacle if flood risk is significantly reduced in the floodplain areas of North Topeka, Oakland and South Topeka. It bears repeating that much of the "center city" of Topeka is also floodplain terrain inside the Federal levees, and it would otherwise be subject to catastrophic flood damage in the future. Flood risk reduction would be a significant stabilizing influence for these neighborhoods.

- **Threats to riverfront redevelopment** *(possible positive cultural, historical and aesthetic impacts)* - The possibility that periodic flooding would blight the riverfront and interfere with successful redevelopment would be greatly reduced.

- **Treatment plant operations** *(positive health and environmental impacts)* - The likelihood of periodic service interruptions at the Oakland and North Topeka sewage treatment plants, resulting in large releases of untreated sewage into the Kansas River, would be greatly reduced.

7.6 RESIDUAL RISK

Although floodplain users and occupants may desire total protection from flooding, it cannot be overemphasized that this is an unachievable goal. No flood risk management project can guarantee total elimination of flooding. It has been said that a flood risk management project designed relative to a 1%-chance flood event (the event that is critical to certification criteria) is an especially dangerous project. The reasoning is that an event of historical magnitude is not necessarily required to overwhelm the project and cause catastrophic damage, yet many floodplain tenants will feel that they have near-total protection against flooding. Therefore, it is important for floodplain users and occupants to be aware of the level of flood risk that remains even after implementation of a recommended project.

The selected plan has substantial economic benefits and reduces study area equivalent annual damages in the existing condition by more than two-thirds. The probability and occurrence of flooding will be greatly diminished. But there remains a significant total of residual equivalent annual damages of $7.4 million. There still would be a 1 in 6 chance of exceedance over a 50-year period (see Table 28). The median annual exceedance probability of 0.003 indicates that there is a 0.3% chance of a damaging flood event in any given year.

If the capacity of the Federal levee system is exceeded in a particular event, most of the areas inside the levees would be affected due to the flat floodplain topography in these areas. Here is a summary of what city leaders and residents could expect in each area in terms of flood depths:

North Topeka - Average depths of at least 10 feet would prevail, and in virtually all of central North Topeka, hundreds of structures would be flooded to 15 feet or more. Depths in some areas would be up to 25 feet or more. The wastewater plant on Button Road and the Cargill plants on N.W. Gordon and N.W. Lower Silver Lake Road are significant industrial properties that would be affected by extreme depths of flooding. Depths at other key businesses include Goodyear, 9 feet; Del Monte, 8 feet; Payless, 5 feet.

Auburndale - Average depths of about 2 feet or more would affect Auburndale, with depths up to 20 feet or more in some areas. The hardest hit locations would include: MacVicar, N.W. 200-400 blocks (including the state printing plant); and Waite, N.W. 200-400 blocks (including several manufactured homes).

South Topeka - Average depths of 3 to 4 feet would flood South Topeka, and maximum depths of at least 14 feet would be found in some areas. Particularly low areas include: Crane, N.E. 400 block to N.W. 400 block, including the Hill's Pet Nutrition plant, where depths would be at least 16 feet, and the city transit garage; Jackson, N.E. 100 block to N.W. 100 block; Van Buren, N.W. 100 block to N.W. 100 block. The Hallmark plant would see depths of 7 feet or more, while the BNSF railroad shops would have at least 5 feet of water.

Oakland - Oakland would see average depths of about 4 feet as well as maximum depths of 16 feet or more. Hard hit areas would include (among others): Forest, N.E. 400-500 blocks; Seward, N.E. 3500 and 4100-4200 blocks; Michigan, N.E. 1100-1300 blocks. The Oakland sewage treatment plant would be flooded to 9 feet and Billard Airport would have about 5 feet of water.

In general, if the amount of water that gets through or over the levees is sufficient to produce severe flood depths, damages in the study area probably would reach $2 billion or more. Prohibitive depths of water would remain inside the levees for at least two weeks and probably longer. Large-scale evacuations of urban neighborhoods would be necessary in advance, followed by relocation assistance. A number of important highways and streets, as well as sections of railroad, would be closed and in some cases inundated. Water supply delivery to the entire city probably would be interrupted, perhaps for a few weeks.

Local leadership and emergency operations staff will need to design plans for these extreme flood events, which may be infrequent, but would hold the potential for catastrophe if they occurred. Effective emergency planning in advance is the best way to protect communities and minimize the damage from these rare flood events. Meanwhile, those who currently hold flood insurance policies might very well find it advantageous to keep their policies, which usually are fairly inexpensive in areas with certified levees.

8.0 PLAN FOR ECONOMIC UPDATES

ER 1105-2-100, para. D-4, requires a plan for conducting updates of the project economic justification. Economic updates, revisiting estimated damages, benefits, costs, affected population, and residual risk, will be required every three years. Updates are not intended to involve major economic analyses or extensive reworking of the feasibility study analysis. They are intended to verify the continuing validity of important assumptions on which the economic justification is founded as well as to convert data to current price levels. It is currently expected that the first economic update would be required in FY 2012.

Project economic justification updates will include the following tasks and estimated labor:

1. Data gathering -- Information supporting the floodplain inventory will be updated as follows:

(a) Windshield survey of study area -- A brief windshield survey including all major portions of the study area will be carried out to initially identify major changes in the scale or condition of residential and nonresidential properties and transportation networks. (8 hours)

(b) Discussions with local leaders and research -- Local city and Chamber of Commerce staff will be consulted to further help identify major changes of the previous three years pertaining to the economic structure inventory and particularly to major nonresidential properties. Discussions will encompass verification of continuing operations at major properties, identification of significant changes in operational scale at major businesses and facilities, and identification of significant new development including major new businesses, public facilities, residential developments, and roads and streets. Business operators may also be consulted briefly for general information on operational scale. (12 hours)

(c) Additional research -- Available information on the internet will be consulted, including totals for new construction permits. (8 hours)

2. Economic structure inventory revisions -- The economic database will be revised, based on the first task, as follows:

(a) Major existing businesses and public facilities -- For the approximately 30-40 major enterprises accounting for a disproportionately large share of damages and project benefits, structure values will be updated using Marshall and Swift square foot cost values and depreciation factors. Contents will be adjusted as appropriate based on information gathered from the first task. (12 hours)

(b) Other existing nonresidential properties -- Structure values of the remaining businesses and public facilities will be updated using BCI (Business Cost Index, Engineering News Record) factors to bring replacement costs up to current price levels. An average depreciation factor for the three-year increment based on Marshall and Swift data will then be applied to produce updated depreciated replacement structure values. Nonresidential contents in this analysis are computed as percentages of structure value and will update automatically when structure values are updated. (4 hours)

(c) Residential values -- Residential updating will be based on the sample of 301 properties used to determine depreciated replacement structure values in the feasibility analysis. Depreciated replacement structure values of the sample properties will be updated individually using Marshall and Swift cost per square foot values and appropriate individual depreciation rates. The average sample change in replacement value versus the feasibility or previous update will be applied to replacement values for the remainder of the residential database. An average depreciation factor will be applied to produce updated depreciated replacement values. (20 hours)

(d) Transportation network -- For roads, streets and railroads, updated average replacement costs per mile, as well as average depreciation factors, will be used to bring depreciated replacement values up to date for each type of road. (1 hour)

(e) New development -- For significant new additions to the property base, including large businesses and facilities, major new roads and streets, and significant new residential projects, appropriate adjustments will be made to the property inventory when properties could account for a disproportionately large share of benefits in view of their structure and content values as well as their damage susceptibility. (8 hours)

(f) Other categories of benefits -- For disaster relief costs, the average percentage change in value will be computed for the residential category and applied to the relief costs. For production losses, the average percentage change in value for the nonresidential category will be computed and applied. Emergency costs will be updated using an average encompassing both the residential and nonresidential percentage changes. Crop damages, a minor damages and benefits category in this study area, will be updated based on current USDA normalized prices. (2 hours)

3. Benefit-cost data computation

(a) HEC-FDA analysis -- The HEC-FDA program will be loaded with the updated property database and new damage and benefit estimates will be produced. (8 hours)

(b) Costs and B/C ratios -- An updated cost estimate will be prepared by engineering staff (labor not included here) and annualized. Benefit-cost ratios and net benefits will be calculated based on the updated benefits and costs. (2 hours)

4. Population -- Estimates of affected population and population at risk will be updated if

significant new block or block-level Census data are available. (4 hours)

5. Documentation -- A brief report will be prepared documenting the tasks completed and the results of the updated analysis. (8 hours)

Total labor: 97 hours.

9.0 CONCLUSION

The feasibility-level socioeconomics analysis of the Topeka Federal flood protection system has found that a strong Federal interest exists in the NED plan. The plan exhibits very strong economic justification with a benefit-cost ratio of 13.2. With net benefits of $14,259,500, the project represents a strong contribution to national economic outputs. The plan also would make important contributions to public safety and regional economic considerations.

Annual benefits	**$15,427.6**
First costs	**$21,157.0**
Annual costs	**$ 1,168.1**
Benefit-cost ratio	**13.2**
Net benefits	**$14,259.5**

FEASIBILITY STUDY REPORT
TOPEKA, KANSAS, FLOOD RISK MANAGEMENT PROJECT

APPENDIX E

COST ESTIMATING

DEPARTMENT OF THE ARMY
Kansas City District, U.S. Army Corps of Engineers
Kansas City, Missouri

APPENDIX E

Project Cost Estimate

A. General

Cost estimating for this study was completed using the Corps of Engineers Micro Computer Aided Cost Estimating Software (MCACES) Gold Edition, Release 5.31. The owner summary and indirect summary MCACES reports for each unit and alternative are included in this appendix.

Also included is the Total Project Cost Summary (TPCS), which provides a consolidated summary of the MCACES report. Costs are shown at the Oct 2007 price level, the updated Oct 2009 price level, and the Fully Funded project cost. The Fully Funded cost is determined by adding inflation from the current year to the expected mid-point of construction for each feature, which is noted in the TPCS.

B. Project Contract Schedule

Cost estimates were prepared on the basis of one construction contract per levee unit, for a total of four separate contracts. These contracts are anticipated to be scheduled simultaneously. The anticipated construction milestone schedule is presented in Section IX of the Feasibility Report.

C. Cost Risk

Uncertainties exist in any construction project that cannot be fully understood until the actual fieldwork begins. Contingencies have been included in this project cost estimate to account for potential cost changes during project design and construction.

Contingencies of 20% to 25% were applied based in each unit based on the estimated base cost of each project feature, and the possibility of unknowns. Unknowns may include unmapped or abandoned underground utilities or potentially hazardous materials in areas outside of currently mapped boundaries. Contingencies up to 30% were applied to features that have the potential for a higher degree of cost fluctuation due to specialized construction practices, such as protection of adjacent structures during excavation.

Pre-Construction Engineering and Design (PED) and Construction Management costs are estimated as a percentage of the estimated construction cost. The percentages applied are based on prior experience with projects of similar scope and were adjusted in consultation with the design team for the specific features of this project.

Project cost estimates are periodically reviewed during future project phases and reevaluated as needed based on actual project progress and status.

**** TOTAL PROJECT COST SUMMARY ****

TOTAL - ALL CONTRACTS

Revision Date: 1 Dec 2008

PROJECT: Topeka Feasibility Study
LOCATION: Topeka, Kansas

DISTRICT: Kansas City District Corps of Engineers
P.O.C.: Patrick J. Miramontez, Cost Engineering Section

	EFFECTIVE PRICING LEVEL: 1 OCT 07					EFFECT. PRICING LEVEL: 1 OCT 08			*** FULLY FUNDED ESTIMATE ***		
ACCOUNT NUMBER	FEATURE DESCRIPTION	COST ($K)	CNTG ($K)	CNTG (%)	TOTAL ($K)	COST ($K)	CNTG ($K)	TOTAL ($K)	COST ($K)	CNTG ($K)	FULL ($K)
06 - - -	FISH & WILDLIFE FACILITIES										
0603- -	WILDLIFE FACILITIES & SANCTUARIES	0	0	0%	0	0	0	0	0	0	0
11- - -	LEVEES & FLOODWALLS										
1101- -	LEVEES	4,422	1,021	23%	5,443	4,515	1,043	5,557	4,993	1,154	6,147
1102- -	FLOODWALLS	9,024	1,805	20%	10,829	9,213	1,843	11,055	10,190	2,038	12,228
13- - -	PUMPING PLANTS										
1300- -	PUMPING PLANTS	225	64	29%	289	229	66	295	254	73	327
	TOTAL CONSTRUCTION COSTS ===>	13,670	2,891	21%	16,561	13,957	2,951	16,908	15,437	3,265	18,702
01 - - -	LANDS AND DAMAGES										
0101- -	LAND VALUES	672	101	15%	773	699	105	804	740	111	851
0102- -	LABOR	87	13	15%	100	94	14	108	106	16	122
02 - - -	RELOCATIONS	304	61	20%	365	311	62	373	344	69	413
30 - - -	PLANNING, ENGINEERING & DESIGN	1,473	307	21%	1,780	1,517	316	1,833	1,657	345	2,002
31 - - -	CONSTRUCTION MANAGEMENT	906	192	21%	1,099	933	198	1,131	1,170	249	1,419
	TOTAL PROJECT COSTS ========>	17,113	3,564	21%	20,678	17,511	3,646	21,158	19,454	4,055	23,509

TOTAL FEDERAL COSTS ==========>	15,281
TOTAL NON-FEDERAL COSTS =====>	8,228
THE MAXIMUM PROJECT COST IS ==>	$23,509

* * * * TOTAL PROJECT COST SUMMARY * * * *

CONTRACT A - South Topeka Unit

Revision Date: 1 Dec 2008

PROJECT: Topeka Feasibility Study
DISTRICT: Kansas City District Corps of Engineers

LOCATION: Topeka, Kansas
P.O.C.: Patrick J. Miramontez, Cost Engineering Section

	CURRENT MCACES ESTIMATE PREPARED: DEC 08 EFFECTIVE PRICING LEVEL: 1 OCT 07					EFFECT. PRICING LEVEL: 1 OCT 08				*** FULLY FUNDED ESTIMATE ***				
ACCOUNT NUMBER	FEATURE DESCRIPTION	COST ($K)	CNTG ($K)	CNTG (%)	TOTAL ($K)	OMB (%)	COST ($K)	CNTG ($K)	TOTAL ($K)	FEATURE MID PT	OMB (%)	COST ($K)	CNTG ($K)	FULL ($K)
06 - - -	FISH & WILDLIFE FACILITIES													
0603- -	WILDLIFE FACILITIES & SANCTUARIES	0	0	0%	0	0.0%	0	0	0		0.0%	0	0	0
11- - -	LEVEES & FLOODWALLS													
1101- -	LEVEES	1,694	339	20%	2,032	2.1%	1,729	346	2,075	Oct-2013	10.6%	1,913	383	2,296
1102- -	FLOODWALLS	9,024	1,805	20%	10,829	2.1%	9,213	1,843	11,055	Oct-2013	10.6%	10,190	2,038	12,228
13- - -	PUMPING PLANTS													
1300- -	PUMPING PLANTS	6	1	20%	7	2.1%	6	1	7	Oct-2013	10.6%	7	1	8
	TOTAL CONSTRUCTION COSTS ===>	10,723	2,145	20%	12,868		10,948	2,190	13,138			12,110	2,422	14,532
01 - - -	LANDS AND DAMAGES													
0101- -	LAND VALUES	426	64	15%	490	4.0%	443	67	510	Apr-2011	6.0%	470	71	541
0102- -	LABOR	37	6	15%	43	7.8%	40	6	46	Apr-2011	13.5%	46	7	53
02 - - -	RELOCATIONS	300	60	20%	360	2.2%	307	61	368	Oct-2013	10.6%	339	68	407
30 - - -	PLANNING, ENGINEERING & DESIGN	1149	227	20%	1,376	3.0%	1,183	234	1,417	Apr-2010	9.2%	1,292	256	1,548
31 - - -	CONSTRUCTION MANAGEMENT	715	143	20%	859	3.0%	736	148	884	Oct-2013	25.3%	923	185	1,108
	TOTAL PROJECT COSTS ========>	13,351	2,645	20%	15,996		13,658	2,706	16,363			15,180	3,009	18,189

Non-Federal Cost Share (	35%) =	$ 6,366 K
Federal Cost Share (	65%) =	$ 11,823 K
Total Fully Funded Estimate	=	$ 18,189 K

**** TOTAL PROJECT COST SUMMARY ****

CONTRACT B - North Topeka Unit

Revision Date: 1 Dec 2008

PROJECT: Topeka Feasibility Study
DISTRICT: Kansas City District Corps of Engineers

LOCATION: Topeka, Kansas
P.O.C.: Patrick J. Miramontez, Cost Engineering Section

CURRENT MCACES ESTIMATE PREPARED: DEC 08
EFFECTIVE PRICING LEVEL: 1 OCT 07

ACCOUNT NUMBER	FEATURE DESCRIPTION	COST ($K)	CNTG ($K)	CNTG (%)	TOTAL ($K)	EFFECT. PRICING LEVEL: 1 OCT 08 OMB (%)	COST ($K)	CNTG ($K)	TOTAL ($K)	*** FULLY FUNDED ESTIMATE *** FEATURE MID PT	OMB (%)	COST ($K)	CNTG ($K)	FULL ($K)
06 - - -	FISH & WILDLIFE FACILITIES													
0603- -	WILDLIFE FACILITIES & SANCTUARIES	0	0	0%	0	0.0%	0	0	0		0.0%	0	0	0
11- - -	LEVEES & FLOODWALLS													
1101- -	LEVEES	1,794	449	25%	2,243	2.1%	1,832	458	2,290	Oct-2013	10.6%	2,026	507	2,533
1102- -	FLOODWALLS	0	0	0%	0	2.1%	0	0	0	Oct-2013	10.6%	0	0	0
13- - -	PUMPING PLANTS													
1300- -	PUMPING PLANTS	46	11	25%	57	2.1%	47	12	59	Oct-2013	10.6%	52	13	65
	TOTAL CONSTRUCTION COSTS ===>	1,840	460	25%	2,300		1,879	470	2,348			2,078	520	2,598
01 - - -	LANDS AND DAMAGES													
0101- -	LAND VALUES	68.47	10.27	15%	79	4.0%	71	11	82	Apr-2011	6.0%	75	11	86
0102- -	LABOR	27.94	4.191	15%	32	7.8%	30	5	35	Apr-2011	13.5%	34	5	39
02 - - -	RELOCATIONS	0	0	0%	0	2.2%	0	0	0	Oct-2013	10.6%	0	0	0
30 - - -	PLANNING, ENGINEERING & DESIGN	194	47	25%	241	3.0%	199	49	248	Apr-2010	9.2%	218	53	271
31 - - -	CONSTRUCTION MANAGEMENT	119	30	25%	149	3.0%	123	31	154	Oct-2013	25.3%	154	39	193
	TOTAL PROJECT COSTS ========>	2,250	552	25%	2,802		2,302	565	2,867			2,559	628	3,187

Non-Federal Cost Share	(35%)	=	$ 1,115 K
Federal Cost Share	(65%)	=	$ 2,072 K
Total Fully Funded Estimate		=	$ 3,187 K

*** * * * TOTAL PROJECT COST SUMMARY * * * ***

CONTRACT C - Oakland Unit — PAGE 4 OF 5

Revision Date: 1 Dec 2008

PROJECT: Topeka Feasibility Study — DISTRICT: Kansas City District Corps of Engineers

LOCATION: Topeka, Kansas — P.O.C.: Patrick J. Miramontez, Cost Engineering Section

ACCOUNT NUMBER	FEATURE DESCRIPTION	CURRENT MCACES ESTIMATE PREPARED: DEC 08; EFFECTIVE PRICING LEVEL: 1 OCT 07 COST ($K)	CNTG ($K)	CNTG (%)	TOTAL ($K)	EFFECT. PRICING LEVEL: 1 OCT 08 OMB (%)	COST ($K)	CNTG ($K)	TOTAL ($K)	*** FULLY FUNDED ESTIMATE *** FEATURE MID PT	OMB (%)	COST ($K)	CNTG ($K)	FULL ($K)
06 - - -	FISH & WILDLIFE FACILITIES													
0603- -	WILDLIFE FACILITIES & SANCTUARIES	0	0	0%	0	0.0%	0	0	0		0.0%	0	0	0
11- - -	LEVEES & FLOODWALLS													
1101- -	LEVEES	905	227	25%	1,132	2.1%	924	232	1,156	Oct-2013	10.6%	1,022	256	1,278
1102- -	FLOODWALLS	0	0	0%	0	2.1%	0	0	0	Oct-2013	10.6%	0	0	0
13- - -	PUMPING PLANTS													
1300- -	PUMPING PLANTS	173	52	30%	225	2.1%	176	53	229	Oct-2013	10.6%	195	59	254
	TOTAL CONSTRUCTION COSTS ===>	1,078	279	26%	1,357		1,101	285	1,385			1,217	315	1,532
01 - - -	LANDS AND DAMAGES													
0101- -	LAND VALUES	177.08	26.56	15%	204	4.0%	184	28	212	Apr-2011	6.0%	195	29	224
0102- -	LABOR	20.56	3.084	15%	24	7.8%	22	3	25	Apr-2011	13.5%	25	4	29
02 - - -	RELOCATIONS	0	0	0%	0	2.2%	0	0	0	Oct-2013	10.6%	0	0	0
30 - - -	PLANNING, ENGINEERING & DESIGN	128	30.84	24%	158	3.0%	131	32	163	Apr-2010	9.2%	143	35	178
31 - - -	CONSTRUCTION MANAGEMENT	70	18	26%	88	3.0%	72	19	91	Oct-2013	25.3%	90	24	114
	TOTAL PROJECT COSTS ========>	1,473	358	24%	1,831		1,510	366	1,876			1,670	407	2,077

Non-Federal Cost Share	(35%)	=	$ 727 K
Federal Cost Share	(65%)	=	$ 1,350 K
Total Fully Funded Estimate		=	$ 2,077 K

**** TOTAL PROJECT COST SUMMARY ****

CONTRACT D - Waterworks

Revision Date: 1 Dec 2008

PROJECT: Topeka Feasibility Study | DISTRICT: Kansas City District Corps of Engineers

LOCATION: Topeka, Kansas | P.O.C.: Patrick J. Miramontez, Cost Engineering Section

CURRENT MCACES ESTIMATE PREPARED: DEC 08

EFFECTIVE PRICING LEVEL: 1 OCT 07

ACCOUNT NUMBER	FEATURE DESCRIPTION	COST ($K)	CNTG ($K)	CNTG (%)	TOTAL ($K)	EFFECT. PRICING LEVEL: 1 OCT 08 OMB (%)	COST ($K)	CNTG ($K)	TOTAL ($K)	*** FULLY FUNDED ESTIMATE *** FEATURE MID PT	OMB (%)	COST ($K)	CNTG ($K)	FULL ($K)
06 - - -	FISH & WILDLIFE FACILITIES													
0603- -	WILDLIFE FACILITIES & SANCTUARIES	0	0	0%	0	0.0%	0	0	0		0.0%	0	0	0
11- - -	LEVEES & FLOODWALLS													
1101- -	LEVEES	29	7	25%	36	2.1%	29	7	37	Oct-2013	10.6%	32	8	40
1102- -	FLOODWALLS	0	0	0%	0	2.1%	0	0	0	Oct-2013	10.6%	0	0	0
13- - -	PUMPING PLANTS													
1300- -	PUMPING PLANTS	0	0	0%	0	2.1%	0	0	0	Oct-2013	10.6%	0	0	0
	TOTAL CONSTRUCTION COSTS ===>	29	7	25%	36		29	7	37			32	8	40
01 - - -	LANDS AND DAMAGES													
0101- -	LAND VALUES	0.404	0.061	15%	0	4.0%	0	0	0	Apr-2011	6.0%	0	0	0
0102- -	LABOR	0.88	0.132	15%	1	7.8%	1	0	1	Apr-2011	13.5%	1	0	1
02 - - -	RELOCATIONS	4.352	1.088	25%	5	2.2%	4	1	6	Oct-2013	10.6%	5	1	6
30 - - -	PLANNING, ENGINEERING & DESIGN	3	0.83	25%	4	3.0%	3	1	4	Apr-2010	9.2%	4	1	5
31 - - -	CONSTRUCTION MANAGEMENT	2	0.54	25%	3	3.0%	2	1	3	Oct-2013	25.3%	3	1	4
	TOTAL PROJECT COSTS ========>	40	10	25%	50		41	10	51			45	11	56

Non-Federal Cost Share	(35%)	=	$	20 K
Federal Cost Share	(65%)	=	$	36 K
Total Fully Funded Estimate		=	$	56 K

Feasibility Study Estimate for:
North Topeka Unit
Topeka, Kansas

dated 1 Dec 2008

Designed By: CENWK
Estimated By: CENWK-EC-DC

Prepared By: Patrick Miramontez 816-389-3322
LATEST ESTIMATE AS OF 1 Dec 08

Preparation Date: 12/01/08
Effective Date of Pricing: 10/01/07

Sales Tax: 0.00%

01- Lands & Damages - The costs include the acquisition of Permanent Right-of-Way. These costs include Non Federal Sponsors cost to perform the Legal work, Title Work, Tract appraisals, and land surveys.

02 - Relocations - N/A

06 - Fish & Wildlife Facilities - N/A

11 - Levees & Floodwalls-
Relief Wells - A cost for six relief well with a collector system was added to the estimate. These relief wells are to be located between stations 246+00 to 250+00 at 75' spacing.

Underseepage berms - It is assumed the material for the underseepage berms will come from a borrow source approximately 4.5 miles away. The area will be stripped before the placement of the underseepage berm and the topsoil material will be reused to facilitate seeding. The borrow will also be stripped, graded and backfilled with topsoil.

13 - Pump Plants - A cost was added for the abandonment of the North Topeka Pump Plant. This includes the removal of equipment and the placement of flowable fill.

30 - Estimated Engineering & Design Cost = 15% of project implementation (less lands & damages) cost. This percentage is based on historical data and adjusted due to size of project.

31 - Estimated Construction Supervision & Administration - 6.5% of project implementation (less Lands & damages) cost. This percentage is based on historical data.

Areas of Cost Sensitivity

- Estimate does not include any costs for sampling/testing for HTRW.
- Estimate does not include any costs for the hauling and disposal of HTRW.
- Estimate does not include O&M costs. Only project implementation (construction, real-estate and associated) costs.

General Cost Information

- The quantities have been calculated by EC-GD, EC-DC, and EC-PS. A contingency determination meeting will be held with all of the designers to apply the appropriate amount of contingency to each line item.
- No tax has been included for the state of Kansas.
- The source for the labor rates used in the estimate is the Jan 2008 Department of Labor Wage rates for Wyandotte County, Kansas.
- The national 2001 Unit Price Book is used to price minor items. Material prices for minor items were taken from the 2008 RS Means Cost books. Quotes were received for major cost items in 2006 and escalated to Oct 2007.
- 2007 equipment rates were used.
- Once all of the databases are normalized to the appropriate price level

date an escalation factor will be added to the owner level to bring the estimate to the appropriate price level date. The escalation factors used were derived from the Civil Works Construction Cost Index System (CWCCIS) EM1110-2-1304. NOTE: Estimate was originally prepared in March 2006.
The databases and material rates were updated to October 2007 price levels.
Price Level Date is now Oct 2007.

CONTINGENCY DETERMINATION REPORT - The reasons for final contingency development and assignment must be included in the cost estimate as part of the project narrative. When then contingency factors shown in Table 13-1 of ER 0100010 are applied to any portion of the cost estimate up to the feature level, the statement "Normal design variances are expected - Normal contingency values used" is acceptable in addressing that specific portion. For this estimate, 25% contingency is considered normal.
*****NOTE*****
Bid item numbers correspond to the summary sheet Bid Item Level WBS identifier. For example:

09.01.30.02.3 Excavation, Common

The "3" at the end of the number string corresponds to Bid Item No. 3 on this Contingency Determination Report.
*****END NOTE*****

01 Account - LANDS AND DAMAGES
-LAND VALUES
Bid Item Nos. 01 thru 05-Typical 15% contingency factor used for Real Estate.

NON-FEDERAL SPONSORS COSTS -
Bid Item Nos. 06&07 - Typical 15% contingency factor used for Real estate

FEDERAL COSTS -
NOT USED

02 ACCOUNT - RELOCATIONS - NOT USED

06 ACCOUNT - FISH & WILDLIFE FACILITIES - NOT USED

11 ACCOUNT - LEVEES AND FLOODWALLS
RELIEF WELLS
Bid Item No. 08 - 25% - Typical Contingency factor used.

BORROW SITE
Bid Items No. 09 & 10 - 25% - Typical Contingency factor used.

LEVEE STRIPPING
Bid Item No. 11 thru 12 - Typical 25% contingency factor used.

UNDERSEEPAGE BERM
Bid Item No. 13 thru 16 - Typical 25% contingency factor used.

SEEDING & MULCHING
Bid Item No. 17 - Typical 25% contingency factor used.

DRAINAGE SYSTEM MODIFICATIONS
Bid Item No. 18 thru 24 - Typical 25% contingency factor was used.

13 - PUMP PLANT

Abandon Pump Plant
Bid Item Nos. 25 thru 27 - Typical 25% contingency factor was used.

Mon 01 Dec 2008 — Tri-Service Automated Cost neering System (TRACES) — IME 14:38:04
Eff. Date 10/0_ — PROJECT N10PK7: Feasibility Stu_ stimate for: - North Topeka Unit

SUMMARY PAGE 1

** PROJECT OWNER SUMMARY - Feature **

	QUANTITY	UOM	CONTRACT	CONTING	ESCALATN	E&D	S&A	TOTAL COST	UNIT COST	NOTES
01 Lands and Damages	1.00	EA	96,410	14,461	0	11,087	0	121,959	121958.62	
11 Levees and Floodwalls	1.00	EA	1,794,346	448,586	0	224,293	145,566	2,612,791	2612791	
13 Pump Plant	1.00	EA	45,870	11,468	0	5,734	3,721	66,793	66793.05	
TOTAL Feasibility Study Estimate for:	1.00	EA	1,936,626	474,515	0	241,114	149,288	2,801,543	2801543	

LABOR ID: TPKA07 EQUIP ID: TPKA07 — Currency in DOLLARS — CREW ID: NAT01A UPB ID: UP01EA

** PROJECT OWNER SUMMARY - Assembly **

	QUANTITY UOM	CONTRACT	CONTING	ESCALATN	E&D	S&A	TOTAL COST	UNIT COST	NOTES
01 Lands and Damages									
01.23 Land Values									
01.23.01 Land Values									
01.23.01.01 Land Values									
01.23.01.01.01 Tract 1	3.15 ACR	21,499	3,225	0	2,472	0	27,196	8633.62	
01.23.01.01.02 Tract 2	1.18 ACR	8,026	1,204	0	923	0	10,152	8637.46	
01.23.01.01.03 Tract 3	1.51 ACR	10,310	1,547	0	1,186	0	13,043	8637.46	
01.23.01.01.04 Tract 4	1.06 ACR	7,210	1,082	0	829	0	9,121	8637.46	
01.23.01.01.05 Tract 5	15.00 ACR	10,500	1,575	0	1,208	0	13,283	885.50	
01.23.01.01.06 Tract 6	1.60 ACR	10,925	1,639	0	1,256	0	13,820	8637.46	
TOTAL Land Values	1.00 EA	68,470	10,270	0	7,874	0	86,615	86614.52	
01.23.01.02 Non Federal Sponsors Costs									
01.23.01.02.06 NFS Costs for Mitigation Area	1.00 EA	6,680	1,002	0	768	0	8,450	8450.20	
01.23.01.02.07 NFS Costs	1.00 EA	14,580	2,187	0	1,677	0	18,444	18443.70	
01.23.01.02.08 NFS Costs for Relief Well Sta	1.00 EA	6,680	1,002	0	768	0	8,450	8450.20	
TOTAL Non Federal Sponsors Costs	1.00 EA	27,940	4,191	0	3,213	0	35,344	35344.10	
01.23.01.03 Federal Costs (Included in PED)									
TOTAL Land Values	1.00 EA	96,410	14,461	0	11,087	0	121,959	121958.62	
TOTAL Land Values	1.00 EA	96,410	14,461	0	11,087	0	121,959	121958.62	
TOTAL Lands and Damages	1.00 EA	96,410	14,461	0	11,087	0	121,959	121958.62	
06 Fish & Wildlife Facilities									
11 Levees and Floodwalls									
11.01 Levees									
11.01.01 Relief Wells									
11.01.01.03 Sta 246+00 to 250+00									
11.01.01.03.08 Relief Wells Sta246+00 to 250+00									
11.01.01.03.08.01 RW Sta 246+00 to 250+00	6.00 EA	204,890	51,222	0	25,611	16,622	298,345	49724.17	

Mon 01 Dec 200
Eff. Date 10/

Tri-Service Automated Cos ineering System (TRACES)
PROJECT NTOPK2: Feasibility Stu Estimate for: - North Topeka Unit

TIME 14:38:04
SUMMARY PAGE 3

** PROJECT OWNER SUMMARY - Assembly **

	QUANTITY	UOM	CONTRACT	CONTING	ESCALATN	E&D	S&A	TOTAL COST	UNIT COST	NOTES
TOTAL Relief Wells Sta246+00 to 250+00	6.00	EA	204,890	51,222	0	25,611	16,622	298,345	49724.17	
TOTAL Sta 246+00 to 250+00	6.00	EA	204,890	51,222	0	25,611	16,622	298,345	49724.17	
TOTAL Relief Wells	6.00	EA	204,890	51,222	0	25,611	16,622	298,345	49724.17	
11.01.02 Borrow Site										
11.01.02.05 Site Prep Borrow Site										
11.01.02.05.09 Site Prep New Borrow Site	34608.00	CY	59,257	14,814	0	7,407	4,807	86,286	2.49	
TOTAL Site Prep Borrow Site	1.00	EA	59,257	14,814	0	7,407	4,807	86,286	86286.03	
11.01.02.10 Final Grade Borrow Site										
11.01.02.10.10 Final Grade Borrow Site	29630.00	CY	56,141	14,035	0	7,018	4,554	81,749	2.76	
TOTAL Final Grade Borrow Site	1.00	EA	56,141	14,035	0	7,018	4,554	81,749	81748.98	
TOTAL Borrow Site	1.00	EA	115,399	28,850	0	14,425	9,362	168,025	168035.02	
11.01.03 Levee Stripping										
11.01.03.07 Sta 165+00 to 189+00										
11.01.03.07.11 Doze Material to Levee										
11.01.03.07.11.01 Doze Material to Levee	10222.00	BCY	11,049	2,762	0	1,381	896	16,089	1.57	
TOTAL Doze Material to Levee	10222.00	BCY	11,049	2,762	0	1,381	896	16,089	1.57	
11.01.03.07.12 Replace Material when Complete	10222.00	BCY	11,828	2,957	0	1,479	960	17,223	1.68	
TOTAL Sta 165+00 to 189+00	10222.00	BCY	22,878	5,719	0	2,860	1,856	33,313	3.26	
TOTAL Levee Stripping	10222.00	BCY	22,878	5,719	0	2,860	1,856	33,313	3.26	
11.01.06 Underseepage Berm (New)										
11.01.06.16 Sta 165+00 to 189+00										
11.01.06.16.13 Excavate Material from Borrow										
11.01.06.16.13.01 Excavate & Haul	122250.00	BCY	941,588	235,397	0	117,699	76,386	1,371,070	11.22	
TOTAL Excavate Material from Borrow	122250.00	BCY	941,588	235,397	0	117,699	76,386	1,371,070	11.22	

LABOR ID: TPKA07 EQUIP ID: TPKA07 Currency in DOLLARS CREW ID: NAT01A UPB ID: UP01EA

	QUANTITY	UOM	CONTRACT	CONTING	ESCALATN	E&D	S&A	TOTAL COST	UNIT COST	NOTES
11.01.06.16.14 Place Mat'l	122250.00	BCY	186,933	46,733	0	23,367	15,165	272,198	2.23	
11.01.06.16.15 Street Repair										
11.01.06.16.15.01 Street Repair	122250.00	BCY	75,344	18,836	0	9,418	6,112	109,710	0.90	
TOTAL Street Repair	122250.00	BCY	75,344	18,836	0	9,418	6,112	109,710	0.90	
11.01.06.16.16 Street Sweeping										
11.01.06.16.16.01 Street Sweeping	122250.00	BCY	48,517	12,129	0	6,065	3,936	70,646	0.58	
TOTAL Street Sweeping	122250.00	BCY	48,517	12,129	0	6,065	3,936	70,646	0.58	
TOTAL Sta 165+00 to 189+00	122250.00	BCY	1,252,382	313,095	0	156,548	101,599	1,823,624	14.92	
TOTAL Underseepage Berm (New)	97800.00	CCY	1,252,382	313,095	0	156,548	101,599	1,823,624	18.65	
11.01.07 Seeding & Mulching										
11.01.07.01 Seeding & Mulching										
11.01.07.01.17 Seeding & Mulching										
11.01.07.01.17.01 Seeding & Mulching	13.00	ACR	25,038	6,259	0	3,130	2,031	36,458	2804.44	
TOTAL Seeding & Mulching	13.00	ACR	25,038	6,259	0	3,130	2,031	36,458	2804.44	
TOTAL Seeding & Mulching	13.00	ACR	25,038	6,259	0	3,130	2,031	36,458	2804.44	
TOTAL Seeding & Mulching	13.00	ACR	25,038	6,259	0	3,130	2,031	36,458	2804.44	
11.01.09 Drainage Systems										
11.01.09.40 Collector System for Relief Well										
11.01.09.40.18 Clearing & Grubbing										
11.01.09.40.18.01 Clearing & Grubbing	148.00	CY	316	79	0	39	26	460	3.11	
TOTAL Clearing & Grubbing	148.00	CY	316	79	0	39	26	460	3.11	
11.01.09.40.19 Excavation										
11.01.09.40.19.01 Excavation	1156.00	CY	3,762	940	0	470	305	5,478	4.74	
TOTAL Excavation	1156.00	CY	3,762	940	0	470	305	5,478	4.74	

** PROJECT OWNER SUMMARY - Assembly **

	QUANTITY	UOM	CONTRACT	CONTING	ESCALATN	E&D	S&A	TOTAL COST	UNIT COST	NOTES
11.01.09.40.20 Clay Backfill										
11.01.09.40.20.01 Clay Backfill	1229.00	CY	9,188	2,297	0	1,149	745	13,379	10.89	
TOTAL Clay Backfill	1229.00	CY	9,188	2,297	0	1,149	745	13,379	10.89	
11.01.09.40.21 12" RCP Class 3										
11.01.09.40.21.01 Purchase Pipe	400.00	LF	6,882	1,721	0	860	558	10,021	25.05	
11.01.09.40.21.02 Unload Pipe	400.00	LF	188	47	0	23	15	274	0.68	
11.01.09.40.21.03 Place Pipe	400.00	LF	5,264	1,316	0	658	427	7,665	19.16	
TOTAL 12" RCP Class 3	400.00	LF	12,334	3,083	0	1,542	1,001	17,959	44.90	
11.01.09.40.22 Manholes for Pumping										
11.01.09.40.22.01 Excavation for Manholes	1536.00	CY	11,417	2,854	0	1,427	926	16,625	10.82	
11.01.09.40.22.05 Base Slab	6.00	EA	15,428	3,857	0	1,929	1,252	22,465	3744.24	
11.01.09.40.22.07 1st Lift	6.00	EA	49,103	12,276	0	6,138	3,983	71,500	11916.59	
11.01.09.40.22.09 Elevated Slab	6.00	EA	18,070	4,518	0	2,259	1,466	26,313	4385.47	
11.01.09.40.22.10 Metals	6.00	EA	10,521	2,630	0	1,315	854	15,320	2553.30	
11.01.09.40.22.12 Backfilling	1731.60	BCY	15,436	3,859	0	1,930	1,252	22,477	12.98	
TOTAL Manholes for Pumping	6.00	EA	119,976	29,994	0	14,997	9,733	174,700	29116.70	
11.01.09.40.23 Ramps										
11.01.09.40.23.11 Borrow Mat'l - Exc,Load, haul/pl	2400.00	BCY	15,256	3,814	0	1,907	1,238	22,215	9.26	
11.01.09.40.23.12 Aggregate Surfacing	300.00	TON	9,630	2,407	0	1,204	781	14,022	46.74	
11.01.09.40.23.13 Street Repair	2400.00	BCY	1,479	370	0	185	120	2,154	0.90	
11.01.09.40.23.14 Street Sweeping	2400.00	BCY	535	134	0	67	43	780	0.32	
11.01.09.40.23.15 Surveying	2400.00	BCY	321	80	0	40	26	467	0.19	
TOTAL Ramps	2.00	EA	27,222	6,805	0	3,403	2,208	39,638	19818.99	
11.01.09.40.24 Seeding & Mulching										
11.01.09.40.24.01 Seeding & Mulching	0.50	ACR	963	241	0	120	78	1,402	2804.44	
TOTAL Seeding & Mulching	0.50	ACR	963	241	0	120	78	1,402	2804.44	
TOTAL Collector System for Relief Well	400.00	LF	173,760	43,440	0	21,720	14,096	253,016	632.54	
TOTAL Drainage Systems	1.00	EA	173,760	43,440	0	21,720	14,096	253,016	253016.50	
TOTAL Levees	1.00	EA	1,794,346	448,586	0	224,293	145,566	2,612,791	2612791	

** PROJECT OWNER SUMMARY - Assembly **

	QUANTITY	UOM	CONTRACT	CONTING	ESCALATN	E&D	S&A	TOTAL COST	UNIT COST	NOTES
TOTAL Levees and Floodwalls	1.00	EA	1,794,346	448,586	0	224,293	145,566	2,612,791	2612791	
13 Pump Plant										
13.01 Pump Plant										
13.01.01 Abandon Pump Plant										
13.01.01.01 Remove Equipment from Plant										
13.01.01.01.25 Remove Equipment from Plant	1.00	EA	22,733	5,683	0	2,842	1,844	33,102	33102.36	
TOTAL Remove Equipment from Plant	1.00	EA	22,733	5,683	0	2,842	1,844	33,102	33102.36	
13.01.01.02 Flowable Fill for Pump Plant										
13.01.01.02.26 Flowable Fill for Pump Plant	182.00	CY	19,863	4,966	0	2,483	1,611	28,923	158.92	
TOTAL Flowable Fill for Pump Plant	182.00	CY	19,863	4,966	0	2,483	1,611	28,923	158.92	
13.01.01.03 Flowable Fill for Pipe										
13.01.01.03.27 Flowable Fill for Pipe	30.00	CY	3,274	819	0	409	266	4,768	158.92	
TOTAL Flowable Fill for Pipe	30.00	CY	3,274	819	0	409	266	4,768	158.92	
TOTAL Abandon Pump Plant	1.00	EA	45,870	11,468	0	5,734	3,721	66,793	66793.05	
13.01.02 Mod Pump Plant-North Topeka Unit										
TOTAL Pump Plant	1.00	EA	45,870	11,468	0	5,734	3,721	66,793	66793.05	
TOTAL Pump Plant	1.00	EA	45,870	11,468	0	5,734	3,721	66,793	66793.05	
TOTAL Feasibility Study Estimate for:	1.00	EA	1,936,626	474,515	0	241,114	149,288	2,801,543	2801543	

Mon 01 Dec 2008 — Tri-Service Automated Cost [illegible]neering System (TRACES) — TIME 14:38:04
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** PROJECT INDIRECT SUMMARY - Feature **

	QUANTITY	UOM	DIRECT	OVERHEAD	% OVRHD	PROFIT	BOND	TOTAL COST	UNIT COST
01 Lands and Damages	1.00	EA	96,410	0	0	0	0	96,410	96409.97
11 Levees and Floodwalls	1.00	EA	1,397,493	0	209,624	160,712	26,517	1,794,346	1794346
13 Pump Plant	1.00	EA	35,725	0	5,359	4,108	678	45,870	45870.41
TOTAL Feasibility Study Estimate for:	1.00	EA	1,529,628	0	214,983	164,820	27,195	1,936,626	1936626
Contingency								474,515	
SUBTOTAL								2,411,141	
Engineering & Design								241,114	
SUBTOTAL								2,652,256	
Supervision & Administration								149,288	
TOTAL INCL OWNER COSTS								2,801,543	

LABOR ID: TPKA07 EQUIP ID: TPKA07 — Currency in DOLLARS — CREW ID: NAT01A UPB ID: UP01EA

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** PROJECT INDIRECT SUMMARY - Assembly **

	QUANTITY	UOM	DIRECT	OVERHEAD	% OVRHD	PROFIT	BOND	TOTAL COST	UNIT COST
01 Lands and Damages									
01.23 Land Values									
01.23.01 Land Values									
01.23.01.01 Land Values									
01.23.01.01.01 Tract 1	3.15	ACR	21,499	0	0	0	0	21,499	6825.00
01.23.01.01.02 Tract 2	1.18	ACR	8,026	0	0	0	0	8,026	6828.03
01.23.01.01.03 Tract 3	1.51	ACR	10,310	0	0	0	0	10,310	6828.03
01.23.01.01.04 Tract 4	1.06	ACR	7,210	0	0	0	0	7,210	6828.03
01.23.01.01.05 Tract 5	15.00	ACR	10,500	0	0	0	0	10,500	700.00
01.23.01.01.06 Tract 6	1.60	ACR	10,925	0	0	0	0	10,925	6828.03
TOTAL Land Values	1.00	EA	68,470	0	0	0	0	68,470	68469.97
01.23.01.02 Non Federal Sponsors Costs									
01.23.01.02.06 NFS Costs for Mitigation Area	1.00	EA	6,680	0	0	0	0	6,680	6680.00
01.23.01.02.07 NFS Costs	1.00	EA	14,580	0	0	0	0	14,580	14580.00
01.23.01.02.08 NFS Costs for Relief Well Sta	1.00	EA	6,680	0	0	0	0	6,680	6680.00
TOTAL Non Federal Sponsors Costs	1.00	EA	27,940	0	0	0	0	27,940	27940.00
01.23.01.03 Federal Costs (Included in PED)									
TOTAL Land Values	1.00	EA	96,410	0	0	0	0	96,410	96409.97
TOTAL Land Values	1.00	EA	96,410	0	0	0	0	96,410	96409.97
TOTAL Lands and Damages	1.00	EA	96,410	0	0	0	0	96,410	96409.97
06 Fish & Wildlife Facilities									
11 Levees and Floodwalls									
11.01 Levees									
11.01.01 Relief Wells									
11.01.01.03 Sta 246+00 to 250+00									
11.01.01.03.08 Relief Wells Sta246+00 to 250+00									
11.01.01.03.08.01 RW Sta 246+00 to 250+00	6.00	EA	159,575	0	23,936	18,351	3,028	204,890	34148.28

** PROJECT INDIRECT SUMMARY - Assembly **

	QUANTITY	UOM	DIRECT	OVERHEAD	OVRHD	PROFIT	BOND	TOTAL COST	UNIT COST
TOTAL Relief Wells Sta246-00 to 250+00	6.00	EA	159,575	0	23,936	18,351	3,028	204,890	34148.28
TOTAL Sta 246+00 to 250-00	6.00	EA	159,575	0	23,936	18,351	3,028	204,890	34148.28
TOTAL Relief Wells	6.00	EA	159,575	0	23,936	18,351	3,028	204,890	34148.28
11.01.02 Borrow Site									
11.01.02.05 Site Prep Borrow Site									
11.01.02.05.09 Site Prep New Borrow Site	34608.00	CY	46,151	0	6,923	5,307	876	59,257	1.71
TOTAL Site Prep Borrow Site	1.00	EA	46,151	0	6,923	5,307	876	59,257	59257.30
11.01.02.10 Final Grade Borrow Site									
11.01.02.10.10 Final Grade Borrow Site	29630.00	CY	43,725	0	6,559	5,028	830	56,141	1.89
TOTAL Final Grade Borrow Site	1.00	EA	43,725	0	6,559	5,028	830	56,141	56141.46
TOTAL Borrow Site	1.00	EA	89,876	0	13,481	10,336	1,705	115,399	115398.76
11.01.03 Levee Stripping									
11.01.03.07 Sta 165+00 to 189+00									
11.01.03.07.11 Doze Material to Levee									
11.01.03.07.11.01 Doze Material to Levee	10222.00	BCY	8,606	0	1,291	990	163	11,049	1.08
TOTAL Doze Material to Levee	10222.00	BCY	8,606	0	1,291	990	163	11,049	1.08
11.01.03.07.12 Replace Material when Complete	10222.00	BCY	9,212	0	1,382	1,059	175	11,828	1.16
TOTAL Sta 165+00 to 189-00	10222.00	BCY	17,818	0	2,673	2,049	338	22,878	2.24
TOTAL Levee Stripping	10222.00	BCY	17,818	0	2,673	2,049	338	22,878	2.24
11.01.06 Underseepage Berm (New)									
11.01.06.16 Sta 165-00 to 189-00									
11.01.06.16.13 Excavate Material from Borrow									
11.01.06.16.13.01 Excavate & Haul	122250.00	BCY	733,338	0	110,001	84,334	13,915	941,588	7.70
TOTAL Excavate Material from Borrow	122250.00	BCY	733,338	0	110,001	84,334	13,915	941,588	7.70

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** PROJECT INDIRECT SUMMARY - Assembly **

	QUANTITY	UOM	DIRECT	OVERHEAD	% OVRHD	PROFIT	BOND	TOTAL COST	UNIT COST
11.01.06.16.14 Place Mat'l	122250.00	BCY	145,589	0	21,838	16,743	2,763	186,933	1.53
11.01.06.16.15 Street Repair									
11.01.06.16.15.01 Street Repair	122250.00	BCY	58,680	0	8,802	6,748	1,113	75,344	0.62
TOTAL Street Repair	122250.00	BCY	58,680	0	8,802	6,748	1,113	75,344	0.62
11.01.06.16.16 Street Sweeping									
11.01.06.16.16.01 Street Sweeping	122250.00	BCY	37,786	0	5,668	4,345	717	48,517	0.40
TOTAL Street Sweeping	122250.00	BCY	37,786	0	5,668	4,345	717	48,517	0.40
TOTAL Sta 165+00 to 189-00	122250.00	BCY	975,394	0	146,309	112,170	18,508	1,252,382	10.24
TOTAL Underseepage Berm (New)	97800.00	CCY	975,394	0	146,309	112,170	18,508	1,252,382	12.81
11.01.07 Seeding & Mulching									
11.01.07.01 Seeding & Mulching									
11.01.07.01.17 Seeding & Mulching									
11.01.07.01.17.01 Seeding & Mulching	13.00	ACR	19,500	0	2,925	2,243	370	25,038	1925.96
TOTAL Seeding & Mulching	13.00	ACR	19,500	0	2,925	2,243	370	25,038	1925.96
TOTAL Seeding & Mulching	13.00	ACR	19,500	0	2,925	2,243	370	25,038	1925.96
TOTAL Seeding & Mulching	13.00	ACR	19,500	0	2,925	2,243	370	25,038	1925.96
11.01.09 Drainage Systems									
11.01.09.40 Collector System for Relief Well									
11.01.09.40.18 Clearing & Grubbing									
11.01.09.40.18.01 Clearing & Grubbing	148.00	CY	246	0	37	28	5	316	2.13
TOTAL Clearing & Grubbing	148.00	CY	246	0	37	28	5	316	2.13
11.01.09.40.19 Excavation									
11.01.09.40.19.01 Excavation	1156.00	CY	2,930	0	439	337	56	3,762	3.25
TOTAL Excavation	1156.00	CY	2,930	0	439	337	56	3,762	3.25

** PROJECT INDIRECT SUMMARY - Assembly **

	QUANTITY UOM	DIRECT	OVERHEAD	% OVRHD	PROFIT	BOND	TOTAL COST	UNIT COST
11.01.09.40.20 Clay Backfill								
11.01.09.40.20.01 Clay Backfill	1229.00 CY	7,156	0	1,073	823	136	9,188	7.48
TOTAL Clay Backfill	1229.00 CY	7,156	0	1,073	823	136	9,188	7.48
11.01.09.40.21 12" RCP Class 3								
11.01.09.40.21.01 Purchase Pipe	400.00 LF	5,360	0	804	616	102	6,882	17.21
11.01.09.40.21.02 Unload Pipe	400.00 LF	146	0	22	17	3	188	0.47
11.01.09.40.21.03 Place Pipe	400.00 LF	4,100	0	615	471	78	5,264	13.16
TOTAL 12" RCP Class 3	400.00 LF	9,606	0	1,441	1,105	182	12,334	30.83
11.01.09.40.22 Manholes for Pumping								
11.01.09.40.22.01 Excavation for Manholes	1536.00 CY	8,892	0	1,334	1,023	169	11,417	7.43
11.01.09.40.22.05 Base Slab	6.00 EA	12,016	0	1,802	1,382	228	15,428	2571.37
11.01.09.40.22.07 1st Lift	6.00 EA	38,243	0	5,736	4,398	726	49,103	8183.77
11.01.09.40.22.09 Elevated Slab	6.00 EA	14,074	0	2,111	1,613	267	18,070	3011.74
11.01.09.40.22.10 Metals	6.00 EA	8,194	0	1,229	942	155	10,521	1753.49
11.01.09.40.22.12 Backfilling	1731.60 BCY	12,022	0	1,803	1,383	228	15,436	8.91
TOTAL Manholes for Pumping	6.00 EA	93,441	0	14,016	10,746	1,773	119,976	19996.01
11.01.09.40.23 Ramps								
11.01.09.40.23.11 Borrow Mat'l - Exc,load, haul/pl	2400.00 BCY	11,882	0	1,782	1,366	225	15,256	6.36
11.01.09.40.23.12 Aggregate Surfacing	300.00 TON	7,500	0	1,125	862	142	9,630	32.10
11.01.09.40.23.13 Street Repair	2400.00 BCY	1,152	0	173	132	22	1,479	0.62
11.01.09.40.23.14 Street Sweeping	2400.00 BCY	417	0	63	48	8	535	0.22
11.01.09.40.23.15 Surveying	2400.00 BCY	250	0	38	29	5	321	0.13
TOTAL Ramps	2.00 EA	21,201	0	3,180	2,438	402	27,222	13610.78
11.01.09.40.24 Seeding & Mulching								
11.01.09.40.24.01 Seeding & Mulching	0.50 ACR	750	0	113	86	14	963	1925.96
TOTAL Seeding & Mulching	0.50 ACR	750	0	113	86	14	963	1925.96
TOTAL Collector System for Relief Well	400.00 LF	135,330	0	20,299	15,563	2,568	173,760	434.40
TOTAL Drainage Systems	1.00 EA	135,330	0	20,299	15,563	2,568	173,760	173760.15
TOTAL Levees	1.00 EA	1,397,493	0	209,624	160,712	26,517	1,794,346	1794346

** PROJECT INDIRECT SUMMARY - Assembly **

	QUANTITY UOM	DIRECT	OVERHEAD	% OVRHD	PROFIT	BOND	TOTAL COST	UNIT COST
TOTAL Levees and Floodwalls	1.00 EA	1,397,493	0	209,624	160,712	26,517	1,794,346	1794346
13 Pump Plant								
13.01 Pump Plant								
13.01.01 Abandon Pump Plant								
13.01.01.01 Remove Equipment from Plant								
13.01.01.01.25 Remove Equipment from Plant	1.00 EA	17,705	0	2,656	2,036	336	22,733	22733.18
TOTAL Remove Equipment from Plant	1.00 EA	17,705	0	2,656	2,036	336	22,733	22733.18
13.01.01.02 Flowable Fill for Pump Plant								
13.01.01.02.26 Flowable Fill for Pump Plant	182.00 CY	15,470	0	2,321	1,779	294	19,863	109.14
TOTAL Flowable Fill for Pump Plant	182.00 CY	15,470	0	2,321	1,779	294	19,863	109.14
13.01.01.03 Flowable Fill for Pipe								
13.01.01.03.27 Flowable Fill for Pipe	30.00 CY	2,550	0	383	293	48	3,274	109.14
TOTAL Flowable Fill for Pipe	30.00 CY	2,550	0	383	293	48	3,274	109.14
TOTAL Abandon Pump Plant	1.00 EA	35,725	0	5,359	4,108	678	45,870	45870.41
13.01.02 Mod Pump Plant-North Topeka Unit								
TOTAL Pump Plant	1.00 EA	35,725	0	5,359	4,108	678	45,870	45870.41
TOTAL Pump Plant	1.00 EA	35,725	0	5,359	4,108	678	45,870	45870.41
TOTAL Feasibility Study Estimate for:	1.00 EA	1,529,628	0	214,983	164,820	27,195	1,936,626	1936626
Contingency							474,515	
SUBTOTAL							2,411,141	
Engineering & Design							241,114	
SUBTOTAL							2,652,256	
Supervision & Administration							149,288	
TOTAL INCL OWNER COSTS							2,801,543	

Mon 01 Dec 2008 | Tri-Service Automated Cost ..neering System (TRACES) | TIME 14:38:04
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ERROR REPORT | | ERROR PAGE 1

No errors detected...

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PROJECT NTOPK7: Feasibility Study Estimate for: - North Topeka Unit

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SUMMARY REPORTS — SUMMARY PAGE

No Detailed Estimate...

No Backup Reports...

* * * END TABLE OF CONTENTS * * *

Feasibility Study Estimate for:
Oakland Unit
Topeka, Kansas

dated 1 Dec 2008

Designed By: CENWK
Estimated By: CENWK-EC-DC

Prepared By: Patrick Miramontez 816-389-3322
LATEST ESTIMATE AS OF 1 Dec 08

Preparation Date: 12/01/08
Effective Date of Pricing: 10/01/07

Sales Tax: 0.00%

01- Lands & Damages - The costs include the acquisition of Permanent Right-of-Way and Temporary Right-of-Way. These costs include Non Federal Sponsors cost to perform the Legal work, Title Work, Tract appraisals, and land surveys.

02 - Relocations - N/A

06 - Fish & Wildlife Facilities - N/A

11 - Levees & Floodwalls- The levees cost consists of 4 different components. These components include: 1) Borrow Site Preparation, 2) Stability/ Underseepage Berm, 3) Aggregate Surfacing, and 4) Drainage System Modifications.

- Borrow Site - It is currently assumed one borrow site will be utilized for impervious material. The costs include the preparation of the borrow site, and the final grading of the borrow site when completed.

- Stability & Underseepage Berms) - Quantities for the berm raise was calculated by hand. The material for the Stability berm (Sta 485+86 to 491+01) is to be excavated, loaded, and hauled using on-highway dump trucks over the existing roads. The material for the Underseepage Berm (Sta 64+00 to 80+00) will be from nearby borrow sources.

- Aggregate Surfacing - A cost is included for new aggregate surfacing on top of the stability berm between stations 485+86 to 491+01.

- Drainage System Modifications - A heel extension was added to the inlet @ Sta 75+50.

- Floodwalls - None in this contract.

13 - Pump Plants

- A cost was added for the addition of a heel extension at the East Oakland Pump Plant. This heel extension is to prevent uplift and is added to the base of the pump plant at opposite ends.

30 - Estimated Engineering & Design Cost = 10% of project implementation (less lands & damages) cost. Percentage based on historical data and adjusted for the size of the project.

31 - Estimated Construction Supervision & Administration = 6.5% of project implementation (less lands & damages) cost. Percentage based on historical data.

Areas of Cost Sensitivity

- Estimate does not include any costs for sampling/testing for HTRW.
- Estimate does not include any costs for the hauling and disposal of HTRW.
- Estimate does not include O&M costs. Only project implementation (construction, real-estate and associated) costs.
- Estimate based on borrow source located approximately 1 mile away for the

underseepage berm and 1 mile away for the stability berm. If actual borrow is located farther away additional costs will have to be considered.

General Cost Information

- The quantities have been calculated by EC-GD, EC-DC, and EC-DS. A contingency determination meeting will be held with all of the designers to apply the appropriate amount of contingency to each line item.
- No tax has been included for the state of Kansas.
- The source for the labor rates used in the estimate is the Jan 2008 Department of Labor Wage rates for Wyandotte County, Kansas.
- The national 2001 Unit Price Book is used to price minor items. Material prices for minor items were taken from 2008 RS Means cost books. Quotes were received for major cost items. An adjustment factor is added to bring the rates to the appropriate price level date.
- 2007 equipment rates were used.
- Once all of the databases are normalized to the appropriate price level date an escalation factor will be added to the owner level to bring the estimate to the appropriate price level date. The escalation factors used were derived from the Civil Works Construction Cost Index System (CWCCIS) EM1110-2-1304. NOTE: Estimate was originally prepared in March 2006. The databases and materials were updated to Oct 2007 price levels. The price level date of this estimate is now Oct 2007.

CONTINGENCY DETERMINATION REPORT - The reasons for final contingency development and assignment must be included in the cost estimate as part of the project narrative. When then contingency factors shown in Table 13-1 of EI 01D010 are applied to any portion of the cost estimate up to the feature level, the statement "Normal design variances are expected - Normal contingency values used" is acceptable in addressing that specific portion. For this estimate, 25% contingency is considered normal.
*****NOTE*****
Bid item numbers correspond to the summary sheet Bid Item Level WBS identifier. For example:

09.01.30.02.3 Excavation, Common

The "3" at the end of the number string corresponds to Bid Item No. 3 on this Contingency Determination Report.
*****END NOTE*****

01 Account - LANDS AND DAMAGES
-LAND VALUES
Bid Item Nos. 01 thru 4-Typical 15% contingency factor used for Real Estate.

NON-FEDERAL SPONSORS COSTS -
Bid Item Nos. 05 thru 07-Typical 15% contingency factor used for Real estate

FEDERAL COSTS - NOT USED

02 ACCOUNT - RELOCATIONS - NOT USED

06 ACCOUNT - FISH & WILDLIFE FACILITIES - NOT USED

11 ACCOUNT - LEVEES AND FLOODWALLS

BORROW SITE
Bid Item No. 08 thru 09 - Typical 25% contingency factor used.

STABILITY BERM
Bid Item No. 10 - 30% used to account for amount of borrow required and access to FW.

LEVEE STRIPPING
Bid Item No. 11 thru 12 - Typical 25% contingency factor used.

UNDERSEEPAGE BERM
Bid Item No. 13 thru 16 - Typical 25% contingency factor used.

SEEDING & MULCHING
Bid Item No. 17 - Typical 25% contingency factor used.

REPLACE AGGREGATE SURFACING
Bid Item No. 18 - Typical 25% contingency factor used.

DRAINAGE SYSTEM MODIFICATIONS

Bid Item No. 19 thru 24 - Typical 25% contingency factor was used.

PUMP PLANT

PUMP PLANT MODIFICATIONS
Bid Item No. 25 thru 34 - 30% contingency factor used to account for difficulty in excavation and placement of heel extension.

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Tri-Service Automated Cost Engineering System (TRACES)
PROJECT OAKL07: Feasibility Study Estimate for: - Oakland Unit

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SUMMARY PAGE 1

** PROJECT OWNER SUMMARY - Feature **

	QUANTITY UOM	CONTRACT	CONTING	ESCALATN	E&D	S&A	TOTAL COST	UNIT COST	NOTES
01 Lands and Damages	1.00 EA	197,642	29,646	0	22,729	0	250,018	250017.66	
11 Levees and Floodwalls	1.00 EA	905,224	226,940	0	113,216	73,477	1,318,858	1318858	
13 Pump Plant	1.00 EA	172,814	51,844	0	22,466	14,580	261,704	261703.74	
TOTAL Feasibility Study Estimate for:	1.00 EA	1,275,680	308,431	0	158,411	88,058	1,830,579	1830579	

LABOR ID: TPKA(EQUIP ID: TPKA07 Currency DLLARS CREW ID: NAT01A ID: UP01EA

** PROJECT OWNER SUMMARY - Assembly **

	QUANTITY UOM	CONTRACT	CONTING	ESCALATN	E&D	S&A	TOTAL COST	UNIT COST	NOTES
01 Lands and Damages									
01.23 Land Values									
01.23.01 Land Values									
01.23.01.01 Land Values									
01.23.01.01.01 Tract 1	0.13 ACR	894	134	0	103	0	1,131	8637.46	
01.23.01.01.02 Tract 2	0.08 ACR	564	85	0	65	0	713	8637.46	
01.23.01.01.03 Tract 3	8.03 ACR	37,515	5,627	0	4,314	0	47,456	5909.84	
01.23.01.01.04 Tract 4	39.46 ACR	138,110	20,717	0	15,883	0	174,709	4427.50	
TOTAL Land Values	1.00 EA	177,082	26,562	0	20,364	0	224,009	224009.26	
01.23.01.02 Non Federal Sponsors Costs									
01.23.01.02.05 NFS Costs for Borrow Area #2	1.00 EA	8,440	1,266	0	971	0	10,677	10676.60	
01.23.01.02.06 NFS Costs For Stability Berm	1.00 EA	11,440	1,716	0	1,316	0	14,472	14471.60	
01.23.01.02.07 NFS Costs For Underseep Berm	1.00 EA	680	102	0	78	0	860	860.20	
TOTAL Non Federal Sponsors Costs	1.00 EA	20,560	3,084	0	2,364	0	26,008	26008.40	
01.23.01.03 Federal Costs									
TOTAL Land Values	1.00 EA	197,642	29,646	0	22,729	0	250,018	250017.66	
TOTAL Land Values	1.00 EA	197,642	29,646	0	22,729	0	250,018	250017.66	
TOTAL Lands and Damages	1.00 EA	197,642	29,646	0	22,729	0	250,018	250017.66	
06 Fish & Wildlife Facilities									
11 Levees and Floodwalls									
11.01 Levees									
11.01.01 Borrow Site									
11.01.01.05 Site Prep Borrow Site									
11.01.01.05.09 Site Prep New Borrow Site	35[illegible]93.00 BCY	61,507	15,377	0	7,698	4,990	89,561	2.49	
TOTAL Site Prep Borrow Site	1.00 EA	61,507	15,377	0	7,688	4,990	89,561	89561.35	
11.01.01.10 Final Grade Borrow Site									

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** PROJECT OWNER SUMMARY - Assembly **

	QUANTITY UOM	CONTRACT	CONTING	ESCALATN	E&D	S&A	TOTAL COST	UNIT COST	NOTES
11.01.01.10.09 Final Grade Borrow Site	32593.00 CY	61,756	15,439	0	7,719	5,010	89,924	2.76	
TOTAL Final Grade Borrow Site	1.00 EA	61,756	15,439	0	7,719	5,010	89,924	89923.90	
TOTAL Borrow Site	1.00 EA	123,262	30,816	0	15,408	10,000	179,485	179485.25	
11.01.02 Stability Berm									
11.01.02.13 Place Fill at LS Toe of FW									
11.01.02.13.10 Place Fill at LS Toe of FW									
11.01.02.13.10.01 Place Fill at LS Toe of FW	310.00 BCY	12,686	3,806	0	1,649	1,070	19,211	61.97	
TOTAL Place Fill at LS Toe of FW	310.00 BCY	12,686	3,806	0	1,649	1,070	19,211	61.97	
TOTAL Place Fill at LS Toe of FW	310.00 BCY	12,686	3,806	0	1,649	1,070	19,211	61.97	
TOTAL Stability Berm	310.00 BCY	12,686	3,806	0	1,649	1,070	19,211	61.97	
11.01.03 Levee Stripping/Replacement									
11.01.03.07 Sta 64+00 to 80+00									
11.01.03.07.11 Doze Material to Levee									
11.01.03.07.11.01 Doze Material to Levee	7407.00 BCY	7,893	1,973	0	987	640	11,492	1.55	
TOTAL Doze Material to Levee	7407.00 BCY	7,893	1,973	0	987	640	11,492	1.55	
11.01.03.07.12 Replace Material when Complete	7407.00 BCY	8,449	2,112	0	1,056	685	12,302	1.66	
TOTAL Sta 64+00 to 80+00	7407.00 BCY	16,341	4,085	0	2,043	1,326	23,795	3.21	
TOTAL Levee Stripping/Replacement	7407.00 BCY	16,341	4,085	0	2,043	1,326	23,795	3.21	
11.01.06 Underseepage Berm (New)									
11.01.06.16 Sta 64+00 to 80+00									
11.01.06.16.13 Excavate Material from Borrow									
11.01.06.16.13.01 Excavate & Haul	84500.00 BCY	502,140	125,535	0	62,767	40,736	731,178	8.65	
TOTAL Excavate Material from Borrow	84500.00 BCY	502,140	125,535	0	62,767	40,736	731,178	8.65	
11.01.06.16.14 Place Mat'l	84500.00 BCY	129,209	32,302	0	16,151	10,482	188,145	2.23	

LABOR ID: TPKA(EQUIP ID: TPKA07 Currency)LLARS CREW ID: NAT01A ID: UP01EA

** PROJECT OWNER SUMMARY - Assembly **

	QUANTITY UOM	CONTRACT	CONTING	ESCALATN	E&D	S&A	TOTAL COST	UNIT COST	NOTES
11.01.06.16.15 Street Repair									
11.01.06.16.15.01 Street Repair	84500.00 BCY	52,078	13,020	0	6,510	4,225	75,832	0.90	
TOTAL Street Repair	84500.00 BCY	52,078	13,020	0	6,510	4,225	75,832	0.90	
11.01.06.16.16 Street Sweeping									
11.01.06.16.16.01 Street Sweeping	84500.00 BCY	33,535	8,384	0	4,192	2,721	48,831	0.58	
TOTAL Street Sweeping	84500.00 BCY	33,535	8,384	0	4,192	2,721	48,831	0.58	
TOTAL Sta 64+00 to 80+00	84500.00 BCY	716,962	179,241	0	89,620	58,164	1,043,987	12.35	
TOTAL Underseepage Berm (New)	67600.00 CCY	716,962	179,241	0	89,620	58,164	1,043,987	15.44	
11.01.07 Seeding & Mulching									
11.01.07.01 Seeding & Mulching									
11.01.07.01.17 Seeding & Mulching									
11.01.07.01.17.01 Seeding & Mulching	10.00 ACR	19,260	4,815	0	2,407	1,562	28,044	2804.44	
TOTAL Seeding & Mulching	10.00 ACR	19,260	4,815	0	2,407	1,562	28,044	2804.44	
TOTAL Seeding & Mulching	10.00 ACR	19,260	4,815	0	2,407	1,562	28,044	2804.44	
TOTAL Seeding & Mulching	10.00 ACR	19,260	4,815	0	2,407	1,562	28,044	2804.44	
11.01.09 Place Aggregate Surfacing									
11.01.09.27 Place Aggregate Surfacing									
11.01.09.27.18 Place Aggregate Surfacing									
11.01.09.27.18.01 Place Aggregate Surfacing	181.00 TON	4,661	1,165	0	583	378	6,787	37.50	
TOTAL Place Aggregate Surfacing	181.00 TON	4,661	1,165	0	583	378	6,787	37.50	
TOTAL Place Aggregate Surfacing	181.00 TON	4,661	1,165	0	583	378	6,787	37.50	
TOTAL Place Aggregate Surfacing	95.00 CY	4,661	1,165	0	583	378	6,787	71.45	
11.01.13 Drainage Systems									
11.01.13.30 Inlet @ Sta 75+50									

** PROJECT OWNER SUMMARY - Assembly **

	QUANTITY UOM	CONTRACT	CONTING	ESCALATN	E&D	S&A	TOTAL COST	UNIT COST	NOTES
11.01.13.30.19 Excavation for Heel #1									
11.01.13.30.19.24 Excavation for Heel Extension	41.00 BCY	702	176	0	88	57	1,023	24.94	
TOTAL Excavation for Heel #1	41.00 CY	702	176	0	88	57	1,023	24.94	
11.01.13.30.20 Backfilling for Heel #1									
11.01.13.30.20.32 Backfilling	48.24 BCY	1,872	468	0	234	152	2,726	56.52	
TOTAL Backfilling for Heel #1	41.00 CCY	1,872	468	0	234	152	2,726	66.49	
11.01.13.30.21 Construct Heel Extension #1									
11.01.13.30.21.01 Base Slab	0.63 CY	711	178	0	89	58	1,036	1644.15	
11.01.13.30.21.02 Buttress	0.37 CY	704	176	0	88	57	1,025	2769.65	
11.01.13.30.21.03 Horz Drilg Holes -2"dia X 6"Deep	21.00 EA	1,292	323	0	161	105	1,881	89.57	
11.01.13.30.21.05 Grouting of holes	21.00 EA	418	105	0	52	34	609	29.01	
11.01.13.30.21.06 Hole Layout	2.00 HR	342	86	0	43	28	498	249.19	
TOTAL Construct Heel Extension #1	1.00 EA	3,467	867	0	433	281	5,049	5049.04	
11.01.13.30.22 Excavation for Heel #2									
11.01.13.30.22.24 Excavation for Heel Extension	41.00 BCY	702	176	0	88	57	1,023	24.94	
TOTAL Excavation for Heel #2	41.00 CY	702	176	0	88	57	1,023	24.94	
11.01.13.30.23 Backfilling for Heel #2									
11.01.13.30.23.32 Backfilling	48.24 BCY	1,839	460	0	230	149	2,678	55.53	
TOTAL Backfilling for Heel #2	41.00 CCY	1,839	460	0	230	149	2,678	65.33	
11.01.13.30.24 Construct Heel Extension #2									
11.01.13.30.24.01 Base Slab	0.63 CY	711	178	0	89	58	1,036	1644.15	
11.01.13.30.24.02 Buttress	0.37 CY	704	176	0	88	57	1,025	2769.65	
11.01.13.30.24.03 Horz Drilg Holes -2"dia X 6"Deep	21.00 EA	1,292	323	0	161	105	1,881	89.57	
11.01.13.30.24.05 Grouting of holes	21.00 EA	418	105	0	52	34	609	29.01	
11.01.13.30.24.06 Hole Layout	2.00 HR	342	86	0	43	28	498	249.19	
TOTAL Construct Heel Extension #2	1.00 EA	3,467	867	0	433	281	5,049	5049.04	
TOTAL Inlet @ Sta 75-50	1.00 EA	12,051	3,013	0	1,506	978	17,548	17547.80	

** PROJECT OWNER SUMMARY - Assembly **

	QUANTITY UOM	CONTRACT	CONTING	ESCALATN	E&D	S&A	TOTAL COST	UNIT COST	NOTES
TOTAL Drainage Systems	1.00 EA	12,051	3,013	0	1,306	978	17,348	17347.80	
TOTAL Levees	1.00 EA	905,224	226,940	0	113,216	73,477	1,318,858	1318858	
TOTAL Levees and Floodwalls	1.00 EA	905,224	226,940	0	113,216	73,477	1,318,858	1318858	
13 Pump Plant									
13.01 Pump Plant									
13.01.02 Mod Pump Plant - East Oakland									
13.01.02.02 Shoring - Augercast Piles									
13.01.02.02.25 Mob/Demob of Crane									
13.01.02.02.25.01 Initial Mob of Crane	2.00 DAY	20,000	6,000	0	2,600	1,687	30,287	15143.70	
TOTAL Mob/Demob of Crane	2.00 DAY	20,000	6,000	0	2,600	1,687	30,287	15143.70	
13.01.02.02.26 Setup Crane									
13.01.02.02.26.01 Setup Crane	1.00 EA	1,725	518	0	224	146	2,613	2613.03	
TOTAL Setup Crane	1.00 EA	1,725	518	0	224	146	2,613	2613.03	
13.01.02.02.27 Setup Pile Equipment									
13.01.02.02.27.01 Setup Pile Equipment	1.00 EA	4,931	1,479	0	641	416	7,467	7466.93	
TOTAL Setup Pile Equipment	1.00 EA	4,931	1,479	0	641	416	7,467	7466.93	
13.01.02.02.28 Set Template & Layout									
13.01.02.02.28.01 Set Template & Layout	1.00 EA	11,212	3,364	0	1,458	946	16,980	16979.52	
TOTAL Set Template & Layout	1.00 EA	11,212	3,364	0	1,458	946	16,980	16979.52	
13.01.02.02.29 Install Augercast Piles									
13.01.02.02.29.01 Install Augercast Piles	3136.00 LF	58,200	17,460	0	7,566	4,910	88,137	28.10	
TOTAL Install Augercast Piles	3136.00 LF	58,200	17,460	0	7,566	4,910	88,137	28.10	
13.01.02.02.30 Augercast Piling Material									

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** PROJECT OWNER SUMMARY - Assembly **

	QUANTITY	UOM	CONTRACT	CONTING	ESCALATN	E&D	S&A	TOTAL COST	UNIT COST	NOTES
13.01.02.02.30.01 Augercast Piling Material	3136.00	LF	50,216	15,065	0	6,528	4,237	76,045	24.25	
TOTAL Augercast Piling Material	3136.00	LF	50,216	15,065	0	6,528	4,237	76,045	24.25	
TOTAL Shoring - Augercast Piles	1.00	EA	146,284	43,885	0	19,017	12,342	221,529	221528.75	
13.01.02.03 Excavation										
13.01.02.03.31 Exc within Piles for Pump Plant	220.00	BCY	5,850	1,755	0	760	494	8,858	40.27	
TOTAL Excavation	220.00	CY	5,850	1,755	0	760	494	8,858	40.27	
13.01.02.06 Backfilling										
13.01.02.06.32 BF within Piles	258.82	BCY	6,670	2,001	0	867	563	10,101	39.03	
TOTAL Backfilling	220.00	CCY	6,670	2,001	0	867	563	10,101	45.91	
13.01.02.16 Construct Heel Extensions										
13.01.02.16.33 Construct Heel Extension (North)										
13.01.02.16.33.01 Base Slab	2.89	CY	3,027	908	0	394	255	4,584	1586.27	
13.01.02.16.33.02 Buttress	0.56	CY	867	260	0	113	73	1,313	2344.06	
13.01.02.16.33.03 Horz Drilg Holes -2"dia X 6"Deep	34.00	EA	2,091	627	0	272	176	3,167	93.15	
13.01.02.16.33.05 Grouting of holes	34.00	EA	677	203	0	88	57	1,026	30.17	
13.01.02.16.33.06 Hole Layout	2.00	HR	342	103	0	44	29	518	259.16	
TOTAL Construct Heel Extension (North)	1.00	EA	7,005	2,101	0	911	591	10,608	10608.08	
13.01.02.16.34 Construct Heel Extension (South)										
13.01.02.16.34.01 Base Slab	2.89	CY	3,027	908	0	394	255	4,584	1586.27	
13.01.02.16.34.02 Buttress	0.56	CY	867	260	0	113	73	1,312	2343.57	
13.01.02.16.34.03 Horz Drilg Holes -2"dia X 6"Deep	34.00	EA	2,091	627	0	272	176	3,167	93.15	
13.01.02.16.34.05 Grouting of holes	34.00	EA	677	203	0	88	57	1,026	30.17	
13.01.02.16.34.06 Hole Layout	2.00	HR	342	103	0	44	29	518	259.16	
TOTAL Construct Heel Extension (South)	1.00	EA	7,005	2,101	0	911	591	10,608	10607.81	
TOTAL Construct Heel Extensions	2.00	EA	14,010	4,203	0	1,821	1,182	21,216	10607.95	
TOTAL Mod Pump Plant - East Oakland	1.00	EA	172,814	51,844	0	22,466	14,580	261,704	261703.74	
TOTAL Pump Plant	1.00	EA	172,814	51,844	0	22,466	14,580	261,704	261703.74	

** PROJECT OWNER SUMMARY - Assembly **

	QUANTITY UOM	CONTRACT	CONTING	ESCALATN	E&D	S&A	TOTAL COST	UNIT COST	NOTES
TOTAL Pump Plant	1.00 EA	172,814	51,844	0	22,466	14,580	261,704	261703.74	
TOTAL Feasibility Study Estimate for:	1.00 EA	1,275,680	308,431	0	158,411	88,058	1,830,579	1830579	

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** PROJECT INDIRECT SUMMARY - Feature **

	QUANTITY UOM	DIRECT	OVERHEAD	% OVRHD	PROFIT	BOND	TOTAL COST	UNIT COST
01 Lands and Damages	1.00 EA	197,642	0	0	0	0	197,642	197642.42
11 Levees and Floodwalls	1.00 EA	705,017	0	105,753	81,077	13,378	905,224	905223.82
13 Pump Plant	1.00 EA	139,016	0	17,852	13,687	2,258	172,814	172813.61
TOTAL Feasibility Study Estimate for:	1.00 EA	1,041,675	0	123,605	94,764	15,636	1,275,680	1275680
Contingency							308,431	
SUBTOTAL							1,584,111	
Engineering & Design							158,411	
SUBTOTAL							1,742,522	
Supervision & Administration							88,058	
TOTAL INCL OWNER COSTS							1,830,579	

LABOR ID: TPKA(EQUIP ID: TPKA07 Currency DLLARS CREW ID: NAT01A ID: UP01EA

** PROJECT INDIRECT SUMMARY - Assembly **

	QUANTITY UOM	DIRECT	OVERHEAD	OVRHD	PROFIT	BOND	TOTAL COST	UNIT COST
01 Lands and Damages								
01.23 Land Values								
01.23.01 Land Values								
01.23.01.01 Land Values								
01.23.01.01.01 Tract 1	0.13 ACR	894	0	0	0	0	894	6828.03
01.23.01.01.02 Tract 2	0.08 ACR	564	0	0	0	0	564	6828.03
01.23.01.01.03 Tract 3	8.03 ACR	37,515	0	0	0	0	37,515	4671.81
01.23.01.01.04 Tract 4	39.46 ACR	138,110	0	0	0	0	138,110	3500.00
TOTAL Land Values	1.00 EA	177,082	0	0	0	0	177,082	177082.42
01.23.01.02 Non Federal Sponsors Costs								
01.23.01.02.05 NFS Costs for Borrow Area #2	1.00 EA	8,440	0	0	0	0	8,440	8440.00
01.23.01.02.06 NFS Costs For Stability Berm	1.00 EA	11,440	0	0	0	0	11,440	11440.00
01.23.01.02.07 NFS Costs For Underseep Berm	1.00 EA	680	0	0	0	0	680	680.00
TOTAL Non Federal Sponsors Costs	1.00 EA	20,560	0	0	0	0	20,560	20560.00
01.23.01.03 Federal Costs								
TOTAL Land Values	1.00 EA	197,642	0	0	0	0	197,642	197642.42
TOTAL Land Values	1.00 EA	197,642	0	0	0	0	197,642	197642.42
TOTAL Lands and Damages	1.00 EA	197,642	0	0	0	0	197,642	197642.42
06 Fish & Wildlife Facilities								
11 Levees and Floodwalls								
11.01 Levees								
11.01.01 Borrow Site								
11.01.01.05 Site Prep Borrow Site								
11.01.01.05.08 Site Prep New Borrow Site	35993.00 BCY	47,903	0	7,185	5,509	909	61,507	1.71
TOTAL Site Prep Borrow Site	1.00 EA	47,903	0	7,185	5,509	909	61,507	61506.64
11.01.01.10 Final Grade Borrow Site								

** PROJECT INDIRECT SUMMARY - Assembly **

	QUANTITY UOM	DIRECT	OVERHEAD	% OVRHD	PROFIT	BOND	TOTAL COST	UNIT COST
11.01.01.10.09 Final Grade Borrow Site	32593.00 CY	48,097	0	7,215	5,531	913	61,756	1.89
TOTAL Final Grade Borrow Site	1.00 EA	48,097	0	7,215	5,531	913	61,756	61755.62
TOTAL Borrow Site	1.00 EA	96,001	0	14,400	11,040	1,822	123,262	123262.25
11.01.02 Stability Berm								
11.01.02.13 Place Fill at LS Toe of FW								
11.01.02.13.10 Place Fill at LS Toe of FW								
11.01.02.13.10.01 Place Fill at LS Toe of FW	310.00 BCY	9,880	0	1,482	1,136	187	12,686	40.92
TOTAL Place Fill at LS Toe of FW	310.00 BCY	9,880	0	1,482	1,136	187	12,686	40.92
TOTAL Place Fill at LS Toe of FW	310.00 BCY	9,880	0	1,482	1,136	187	12,686	40.92
TOTAL Stability Berm	310.00 BCY	9,880	0	1,482	1,136	187	12,686	40.92
11.01.03 Levee Stripping/Replacement								
11.01.03.07 Sta 64-00 to 80+00								
11.01.03.07.11 Doze Material to Levee								
11.01.03.07.11.01 Doze Material to Levee	7407.00 BCY	6,147	0	922	707	117	7,893	1.07
TOTAL Doze Material to Levee	7407.00 BCY	6,147	0	922	707	117	7,893	1.07
11.01.03.07.12 Replace Material when Complete	7407.00 BCY	6,580	0	987	757	125	8,449	1.14
TOTAL Sta 64+00 to 80+00	7407.00 BCY	12,727	0	1,909	1,464	241	16,341	2.21
TOTAL Levee Stripping/Replacement	7407.00 BCY	12,727	0	1,909	1,464	241	16,341	2.21
11.01.06 Underseepage Berm (New)								
11.01.06.16 Sta 64+00 to 80+00								
11.01.06.16.13 Excavate Material from Borrow								
11.01.06.16.13.01 Excavate & Haul	84500.00 BCY	391,082	0	58,662	44,974	7,421	502,140	5.94
TOTAL Excavate Material from Borrow	84500.00 BCY	391,082	0	58,662	44,974	7,421	502,140	5.94
11.01.06.16.14 Place Mat'l	84500.00 BCY	100,632	0	15,095	11,573	1,909	129,209	1.53

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** PROJECT INDIRECT SUMMARY - Assembly **

	QUANTITY UOM	DIRECT	OVERHEAD	OVRHD	PROFIT	BOND	TOTAL COST	UNIT COST
11.01.06.16.15 Street Repair								
11.01.06.16.15.01 Street Repair	84500.00 BCY	40,560	0	6,084	4,664	770	52,078	0.62
TOTAL Street Repair	84500.00 BCY	40,560	0	6,084	4,664	770	52,078	0.62
11.01.06.16.16 Street Sweeping								
11.01.06.16.16.01 Street Sweeping	84500.00 BCY	26,118	0	3,918	3,004	496	33,535	0.40
TOTAL Street Sweeping	84500.00 BCY	26,118	0	3,918	3,004	496	33,535	0.40
TOTAL Sta 64+00 to 80+00	84500.00 BCY	558,393	0	83,759	64,215	10,596	716,962	8.48
TOTAL Underseepage Berm (New)	67600.00 CCY	558,393	0	83,759	64,215	10,596	716,962	10.61
11.01.07 Seeding & Mulching								
11.01.07.01 Seeding & Mulching								
11.01.07.01.17 Seeding & Mulching								
11.01.07.01.17.01 Seeding & Mulching	10.00 ACR	15,000	0	2,250	1,725	285	19,260	1925.96
TOTAL Seeding & Mulching	10.00 ACR	15,000	0	2,250	1,725	285	19,260	1925.96
TOTAL Seeding & Mulching	10.00 ACR	15,000	0	2,250	1,725	285	19,260	1925.96
TOTAL Seeding & Mulching	10.00 ACR	15,000	0	2,250	1,725	285	19,260	1925.96
11.01.09 Place Aggregate Surfacing								
11.01.09.27 Place Aggregate Surfacing								
11.01.09.27.18 Place Aggregate Surfacing								
11.01.09.27.18.01 Place Aggregate Surfacing	181.00 TON	3,630	0	545	417	69	4,661	25.75
TOTAL Place Aggregate Surfacing	181.00 TON	3,630	0	545	417	69	4,661	25.75
TOTAL Place Aggregate Surfacing	181.00 TON	3,630	0	545	417	69	4,661	25.75
TOTAL Place Aggregate Surfacing	93.00 CY	3,630	0	545	417	69	4,661	49.07
11.01.13 Drainage Systems								
11.01.13.30 Inlet @ Sta 75+30								

LABOR ID: TPKA07 EQUIP ID: TPKA07 Currency in DOLLARS CREW ID: NAT01A UPB ID: UP01EA

** PROJECT INDIRECT SUMMARY - Assembly **

	QUANTITY UOM	DIRECT	OVERHEAD	% OVRHD	PROFIT	BOND	TOTAL COST	UNIT COST
11.01.13.30.19 Excavation for Heel #1								
11.01.13.30.19.24 Excavation for Heel Extension	41.00 BCY	547	0	82	63	10	702	17.13
TOTAL Excavation for Heel #1	41.00 CY	547	0	82	63	10	702	17.13
11.01.13.30.20 Backfilling for Heel #1								
11.01.13.30.20.32 Backfilling	48.24 BCY	1,458	0	219	168	28	1,872	38.82
TOTAL Backfilling for Heel #1	41.00 CCY	1,458	0	219	168	28	1,872	45.67
11.01.13.30.21 Construct Heel Extension #1								
11.01.13.30.21.01 Base Slab	0.63 CY	554	0	83	64	11	711	1129.13
11.01.13.30.21.02 Buttress	0.37 CY	548	0	82	63	10	704	1902.07
11.01.13.30.21.03 Horz Drilg Holes -2"dia X 6"Deep	21.00 EA	1,006	0	151	116	19	1,292	61.51
11.01.13.30.21.05 Grouting of holes	21.00 EA	326	0	49	37	6	418	19.92
11.01.13.30.21.06 Hole Layout	2.00 HR	267	0	40	31	5	342	171.13
TOTAL Construct Heel Extension #1	1.00 EA	2,701	0	405	311	51	3,467	3467.45
11.01.13.30.22 Excavation for Heel #2								
11.01.13.30.22.24 Excavation for Heel Extension	41.00 BCY	547	0	82	63	10	702	17.13
TOTAL Excavation for Heel #2	41.00 CY	547	0	82	63	10	702	17.13
11.01.13.30.23 Backfilling for Heel #2								
11.01.13.30.23.32 Backfilling	48.24 BCY	1,433	0	215	165	27	1,839	38.13
TOTAL Backfilling for Heel #2	41.00 CCY	1,433	0	215	165	27	1,839	44.86
11.01.13.30.24 Construct Heel Extension #2								
11.01.13.30.24.01 Base Slab	0.63 CY	554	0	83	64	11	711	1129.13
11.01.13.30.24.02 Buttress	0.37 CY	548	0	82	63	10	704	1902.07
11.01.13.30.24.03 Horz Drilg Holes -2"dia X 6"Deep	21.00 EA	1,006	0	151	116	19	1,292	61.51
11.01.13.30.24.05 Grouting of holes	21.00 EA	326	0	49	37	6	418	19.92
11.01.13.30.24.06 Hole Layout	2.00 HR	267	0	40	31	5	342	171.13
TOTAL Construct Heel Extension #2	1.00 EA	2,701	0	405	311	51	3,467	3467.45
TOTAL Inlet @ Sta 75+50	1.00 EA	9,386	0	1,408	1,079	178	12,051	12051.02

** PROJECT INDIRECT SUMMARY - Assembly **

	QUANTITY	UOM	DIRECT	OVERHEAD	OVRHD	PROFIT	BOND	TOTAL COST	UNIT COST
TOTAL Drainage Systems	1.00	EA	9,386	0	1,408	1,079	178	12,051	12051.02
TOTAL Levees	1.00	EA	705,017	0	105,753	81,077	13,378	905,224	905223.82
TOTAL Levees and Floodwalls	1.00	EA	705,017	0	105,753	81,077	13,378	905,224	905223.82
13 Pump Plant									
13.01 Pump Plant									
13.01.02 Mod Pump Plant - East Oakland									
13.01.02.02 Shoring - Augercast Piles									
13.01.02.02.25 Mob/Demob of Crane									
13.01.02.02.25.01 Initial Mob of Crane	2.00	DAY	20,000	0	0	0	0	20,000	10000.00
TOTAL Mob/Demob of Crane	2.00	DAY	20,000	0	0	0	0	20,000	10000.00
13.01.02.02.26 Setup Crane									
13.01.02.02.26.01 Setup Crane	1.00	EA	1,344	0	202	155	25	1,725	1725.49
TOTAL Setup Crane	1.00	EA	1,344	0	202	155	25	1,725	1725.49
13.01.02.02.27 Setup Pile Equipment									
13.01.02.02.27.01 Setup Pile Equipment	1.00	EA	3,840	0	576	442	73	4,931	4930.72
TOTAL Setup Pile Equipment	1.00	EA	3,840	0	576	442	73	4,931	4930.72
13.01.02.02.28 Set Template & Layout									
13.01.02.02.28.01 Set Template & Layout	1.00	EA	8,732	0	1,310	1,004	166	11,212	11212.27
TOTAL Set Template & Layout	1.00	EA	8,732	0	1,310	1,004	166	11,212	11212.27
13.01.02.02.29 Install Augercast Piles									
13.01.02.02.29.01 Install Augercast Piles	3136.00	LF	45,328	0	6,799	5,213	860	58,200	18.56
TOTAL Install Augercast Piles	3136.00	LF	45,328	0	6,799	5,213	860	58,200	18.56
13.01.02.02.30 Augercast Piling Material									

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** PROJECT INDIRECT SUMMARY - Assembly **

	QUANTITY UOM	DIRECT	OVERHEAD	% OVRHD	PROFIT	BOND	TOTAL COST	UNIT COST
13.01.02.02.30.01 Augercast Piling Material	3136.00 LF	39,110	0	5,866	4,498	742	50,216	16.01
TOTAL Augercast Piling Material	3136.00 LF	39,110	0	5,866	4,498	742	50,216	16.01
TOTAL Shoring - Augercast Piles	1.00 EA	118,354	0	14,753	11,311	1,866	146,284	146284.43
13.01.02.03 Excavation								
13.01.02.03.31 Exc within Piles for Pump Plant	220.00 BCY	4,556	0	683	524	86	5,850	26.59
TOTAL Excavation	220.00 CY	4,556	0	683	524	86	5,850	26.59
13.01.02.06 Backfilling								
13.01.02.06.32 BF within Piles	258.82 BCY	5,195	0	779	597	99	6,670	25.77
TOTAL Backfilling	220.00 CCY	5,195	0	779	597	99	6,670	30.32
13.01.02.16 Construct Heel Extensions								
13.01.02.16.33 Construct Heel Extension (North)								
13.01.02.16.33.01 Base Slab	2.89 CY	2,358	0	354	271	45	3,027	1047.48
13.01.02.16.33.02 Buttress	0.56 CY	675	0	101	78	13	867	1547.88
13.01.02.16.33.03 Horz Drilg Holes -2"dia X 6"Deep	34.00 EA	1,629	0	244	187	31	2,091	61.51
13.01.02.16.33.05 Grouting of holes	34.00 EA	528	0	79	61	10	677	19.92
13.01.02.16.33.06 Hole Layout	2.00 HR	267	0	40	31	5	342	171.13
TOTAL Construct Heel Extension (North)	1.00 EA	5,456	0	818	627	104	7,005	7004.95
13.01.02.16.34 Construct Heel Extension (South)								
13.01.02.16.34.01 Base Slab	2.89 CY	2,358	0	354	271	45	3,027	1047.48
13.01.02.16.34.02 Buttress	0.56 CY	675	0	101	78	13	867	1547.55
13.01.02.16.34.03 Horz Drilg Holes -2"dia X 6"Deep	34.00 EA	1,629	0	244	187	31	2,091	61.51
13.01.02.16.34.05 Grouting of holes	34.00 EA	528	0	79	61	10	677	19.92
13.01.02.16.34.06 Hole Layout	2.00 HR	267	0	40	31	5	342	171.13
TOTAL Construct Heel Extension (South)	1.00 EA	5,456	0	818	627	104	7,005	7004.77
TOTAL Construct Heel Extensions	2.00 EA	10,911	0	1,637	1,255	207	14,010	7004.86
TOTAL Mod Pump Plant - East Oakland	1.00 EA	139,016	0	17,852	13,687	2,258	172,814	172813.61
TOTAL Pump Plant	1.00 EA	139,016	0	17,852	13,687	2,258	172,814	172813.61

** PROJECT INDIRECT SUMMARY - Assembly **

	QUANTITY UOM	DIRECT	OVERHEAD	% OVRHD	PROFIT	BOND	TOTAL COST	UNIT COST
TOTAL Pump Plant	1.00 EA	139,016	0	17,852	13,687	2,258	172,814	172813.61
TOTAL Feasibility Study Estimate for:	1.00 EA	1,041,675	0	123,605	94,764	15,636	1,275,680	1275680
Contingency							308,431	
SUBTOTAL							1,584,111	
Engineering & Design							158,411	
SUBTOTAL							1,742,522	
Supervision & Administration							88,058	
TOTAL INCL OWNER COSTS							1,830,579	

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No errors detected...

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No Detailed Estimate...

No Backup Reports...

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Feasibility Study Estimate for:
South Topeka Unit
Topeka, Kansas

dated 1 Dec 2008

Designed By: CENWK
Estimated By: CENWK-EC-DC

Prepared By: Patrick Miramontez 816-389-3322
LATEST ESTIMATE AS OF 1 Dec 08

Preparation Date: 12/01/08
Effective Date of Pricing: 10/01/07

Sales Tax: 0.00%

01- Lands & Damages - The costs include the acquisition of Permanent Right-of-Way, and Temporary Right-of-Way. These costs include Non Federal Sponsors cost to perform the legal work, Title Work, Tract appraisals, and land surveys.

02 - Relocations - This item currently includes only utility relocations. There are two types of utility relocations:

1) Utilities crossing the levee - These are utilities identified as having to be removed from their current location and placed up and over the new levee raise. This will require a fill zone that will be evident above the levee projected lines. All abandoned pipes crossing the levee will be removed. An allowance of $200,000 has been included in the estimate to cover this item.

2) Fences, Gates, and Power Poles - These structures/utilities are currently in or near the levee. They will be impacted in the levee raise, and therefore will need to be relocated. An allowance of $100,000 has been included in this estimate to cover this item.

06 - Fish & Wildlife Facilities - NOT USED

11 - Levees & Floodwalls- The levees cost consists of 2 different components. These components include: 1) Underseepage berms (including stripping of landside area), and 2) Drainage System Modifications.

- Levee Stripping - Quantities for stripping of topsoil from the landside of the existing levee were based on hand calculations. It was assumed this material will be dozed off and windrowed next to the levee for reuse at a later date.

- Underseepage Berms - Quantities for the underseepage berm was calculated by hand. The fill material for this item is assumed to be delivered to the site by the prime contractor utilizing borrow from a sponsor provided borrow source.

- Drainage System Modifications - This item includes costs to replace 3 gatewell structures and the installation of reel extension on 3 inlet structures. Augercast piles are included for shoring protection.

- Floodwalls - The existing floodwall will be removed and replaced with a new floodwall in the same location. This new floodwall included pipe piles.

13- PUMP PLANT
- One of the gatewells and one pump plant will be replaced by one new pump plant. A wall stiffner will be added to the Kansas Avenue Pump Plant.

30 - Estimated Engineering & Design Cost - 10 of project implementation (less lands & damages) cost. This percentage is based on historical data and adjusted due to size of project.

31 - Estimated Construction Supervision & Administration - 6.5% of project implementation (Less lands & damages) cost. This percentage is based on

historical data.

Areas of Cost Sensitivity

- Estimate does not include any costs for sampling/testing for HTRW.
- Estimate does not include any costs for the hauling and disposal of HTRW.
- Estimate does not include O&M costs. Only project implementation (construction, real-estate and associated) costs.

General Cost Information

- The quantities have been calculated by EC-GD, EC-DC, and EC-DS. A contingency determination meeting will be held with all of the designers to apply the appropriate amount of contingency to each line item.
- No tax has been included for the state of Kansas
- The source for the labor rates used in the estimate is the Jan 2008 Department of Labor Wage rates for Wyandotte County, Kansas.
- The national 2001 Unit Price Book is used to price minor items. Material prices for minor items were taken from the 2008 RS Means Cost Books. Quotes were received for major cost items. An adjustment factor is added to bring the rates to the appropriate price level date.
- 2007 equipment rates were used.
- Once all of the databases are normalized to the appropriate price level date an escalation factor will be added to the owner level to bring the estimate to the appropriate price level date. The escalation factors used were derived from the Civil Works Construction Cost Index System (CWCCIS) EM1110-2-1304. NOTE: Estimate was originally prepared in March 2006. The databases and materials were updated to Oct 2007 price levels. Price Level date is now Oct 2007.

CONTINGENCY DETERMINATION REPORT - The reasons for final contingency development and assignment must be included in the cost estimate as part of the project narrative. When then contingency factors shown in Table 13-1 of ER 010010 are applied to any portion of the cost estimate up to the feature level, the statement "Normal design variances are expected - Normal contingency values used" is acceptable in addressing that specific portion. For this estimate, 20% contingency is considered normal.
*****NOTE*****
Bid item numbers correspond to the summary sheet Bid Item Level WBS identifier. For example:

09.01.30.02.3 Excavation, Common

The "3" at the end of the number string corresponds to Bid Item No. 3 on this Contingency Determination Report.
*****END NOTE*****

01 Account - LANDS AND DAMAGES
-LAND VALUES
Bid Item Nos. 01 thru 05-Typical 15% contingency factor used for Real Estate.

NON-FEDERAL SPONSORS COSTS -
Bid Item Nos. 06 thru 08-Typical 15% contingency factor used for Real estate

FEDERAL COSTS -
NOT USED

02 ACCOUNT - RELOCATIONS
UTILITIES CROSSING LEVEE
Bid Item No. 08 - 20% - Typical contingency factor was used.

FENCES, GATES, & POWER POLES
Bid Item No. 09 - 20% - Typical contingency factor was used.

06 ACCOUNT - FISH & WILDLIFE FACILITIES
- NOT USED

11 ACCOUNT - LEVEES AND FLOODWALLS

Bid item No. 10 thru 44 - 20% - Typical Contingency factor used.

13 ACCOUNT - PUMP PLANTS

Bid Item No. 45 thru 47 - 20% - Typical Contingency factor used.

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** PROJECT OWNER SUMMARY - Feature **

	QUANTITY UOM	CONTRACT	CONTING	ESCALATN	E&D	S&A	TOTAL COST	UNIT COST	NOTES
01 Lands and Damages	1.00 EA	463,805	69,571	0	53,338	0	586,713	586712.84	
02 Relocations	1.00 EA	300,000	60,000	0	36,000	23,364	419,364	419364.00	
11 Levees and Floodwalls	1.00 EA	10,717,604	2,143,521	0	1,286,112	834,687	14,981,924	14981924	
13 Pump Plants	1.00 EA	5,880	1,176	0	706	458	8,220	8219.58	
TOTAL Feasibility Study Estimate for:	1.00 EA	11,487,289	2,274,267	0	1,376,156	858,509	15,996,221	15996221	

LABOR ID: TPKA0 EQUIP ID: TPKA07 Currency :LLARS CREW ID: NAT01A :D: UP01EA

** PROJECT OWNER SUMMARY - Assembly **

	QUANTITY	UOM	CONTRACT	CONTING	ESCALATN	E&D	S&A	TOTAL COST	UNIT COST	NOTES
01 Lands and Damages										
01.23 Land Values										
01.23.01 Land Values										
01.23.01.01 Land Values										
01.23.01.01.01 Tract 1	0.50	ACR	15,586	2,338	0	1,792	0	19,717	39767.48	
01.23.01.01.02 Tract 2	0.21	ACR	1,411	212	0	162	0	1,784	8637.46	
01.23.01.01.04 Tract 4	1.51	ACR	7,748	1,162	0	891	0	9,801	6490.55	
01.23.01.01.05 Tract 5	114.76	ACR	401,660	60,249	0	46,191	0	508,100	4427.50	
TOTAL Land Values	1.00	EA	426,405	63,961	0	49,037	0	539,402	539401.84	
01.23.01.02 Non Federal Sponsors Costs										
01.23.01.02.06 NFS Costs for Borrow Area	1.00	EA	8,440	1,266	0	971	0	10,677	10676.60	
01.23.01.02.07 NFS Costs for Floodwall	1.00	EA	21,600	3,240	0	2,484	0	27,324	27324.00	
01.23.01.02.08 NFS Costs for Underseep Berm	1.00	EA	7,360	1,104	0	846	0	9,310	9310.40	
TOTAL Non Federal Sponsors Costs	1.00	EA	37,400	5,610	0	4,301	0	47,311	47311.00	
01.23.01.03 Federal Costs (Included in PED)										
TOTAL Land Values	1.00	EA	463,805	69,571	0	53,338	0	586,713	586712.84	
TOTAL Land Values	1.00	EA	463,805	69,571	0	53,338	0	586,713	586712.84	
TOTAL Lands and Damages	1.00	EA	463,805	69,571	0	53,338	0	586,713	586712.84	
02 Relocations										
02.01 Utility Relocations										
02.01.03 Cemetery, Utilities, & Structure										
02.01.03.18 Util Crossing Levee										
02.01.03.18.08 Util Crossing Levee (allowance)	1.00	EA	200,000	40,000	0	24,000	15,576	279,576	279576.00	
TOTAL Util Crossing Levee	1.00	EA	200,000	40,000	0	24,000	15,576	279,576	279576.00	
02.01.03.20 Fencing, Gates, & Power Poles										
02.01.03.20.09 Fencing, Gates, and Power Poles	1.00	EA	100,000	20,000	0	12,000	7,788	139,788	139788.00	

** PROJECT OWNER SUMMARY - Assembly **

	QUANTITY UOM	CONTRACT	CONTING	ESCALATN	E&D	S&A	TOTAL COST	UNIT COST	NOTES
TOTAL Fencing, Gates, & Power Poles	1.00 EA	100,000	20,000	0	12,000	7,788	139,788	139788.00	
TOTAL Cemetery, Utilities, & Structure		300,000	60,000	0	36,000	23,364	419,364		
TOTAL Utility Relocations	1.00 EA	300,000	60,000	0	36,000	23,364	419,364	419364.00	
TOTAL Relocations	1.00 EA	300,000	60,000	0	36,000	23,364	419,364	419364.00	
06 Fish & Wildlife Facilities									
11 Levees and Floodwalls									
11.01 Levees									
11.01.02 Borrow Site									
11.01.02.05 Site Prep Borrow Site									
11.01.02.05.10 Site Prep New Borrow Site	17304.00 CY	31,154	6,231	0	3,739	2,426	43,550	2.52	
TOTAL Site Prep Borrow Site	1.00 EA	31,154	6,231	0	3,739	2,426	43,550	43550.05	
11.01.02.10 Final Grade Borrow Site									
11.01.02.10.11 Final Grade Borrow Site	14815.00 CY	28,071	5,614	0	3,368	2,186	39,240	2.65	
TOTAL Final Grade Borrow Site	1.00 EA	28,071	5,614	0	3,368	2,186	39,240	39239.52	
TOTAL Borrow Site	1.00 EA	59,225	11,845	0	7,107	4,612	82,790	82789.57	
11.01.03 Levee Stripping									
11.01.03.07 Sta 22+00 to 48+00									
11.01.03.07.12 Doze Material to Levee									
11.01.03.07.12.01 Doze Material to Levee	5778.00 BCY	6,314	1,263	0	758	492	8,826	1.53	
TOTAL Doze Material to Levee	5778.00 BCY	6,314	1,263	0	758	492	8,826	1.53	
11.01.03.07.13 Replace Material when Complete	5778.00 BCY	6,759	1,352	0	811	526	9,448	1.64	
TOTAL Sta 22+00 to 48+00	5778.00 BCY	13,073	2,615	0	1,569	1,018	18,275	3.16	
TOTAL Levee Stripping	5778.00 BCY	13,073	2,615	0	1,569	1,018	18,275	3.16	
11.01.06 Underseepage Berm (New)									

	QUANTITY UOM	CONTRACT	CONTING	ESCALATN	E&D	S&A	TOTAL COST	UNIT COST	NOTES
11.01.06.16 Sta 22+00 to 48+00									
11.01.06.16.14 Excavate Material from Borrow									
11.01.06.16.14.01 Excavate & Haul	48150.00 BCY	285,455	57,091	0	34,255	22,231	399,032	8.29	
TOTAL Excavate Material from Borrow	48150.00 BCY	285,455	57,091	0	34,255	22,231	399,032	8.29	
11.01.06.16.15 Place Mat'l	48150.00 BCY	71,626	14,725	0	8,835	5,734	102,921	2.14	
TOTAL Sta 22+00 to 48+00	48150.00 BCY	359,081	71,816	0	43,090	27,965	501,952	10.42	
TOTAL Underseepage Berm (New)	38520.00 CCY	359,081	71,816	0	43,090	27,965	501,952	13.03	
11.01.07 Seeding & Mulching									
11.01.07.01 Seeding & Mulching									
11.01.07.01.16 Seeding & Mulching									
11.01.07.01.16.01 Seeding & Mulching	8.00 ACR	15,408	3,082	0	1,849	1,200	21,538	2692.26	
TOTAL Seeding & Mulching	8.00 ACR	15,408	3,082	0	1,849	1,200	21,538	2692.26	
TOTAL Seeding & Mulching	8.00 ACR	15,408	3,082	0	1,849	1,200	21,538	2692.26	
TOTAL Seeding & Mulching	8.00 ACR	15,408	3,082	0	1,849	1,200	21,538	2692.26	
11.01.08 Rem Aggr Surfacing at FW									
11.01.08.05 Remove Aggregate Surfacing									
11.01.08.05.17 Excavate Aggregate from FW	756.00 BCY	4,408	882	0	529	343	6,161	8.15	
TOTAL Remove Aggregate Surfacing	756.00 BCY	4,408	882	0	529	343	6,161	8.15	
TOTAL Rem Aggr Surfacing at FW	756.00 BCY	4,408	882	0	529	343	6,161	8.15	
11.01.09 Repl Aggr Surfacing At FW									
11.01.09.27 Replace Aggregate Surfacing									
11.01.09.27.18 Replace Aggregate Surfacing									
11.01.09.27.18.01 Replace Aggregate Surfacing	1436.00 TON	35,377	7,075	0	4,245	2,755	49,453	34.44	
TOTAL Replace Aggregate Surfacing	1436.00 TON	35,377	7,075	0	4,245	2,755	49,453	34.44	

** PROJECT OWNER SUMMARY - Assembly **

	QUANTITY	UOM	CONTRACT	CONTING	ESCALATN	E&D	S&A	TOTAL COST	UNIT COST	NOTES
TOTAL Replace Aggregate Surfacing	1436.00	TON	35,377	7,075	0	4,245	2,755	49,453	34.44	
TOTAL Repl Aggr Surfacing At FW	756.00	CY	35,377	7,075	0	4,245	2,755	49,453	65.41	
11.01.13 Drainage Systems										
11.01.13.01 Shoring - Augercast Piles										
11.01.13.01.19 Mob/Demob of Crane										
11.01.13.01.19.01 Initial Mob of Crane	2.00	DAY	20,000	4,000	0	2,400	1,558	27,958	13978.80	
TOTAL Mob/Demob of Crane	2.00	DAY	20,000	4,000	0	2,400	1,558	27,958	13978.80	
11.01.13.01.20 Setup Crane										
11.01.13.01.20.01 Setup Crane	1.00	EA	1,725	345	0	207	134	2,412	2412.03	
TOTAL Setup Crane	1.00	EA	1,725	345	0	207	134	2,412	2412.03	
11.01.13.01.21 Setup Pile Equipment										
11.01.13.01.21.01 Setup Pile Equipment	1.00	EA	4,931	986	0	592	384	6,893	6892.55	
TOTAL Setup Pile Equipment	1.00	EA	4,931	986	0	592	384	6,893	6892.55	
11.01.13.01.22 Set Template & Layout										
11.01.13.01.22.01 Set Template & Layout	1.00	EA	101,158	20,232	0	12,139	7,878	141,407	141407.36	
TOTAL Set Template & Layout	1.00	EA	101,158	20,232	0	12,139	7,878	141,407	141407.36	
11.01.13.01.23 Install Augercast Piles										
11.01.13.01.23.01 Install Augercast Piles	4800.00	LF	96,966	19,393	0	11,636	7,552	135,547	28.24	
TOTAL Install Augercast Piles	4800.00	LF	96,966	19,393	0	11,636	7,552	135,547	28.24	
11.01.13.01.24 Augercast Piling Material										
11.01.13.01.24.01 Augercast Piling Material	4800.00	LF	80,817	16,163	0	9,698	6,294	112,972	23.54	
TOTAL Augercast Piling Material	4800.00	LF	80,817	16,163	0	9,698	6,294	112,972	23.54	
TOTAL Shoring - Augercast Piles	4800.00	LF	305,597	61,119	0	36,672	23,800	427,188	89.00	

** PROJECT OWNER SUMMARY - Assembly **

		QUANTITY UOM	CONTRACT	CONTING	ESCALATN	E&D	S&A	TOTAL COST	UNIT COST	NOTES
11.01.13.16	Gatewell - Sta 75+62									
11.01.13.16.25	Base Slab	7.00 CY	4,423	885	0	531	344	6,183	883.30	
11.01.13.16.26	1st Lift (Wall)	27.41 CY	24,591	4,918	0	2,951	1,915	34,375	1254.12	
11.01.13.16.27	2nd Lift (Wall)	27.41 CY	24,446	4,889	0	2,934	1,904	34,173	1246.72	
11.01.13.16.28	3rd Lift (Wall)	20.56 CY	21,784	4,357	0	2,614	1,697	30,451	1481.07	
11.01.13.16.29	4th Lift (Wall)	10.28 CY	11,649	2,330	0	1,398	907	16,284	1584.02	
11.01.13.16.30	Elevated Slab	4.64 CY	4,395	879	0	527	342	6,143	1323.98	
11.01.13.16.31	Metals		91,617	18,323	0	10,994	7,135	128,069		
11.01.13.16.32	Pipe	30.00 LF	21,744	4,349	0	2,609	1,693	30,396	1013.20	
11.01.13.16.33	Cradle	11.11 CY	5,128	1,026	0	615	399	7,168	645.19	
11.01.13.16.34	Concrete Collar	2.67 CY	2,490	498	0	299	194	3,481	1303.87	
11.01.13.16.35	Outlet Structure for 48" RCP									
11.01.13.16.35.01	Toe	3.47 CY	1,563	313	0	188	122	2,185	629.56	
11.01.13.16.35.03	Slab	8.16 CY	4,518	904	0	542	352	6,316	774.04	
11.01.13.16.35.04	Wingwall	5.30 CY	6,326	1,265	0	759	493	8,843	1668.49	
11.01.13.16.35.05	Headwall	4.10 CY	61,785	12,357	0	7,414	4,812	86,368	21065.41	
11.01.13.16.35.06	Riprap	15.56 CY	1,530	306	0	184	119	2,139	137.49	
	TOTAL Outlet Structure for 48" RCP	1.00 EA	75,723	15,145	0	9,087	5,897	105,851	105851.31	
	TOTAL Gatewell - Sta 75-62	1.00 EA	287,990	57,598	0	34,559	22,429	402,575	402575.04	
11.01.13.20	New Pump Plant @ Sta 86+10									
11.01.13.22	GW @ Sta 88+69									
11.01.13.22.36	Base Slab	7.17 CY	4,560	912	0	547	355	6,374	888.99	
11.01.13.22.37	1st Lift (Wall)	24.07 CY	21,844	4,369	0	2,621	1,701	30,535	1268.61	
11.01.13.22.38	2nd Lift (Wall)	24.07 CY	21,665	4,333	0	2,600	1,687	30,285	1258.21	
11.01.13.22.39	3rd Lift (Wall)	16.94 CY	18,087	3,617	0	2,170	1,409	25,284	1492.55	
11.01.13.22.40	4th Lift (Wall)	8.47 CY	9,673	1,935	0	1,161	753	13,522	1596.41	
11.01.13.22.41	Elevated Slab	3.44 CY	3,717	743	0	446	289	5,196	1510.48	
11.01.13.22.42	Metals		78,930	15,786	0	9,472	6,147	110,334		
11.01.13.22.43	Pipe	30.00 LF	9,617	1,923	0	1,154	749	13,443	448.10	
11.01.13.22.44	Cradle	11.11 CY	5,128	1,026	0	615	399	7,168	645.19	
11.01.13.22.45	Concrete Collar	2.67 CY	2,490	498	0	299	194	3,481	1303.87	
11.01.13.22.46	Outlet Structure for 36" RCP									
11.01.13.22.46.01	Toe	3.47 CY	1,563	313	0	188	122	2,185	629.56	
11.01.13.22.46.03	Slab	8.16 CY	4,518	904	0	542	352	6,316	774.04	
11.01.13.22.46.04	Wingwall	5.30 CY	6,326	1,265	0	759	493	8,843	1668.49	
11.01.13.22.46.05	Headwall	4.10 CY	51,568	10,314	0	6,188	4,016	72,086	17581.91	
11.01.13.22.46.06	Riprap	15.36 CY	1,496	299	0	180	117	2,092	134.44	
	TOTAL Outlet Structure for 36" RCP	1.00 EA	65,472	13,094	0	7,857	5,099	91,522	91521.60	

** PROJECT OWNER SUMMARY - Assembly **

	QUANTITY	UOM	CONTRACT	CONTING	ESCALATN	E&D	S&A	TOTAL COST	UNIT COST	NOTES
TOTAL GW @ Sta 88+69	1.00	EA	241,182	48,236	0	28,942	18,783	337,144	337143.82	
11.01.13.24 GW @ Sta 91+02										
11.01.13.24.47 Base Slab	7.00	CY	4,423	885	0	531	344	6,183	883.30	
11.01.13.24.48 1st Lift (Wall)	27.41	CY	24,584	4,917	0	2,950	1,915	34,366	1253.77	
11.01.13.24.49 2nd Lift (Wall)	27.41	CY	24,446	4,889	0	2,934	1,904	34,173	1246.72	
11.01.13.24.50 3rd Lift (Wall)	20.56	CY	21,784	4,357	0	2,614	1,697	30,451	1481.07	
11.01.13.24.51 4th Lift (Wall)	10.28	CY	11,646	2,329	0	1,397	907	16,279	1583.57	
11.01.13.24.52 Elevated Slab	4.64	CY	4,395	879	0	527	342	6,143	1323.98	
11.01.13.24.53 Metals			104,496	20,899	0	12,539	8,138	146,072		
11.01.13.24.54 Pipe	30.00	LF	17,655	3,531	0	2,119	1,375	24,679	822.64	
11.01.13.24.55 Cradle	11.11	CY	5,128	1,026	0	615	399	7,168	645.19	
11.01.13.24.56 Concrete Collar	2.67	CY	2,490	498	0	299	194	3,481	1303.87	
11.01.13.24.57 Outlet Structure for 54" RCP										
11.01.13.24.57.01 Toe	3.47	CY	1,563	313	0	188	122	2,185	629.56	
11.01.13.24.57.03 Slab	8.16	CY	4,518	904	0	542	352	6,316	774.04	
11.01.13.24.57.04 Wingwall	5.30	CY	6,326	1,265	0	759	493	8,843	1668.49	
11.01.13.24.57.05 Headwall	4.10	CY	71,701	14,340	0	8,604	5,584	100,229	24446.03	
11.01.13.24.57.06 Riprap	15.56	CY	1,496	299	0	180	117	2,092	134.44	
TOTAL Outlet Structure for 54" RCP	1.00	EA	85,604	17,121	0	10,273	6,667	119,664	119664.39	
TOTAL GW @ Sta 91+02	1.00	EA	306,650	61,330	0	36,798	23,882	428,660	428660.09	
11.01.13.26 Inlet @ Sta 84+10										
11.01.13.26.58 Excavation										
11.01.13.26.58.24 Exc within Piles for Pump Plant	424.00	BCY	3,511	702	0	421	273	4,908	11.58	
TOTAL Excavation	424.00	CY	3,511	702	0	421	273	4,908	11.58	
11.01.13.26.59 Backfilling										
11.01.13.26.59.32 Backfilling	498.82	BCY	9,823	1,965	0	1,179	765	13,732	27.53	
TOTAL Backfilling	424.00	CCY	9,823	1,965	0	1,179	765	13,732	32.39	
11.01.13.26.60 Construct Heel Extensions										
11.01.13.26.60.01 Base Slab	1.53	CY	1,608	322	0	193	125	2,248	1469.23	
11.01.13.26.60.02 Buttress	1.48	CY	2,731	546	0	328	213	3,818	2579.76	
11.01.13.26.60.03 Horz Drilg Holes -2"dia x 6"Deep	40.00	EA	2,460	492	0	295	192	3,439	85.98	
11.01.13.26.60.05 Grouting of holes	40.00	EA	797	159	0	96	62	1,114	27.85	

** PROJECT OWNER SUMMARY - Assembly **

	QUANTITY UOM	CONTRACT	CONTING	ESCALATN	E&D	S&A	TOTAL COST	UNIT COST	NOTES
11.01.13.26.60.06 Hole Layout	2.00 HR	342	68	0	41	27	478	239.23	
TOTAL Construct Heel Extensions	1.00 EA	7,939	1,588	0	953	618	11,098	11097.66	
TOTAL Inlet @ Sta 84+10	1.00 EA	21,273	4,255	0	2,553	1,657	29,737	29737.39	
11.01.13.28 Inlet @ Sta 84-10a									
11.01.13.28.61 Excavation									
11.01.13.28.61.24 Exc within Piles for Pump Plant	424.00 BCY	3,511	702	0	421	273	4,908	11.58	
TOTAL Excavation	424.00 CY	3,511	702	0	421	273	4,908	11.58	
11.01.13.28.62 Backfilling									
11.01.13.28.62.32 Backfilling	498.82 BCY	9,823	1,965	0	1,179	765	13,732	27.53	
TOTAL Backfilling	424.00 CCY	9,823	1,965	0	1,179	765	13,732	32.39	
11.01.13.28.63 Construct Heel Extensions									
11.01.13.28.63.01 Base Slab	1.53 CY	1,608	322	0	193	125	2,248	1469.23	
11.01.13.28.63.02 Buttress	1.48 CY	2,731	546	0	328	213	3,817	2579.07	
11.01.13.28.63.03 Horz Drilg Holes -2"dia X 6"Deep	40.00 EA	2,460	492	0	295	192	3,439	85.98	
11.01.13.28.63.05 Grouting of holes	40.00 EA	797	159	0	96	62	1,114	27.85	
11.01.13.28.63.06 Hole Layout	2.00 HR	342	68	0	41	27	478	239.23	
TOTAL Construct Heel Extensions	1.00 EA	7,938	1,588	0	953	618	11,097	11096.65	
TOTAL Inlet @ Sta 84-10a	1.00 EA	21,272	4,254	0	2,553	1,657	29,736	29736.38	
11.01.13.30 Inlet @ Sta 85+57									
11.01.13.30.64 Excavation for Heel #1									
11.01.13.30.64.24 Excavation for Heel Extension	265.00 BCY	2,809	562	0	337	219	3,927	14.82	
TOTAL Excavation for Heel #1	265.00 CY	2,809	562	0	337	219	3,927	14.82	
11.01.13.30.65 Backfilling for Heel #1									
11.01.13.30.65.32 Backfilling	311.76 BCY	5,056	1,011	0	607	394	7,068	22.67	
TOTAL Backfilling for Heel #1	265.00 CCY	5,056	1,011	0	607	394	7,068	26.67	

** PROJECT OWNER SUMMARY - Assembly **

	QUANTITY	UOM	CONTRACT	CONTING	ESCALATN	E&D	S&A	TOTAL COST	UNIT COST	NOTES
11.01.13.30.66 Construct Heel Extension #1										
11.01.13.30.66.01 Base Slab	1.63	CY	1,720	344	0	206	134	2,405	1475.49	
11.01.13.30.66.02 Buttress	0.37	CY	726	145	0	87	57	1,015	2742.17	
11.01.13.30.66.03 Horz Drilg Holes -2"dia X 6"Deep	36.00	EA	2,214	443	0	266	172	3,095	85.98	
11.01.13.30.66.05 Grouting of holes	36.00	EA	717	143	0	86	56	1,002	27.85	
11.01.13.30.66.06 Hole Layout	2.00	HR	342	68	0	41	27	478	239.23	
TOTAL Construct Heel Extension #1	1.00	EA	5,720	1,144	0	686	445	7,996	7996.02	
11.01.13.30.67 Excavation for Heel #2										
11.01.13.30.67.24 Excavation for Heel Extension	180.00	BCY	1,404	281	0	169	109	1,963	10.91	
TOTAL Excavation for Heel #2	180.00	CY	1,404	281	0	169	109	1,963	10.91	
11.01.13.30.68 Backfilling for Heel #2										
11.01.13.30.68.32 Backfilling	211.76	BCY	3,968	794	0	476	309	5,546	26.19	
TOTAL Backfilling for Heel #2	180.00	CCY	3,968	794	0	476	309	5,546	30.81	
11.01.13.30.69 Construct Heel Extension #2										
11.01.13.30.69.01 Base Slab	0.97	CY	1,061	212	0	127	83	1,483	1528.38	
11.01.13.30.69.02 Buttress	0.37	CY	711	142	0	85	55	994	2687.59	
11.01.13.30.69.03 Horz Drilg Holes -2"dia X 6"Deep	26.00	EA	1,599	320	0	192	125	2,236	85.98	
11.01.13.30.69.05 Grouting of holes	26.00	EA	518	104	0	62	40	724	27.85	
11.01.13.30.69.06 Hole Layout	2.00	HR	342	68	0	41	27	478	239.23	
TOTAL Construct Heel Extension #2	1.00	EA	4,231	846	0	508	330	5,915	5914.99	
TOTAL Inlet @ Sta 85+57	1.00	EA	23,189	4,638	0	2,783	1,806	32,415	32414.95	
TOTAL Drainage Systems	1.00	EA	1,207,154	241,431	0	144,858	94,013	1,687,456	1687456	
TOTAL Levees	1.00	EA	1,693,725	338,745	0	203,247	131,907	2,367,625	2367625	

11.02 Floodwalls

11.02.02 Floodwalls

11.02.02.01 Demolish Existing Floodwall

11.02.02.01.25 Excavation for Demolition

	QUANTITY UOM	CONTRACT	CONTING	ESCALATN	E&D	S&A	TOTAL COST	UNIT COST	NOTES
11.02.02.01.25.03 Excavate to Base	7169.00 CY	108,841	21,768	0	13,061	8,477	152,147	21.22	
TOTAL Excavation for Demolition	1.00 EA	108,841	21,768	0	13,061	8,477	152,147	152147.00	
11.02.02.01.26 Demolition of Exist Floodwall									
11.02.02.01.26.01 Demolish Exist Floodwall	3667.00 CY	346,286	69,257	0	41,554	26,969	484,067	132.01	
11.02.02.01.26.02 Load & Haul Demo Debris	3667.00 CY	306,066	61,213	0	36,728	23,836	427,843	116.67	
11.02.02.01.26.03 Dispose of Demo Debris	3667.00 CY	54,626	10,925	0	6,555	4,254	76,361	20.82	
TOTAL Demolition of Exist Floodwall	3667.00 CY	706,978	141,396	0	84,837	55,059	988,270	269.50	
11.02.02.01.27 Backfill to New Base elevation									
11.02.02.01.27.01 Backfill to New Base Elevation	2666.00 BCY	36,688	7,338	0	4,403	2,857	51,286	19.24	
TOTAL Backfill to New Base elevation	1.00 EA	36,688	7,338	0	4,403	2,857	51,286	51285.76	
11.02.02.01.28 RW MH Protection (Allowance)	20.00 EA	25,680	5,136	0	3,082	2,000	35,897	1794.84	
TOTAL Demolish Existing Floodwall	3667.00 CY	878,187	175,637	0	105,382	68,393	1,227,600	334.77	
11.02.02.02 Place Rockfill									
11.02.02.02.29 Rockfill placed riverside of FW									
11.02.02.02.29.06 Haul/Stockpile Rockfill for Emer	5667.00 TON	98,230	19,646	0	11,788	7,650	137,314	24.23	
11.02.02.02.29.07 Haul and Stockpile Rockfill	29934.00 TON	518,866	103,773	0	62,264	40,409	725,312	24.23	
11.02.02.02.29.08 Place Rockfill	29934.00 TON	290,565	58,113	0	34,868	22,629	406,176	13.57	
11.02.02.02.29.09 Finish Rockfill	29934.00 TON	15,808	3,162	0	1,897	1,231	22,098	0.74	
11.02.02.02.29.10 Place Pipe Crossings (allowance)	6.00 EA	38,519	7,704	0	4,622	3,000	53,845	8974.21	
TOTAL Rockfill placed riverside of FW	29934.00 TON	961,989	192,398	0	115,439	74,920	1,344,745	44.92	
TOTAL Place Rockfill	29934.00 TON	961,989	192,398	0	115,439	74,920	1,344,745	44.92	
11.02.02.03 Pipe Piles									
11.02.02.03.30 Install Pipe Piles									
11.02.02.03.30.01 Pipe Pile Materials	11137.50 VLF	824,779	164,956	0	98,973	64,234	1,152,941	103.52	
11.02.02.03.30.02 Install Pipe Piles	9900.00 VLF	306,069	61,214	0	36,728	23,837	427,848	43.22	
11.02.02.03.30.03 Install Pile Caps & Rebar	220.00 EA	50,127	10,025	0	6,015	3,904	70,071	318.50	
11.02.02.03.30.04 Siesmic Monitoring	1.00 EA	4,879	976	0	585	380	6,820	6820.40	
TOTAL Install Pipe Piles	9900.00 VLF	1,185,853	237,171	0	142,302	92,354	1,657,680	167.44	

** PROJECT OWNER SUMMARY - Assembly **

	QUANTITY UOM	CONTRACT	CONTING	ESCALATN	E&D	S&A	TOTAL COST	UNIT COST	NOTES
TOTAL Pipe Piles	9900.00 VLF	1,185,853	237,171	0	142,302	92,354	1,657,680	167.44	
11.02.02.04 Sheetpile Cutoff Wall									
11.02.02.04.31 Mob/Demob Crane	1.00 EA	31,954	6,391	0	3,834	2,489	44,667	44667.18	
TOTAL Mob/Demob Crane	1.00 EA	31,954	6,391	0	3,834	2,489	44,667	44667.18	
11.02.02.04.32 Install Template									
11.02.02.04.32.01 Install Template	1.00 EA	119,647	23,929	0	14,358	9,318	167,252	167252.39	
TOTAL Install Template	1.00 EA	119,647	23,929	0	14,358	9,318	167,252	167252.39	
11.02.02.04.33 Install Sheetpiling									
11.02.02.04.33.01 Sheetpile Materials	48625.00 SF	871,648	174,330	0	104,598	67,884	1,218,459	25.06	
11.02.02.04.33.02 Install Sheetpile	38900.00 SF	1,202,536	240,507	0	144,304	93,654	1,681,002	43.21	
TOTAL Install Sheetpiling	38900.00 SF	2,074,184	414,837	0	248,902	161,537	2,899,461	74.54	
TOTAL Sheetpile Cutoff Wall	38900.00 SF	2,225,785	445,157	0	267,094	173,344	3,111,380	79.98	
11.02.02.05 Floodwall Base									
11.02.02.05.34 Monolith 1									
11.02.02.05.34.01 Forming (Slab)	115.00 CY	6,750	1,350	0	810	526	9,436	82.05	
11.02.02.05.34.02 Reinforcing	115.00 CY	29,948	5,990	0	3,594	2,332	41,864	364.03	
11.02.02.05.34.03 Concrete	115.00 CY	29,598	5,920	0	3,552	2,305	41,375	359.78	
11.02.02.05.34.04 Finishing	115.00 CY	2,086	417	0	250	162	2,915	25.35	
11.02.02.05.34.05 Misc	115.00 CY	156	31	0	19	12	219	1.90	
11.02.02.05.34.06 Crane Support	115.00 CY	7,837	1,567	0	940	610	10,955	95.26	
TOTAL Monolith 1	115.00 CY	76,376	15,275	0	9,165	5,948	106,764	928.38	
11.02.02.05.35 Monolith 2 thru 23									
11.02.02.05.35.01 Forming (Slab)	2415.00 CY	131,058	26,212	0	15,727	10,207	183,204	75.86	
11.02.02.05.35.02 Reinforcing	2415.00 CY	628,915	125,783	0	75,470	48,980	879,147	364.04	
11.02.02.05.35.03 Concrete	2415.00 CY	621,568	124,314	0	74,588	48,408	868,877	359.78	
11.02.02.05.35.04 Finishing	2415.00 CY	43,050	8,610	0	5,166	3,353	60,179	24.92	
11.02.02.05.35.05 Misc	2415.00 CY	3,284	657	0	394	256	4,590	1.90	
11.02.02.05.35.06 Crane Support	2415.00 CY	164,576	32,915	0	19,749	12,817	230,057	95.26	

** PROJECT OWNER SUMMARY - Assembly **

	QUANTITY UOM	CONTRACT	CONTING	ESCALATN	L&D	S&A	TOTAL COST	UNIT COST	NOTES
TOTAL Monolith 2 thru 23	2415.00 CY	1,592,451	318,490	0	191,094	124,020	2,226,055	921.76	
TOTAL Floodwall Base	2530.00 CY	1,668,826	333,765	0	200,259	129,968	2,332,819	922.06	
11.02.02.07 Floodwall Stem									
11.02.02.07.36 Stem on Monolith 1									
11.02.02.07.36.01 Forming	17.78 CY	17,435	3,487	0	2,092	1,358	24,372	1370.77	
11.02.02.07.36.02 Reinforcing	17.78 CY	4,962	992	0	595	386	6,937	390.13	
11.02.02.07.36.03 Concrete	17.78 CY	7,297	1,459	0	876	568	10,200	573.68	
11.02.02.07.36.04 Finishing	17.78 CY	1,241	248	0	149	97	1,735	97.60	
11.02.02.07.36.05 Misc	17.78 CY	690	138	0	83	54	964	54.23	
11.02.02.07.36.06 Crane Support	17.78 CY	257	51	0	31	20	359	20.21	
TOTAL Stem on Monolith 1	17.78 CY	31,882	6,376	0	3,826	2,483	44,568	2506.61	
11.02.02.07.37 Stem on Monoliths 2 thru 65									
11.02.02.07.37.01 Forming	1137.92 CY	1,097,851	219,570	0	131,742	85,501	1,534,664	1348.66	
11.02.02.07.37.02 Reinforcing	1137.92 CY	317,552	63,510	0	38,106	24,731	443,899	390.10	
11.02.02.07.37.03 Concrete	1137.92 CY	339,208	67,842	0	40,705	26,418	474,172	416.70	
11.02.02.07.37.04 Finishing	1137.92 CY	78,311	15,662	0	9,397	6,099	109,469	96.20	
11.02.02.07.37.05 Misc	1137.92 CY	45,285	9,057	0	5,434	3,527	63,303	55.63	
11.02.02.07.37.06 Crane Support	1137.92 CY	16,449	3,290	0	1,974	1,281	22,994	20.21	
TOTAL Stem on Monoliths 2 thru 65	1137.92 CY	1,894,655	378,931	0	227,359	147,556	2,648,501	2327.49	
TOTAL Floodwall Stem	1155.70 CY	1,926,538	385,308	0	231,185	150,039	2,693,068	2330.25	
11.02.02.08 Toe Drain									
11.02.02.08.38 Excavate for Toe Drain									
11.02.02.08.38.01 Exc Trench for Toe Drain @ FW	675.00 BCY	3,750	750	0	450	292	5,242	7.77	
TOTAL Excavate for Toe Drain	675.00 BCY	3,750	750	0	450	292	5,242	7.77	
11.02.02.08.39 Place Filter Fabric									
11.02.02.08.39.01 Place Filter Fabric	29205.00 SF	7,286	1,457	0	874	567	10,185	0.35	
TOTAL Place Filter Fabric	29205.00 SF	7,286	1,457	0	874	567	10,185	0.35	
11.02.02.08.40 Place PVC Pipe									

** PROJECT OWNER SUMMARY - Assembly **

	QUANTITY UOM	CONTRACT	CONTING	ESCALATN	E&D	S&A	TOTAL COST	UNIT COST	NOTES
11.02.02.08.40.01 Place PVC Pipe	1945.00 LF	24,935	4,987	0	2,992	1,942	34,856	17.92	
TOTAL Place PVC Pipe	1945.00 LF	24,935	4,987	0	2,992	1,942	34,856	17.92	
11.02.02.08.41 Fill For Toe Drain									
11.02.02.08.41.01 Fill For Toe Drain	750.00 BCY	25,224	5,045	0	3,027	1,964	35,260	47.01	
TOTAL Fill For Toe Drain	750.00 BCY	25,224	5,045	0	3,027	1,964	35,260	47.01	
11.02.02.08.42 Riser protection									
11.02.02.08.42.01 Concrete Pad	6.00 EA	4,117	823	0	494	321	5,755	959.18	
11.02.02.08.42.02 RCP Manhole Riser w/lid	6.00 EA	11,076	2,215	0	1,329	863	15,482	2580.39	
11.02.02.08.42.03 Guard Post	6.00 EA	4,018	804	0	482	313	5,617	936.18	
TOTAL Riser protection	6.00 EA	19,211	3,842	0	2,305	1,496	26,855	4475.75	
TOTAL Toe Drain	1945.00 LF	80,405	16,081	0	9,649	6,262	112,397	57.79	
11.02.02.12 Foundation Preparation									
11.02.02.12.43 Foundation Preparation	2495.00 SY	1,033	207	0	124	80	1,444	0.58	
TOTAL Foundation Preparation	2495.00 SY	1,033	207	0	124	80	1,444	0.58	
11.02.02.13 Backfill Remainder									
11.02.02.13.44 Backfill to Final Elevation									
11.02.02.13.44.01 Backfill to Final Elevation	6553.00 BCY	95,262	19,052	0	11,431	7,419	133,165	20.32	
TOTAL Backfill to Final Elevation	6553.00 BCY	95,262	19,052	0	11,431	7,419	133,165	20.32	
TOTAL Backfill Remainder	6553.00 BCY	95,262	19,052	0	11,431	7,419	133,165	20.32	
TOTAL Floodwalls	1.00 EA	9,023,878	1,804,776	0	1,082,865	702,780	12,614,299	12614299	
TOTAL Floodwalls	1.00 EA	9,023,878	1,804,776	0	1,082,865	702,780	12,614,299	12614299	
TOTAL Levees and Floodwalls	1.00 EA	10,717,604	2,143,521	0	1,286,112	834,687	14,981,924	14981924	
13 Pump Plants									
13.01 Pump Plant									

** PROJECT OWNER SUMMARY - Assembly **

	QUANTITY	UOM	CONTRACT	CONTING	ESCALATN	E&D	S&A	TOTAL COST	UNIT COST	NOTES
13.01.01 Modify Pump Plants										
13.01.01.01 Modify Kansas Avenue Pump Plant										
13.01.01.01.45 Wall Stiffner										
13.01.01.01.45. 1 Sand Blasting	20.00	SF	111	22	0	13	9	155	7.73	
13.01.01.01.45. 3 Concrete	1.85	CY	902	180	0	108	70	1,261	681.63	
13.01.01.01.45. 4 Forms	60.00	SF	1,212	242	0	145	94	1,695	28.25	
13.01.01.01.45. 5 Reinforcing Steel	827.00	LB	1,358	272	0	163	106	1,899	2.30	
13.01.01.01.45. 9 Horz Drilg Holes -2"diaX6"Deep	12.00	EA	738	148	0	89	57	1,032	85.98	
13.01.01.01.45.10 Vertcl Drilg Holes -2"diaX6"Deep	12.00	EA	738	148	0	89	57	1,032	85.98	
13.01.01.01.45.15 Grouting of holes	24.00	EA	478	96	0	57	37	668	27.85	
13.01.01.01.45.30 Hole Layout	2.00	HR	342	68	0	41	27	478	239.23	
TOTAL Wall Stiffner	1.00	EA	5,880	1,176	0	706	458	8,220	8219.58	
TOTAL Modify Kansas Avenue Pump Plant	1.00	EA	5,880	1,176	0	706	458	8,220	8219.58	
TOTAL Modify Pump Plants	1.00	EA	5,880	1,176	0	706	458	8,220	8219.58	
13.01.02 New Pump Plant @ Sta 86+10										
TOTAL Pump Plant	1.00	EA	5,880	1,176	0	706	458	8,220	8219.58	
TOTAL Pump Plants	1.00	EA	5,880	1,176	0	706	458	8,220	8219.58	
TOTAL Feasibility Study Estimate for:	1.00	EA	11,487,289	2,274,267	0	1,376,156	858,509	15,996,221	15996221	

Mon 01 Dec 2008 — Tri-Service Automated Cost Engineering System (TRACES) — TIME 14:44:06
Eff. Date 10/01/07 — PROJECT STOPK7: Feasibility Study Estimate for: - South Topeka Unit
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** PROJECT INDIRECT SUMMARY - Feature **

	QUANTITY	UOM	DIRECT	OVERHEAD	% OVRHD	PROFIT	BOND	TOTAL COST	UNIT COST
01 Lands and Damages	1.00	EA	463,805	0	0	0	0	463,805	463804.62
02 Relocations	1.00	EA	300,000	0	0	0	0	300,000	300000.00
11 Levees and Floodwalls	1.00	EA	8,351,629	0	1,249,744	958,137	158,093	10,717,604	10717604
13 Pump Plants	1.00	EA	4,580	0	687	527	87	5,880	5880.03
TOTAL Feasibility Study Estimate for:	1.00	EA	9,120,014	0	1,250,431	958,664	158,180	11,487,289	11487289
Contingency								2,274,267	
SUBTOTAL								13,761,556	
Engineering & Design								1,376,156	
SUBTOTAL								15,137,712	
Supervision & Administration								858,509	
TOTAL INCL OWNER COSTS								15,996,221	

LABOR ID: TPKA0 EQUIP ID: TPKA07 Currency LLARS CREW ID: NAT01A ID: UP01EA

** PROJECT INDIRECT SUMMARY - Assembly **

	QUANTITY	UOM	DIRECT	OVERHEAD	% OVRHD	PROFIT	BOND	TOTAL COST	UNIT COST
01 Lands and Damages									
01.23 Land Values									
01.23.01 Land Values									
01.23.01.01 Land Values									
01.23.01.01.01 Tract 1	0.50	ACR	15,586	0	0	0	0	15,586	31436.74
01.23.01.01.02 Tract 2	0.21	ACR	1,411	0	0	0	0	1,411	6828.93
01.23.01.01.04 Tract 4	1.51	ACR	7,748	0	0	0	0	7,748	5130.87
01.23.01.01.05 Tract 5	114.76	ACR	401,660	0	0	0	0	401,660	3500.00
TOTAL Land Values	1.00	EA	426,405	0	0	0	0	426,405	426404.62
01.23.01.02 Non Federal Sponsors Costs									
01.23.01.02.06 NFS Costs for Borrow Area	1.00	EA	8,440	0	0	0	0	8,440	8440.00
01.23.01.02.07 NFS Costs for Floodwall	1.00	EA	21,600	0	0	0	0	21,600	21600.00
01.23.01.02.08 NFS Costs for Underseep Berm	1.00	EA	7,360	0	0	0	0	7,360	7360.00
TOTAL Non Federal Sponsors Costs	1.00	EA	37,400	0	0	0	0	37,400	37400.00
01.23.01.03 Federal Costs (Included in FED)									
TOTAL Land Values	1.00	EA	463,805	0	0	0	0	463,805	463804.62
TOTAL Land Values	1.00	EA	463,805	0	0	0	0	463,805	463804.62
TOTAL Lands and Damages	1.00	EA	463,805	0	0	0	0	463,805	463804.62
02 Relocations									
02.01 Utility Relocations									
02.01.03 Cemetery, Utilities, & Structure									
02.01.03.18 Util Crossing Levee									
02.01.03.18.08 Util Crossing Levee (allowance)	1.00	EA	200,000	0	0	0	0	200,000	200000.00
TOTAL Util Crossing Levee	1.00	EA	200,000	0	0	0	0	200,000	200000.00
02.01.03.20 Fencing, Gates, & Power Poles									
02.01.03.20.09 Fencing, Gates, and Power Poles	1.00	EA	100,000	0	0	0	0	100,000	100000.00

** PROJECT INDIRECT SUMMARY - Assembly **

	QUANTITY	UOM	DIRECT	OVERHEAD	% OVRHD	PROFIT	BOND	TOTAL COST	UNIT COST
TOTAL Fencing, Gates, & Power Poles	1.00	EA	100,000	0	0	0	0	100,000	100000.00
TOTAL Cemetery, Utilities, & Structure			300,000	0	0	0	0	300,000	
TOTAL Utility Relocations	1.00	EA	300,000	0	0	0	0	300,000	300000.00
TOTAL Relocations	1.00	EA	300,000	0	0	0	0	300,000	300000.00
06 Fish & Wildlife Facilities									
11 Levees and Floodwalls									
11.01 Levees									
11.01.02 Borrow Site									
11.01.02.05 Site Prep Borrow Site									
11.01.02.05.10 Site Prep New Borrow Site	17304.00	CY	24,264	0	3,640	2,790	460	31,154	1.80
TOTAL Site Prep Borrow Site	1.00	EA	24,264	0	3,640	2,790	460	31,154	31154.35
11.01.02.10 Final Grade Borrow Site									
11.01.02.10.11 Final Grade Borrow Site	14815.00	CY	21,862	0	3,279	2,514	415	28,071	1.89
TOTAL Final Grade Borrow Site	1.00	EA	21,862	0	3,279	2,514	415	28,071	28070.74
TOTAL Borrow Site	1.00	EA	46,126	0	6,919	5,305	875	59,225	59225.09
11.01.03 Levee Stripping									
11.01.03.07 Sta 22+00 to 48+00									
11.01.03.07.12 Doze Material to Levee									
11.01.03.07.12.01 Doze Material to Levee	5778.00	BCY	4,918	0	738	566	93	6,314	1.09
TOTAL Doze Material to Levee	5778.00	BCY	4,918	0	738	566	93	6,314	1.09
11.01.03.07.13 Replace Material when Complete	5778.00	BCY	5,264	0	790	605	100	6,759	1.17
TOTAL Sta 22+00 to 48+00	5778.00	BCY	10,182	0	1,527	1,171	193	13,073	2.26
TOTAL Levee Stripping	5778.00	BCY	10,182	0	1,527	1,171	193	13,073	2.26
11.01.06 Underseepage Berm (New)									

** PROJECT INDIRECT SUMMARY - Assembly **

	QUANTITY	UOM	DIRECT	OVERHEAD	OVRHD	PROFIT	BOND	TOTAL COST	UNIT COST
11.01.06.16 Sta 22-00 to 48+00									
11.01.06.16.14 Excavate Material from Borrow									
11.01.06.16.14.01 Excavate & Haul	48150.00	BCY	222,321	0	33,348	25,567	4,219	285,455	5.93
TOTAL Excavate Material from Borrow	48150.00	BCY	222,321	0	33,348	25,567	4,219	285,455	5.93
11.01.06.16.15 Place Mat'l	48150.00	BCY	57,343	0	8,601	6,594	1,088	73,626	1.53
TOTAL Sta 22-00 to 48+00	48150.00	BCY	279,664	0	41,950	32,161	5,307	359,081	7.46
TOTAL Underseepage Berm (New)	38520.00	CCY	279,664	0	41,950	32,161	5,307	359,081	9.32
11.01.07 Seeding & Mulching									
11.01.07.01 Seeding & Mulching									
11.01.07.01.16 Seeding & Mulching									
11.01.07.01.16.01 Seeding & Mulching	8.00	ACR	12,000	0	1,800	1,380	228	15,408	1925.96
TOTAL Seeding & Mulching	8.00	ACR	12,000	0	1,800	1,380	228	15,408	1925.96
TOTAL Seeding & Mulching	8.00	ACR	12,000	0	1,800	1,380	228	15,408	1925.96
TOTAL Seeding & Mulching	8.00	ACR	12,000	0	1,800	1,380	228	15,408	1925.96
11.01.08 Rem Aggr Surfacing at FW									
11.01.08.05 Remove Aggregate Surfacing									
11.01.08.05.17 Excavate Aggregate from FW	756.00	BCY	3,433	0	515	395	65	4,408	5.83
TOTAL Remove Aggregate Surfacing	756.00	BCY	3,433	0	515	395	65	4,408	5.83
TOTAL Rem Aggr Surfacing at FW	756.00	BCY	3,433	0	515	395	65	4,408	5.83
11.01.09 Repl Aggr Surfacing At FW									
11.01.09.27 Replace Aggregate Surfacing									
11.01.09.27.18 Replace Aggregate Surfacing									
11.01.09.27.18.01 Replace Aggregate Surfacing	1436.00	TON	27,553	0	4,133	3,169	523	35,377	24.64
TOTAL Replace Aggregate Surfacing	1436.00	TON	27,553	0	4,133	3,169	523	35,377	24.64

** PROJECT INDIRECT SUMMARY - Assembly **

	QUANTITY UOM	DIRECT	OVERHEAD	% OVRHD	PROFIT	BOND	TOTAL COST	UNIT COST
TOTAL Replace Aggregate Surfacing	1436.00 TON	27,553	0	4,133	3,169	523	35,377	24.64
TOTAL Repl Aggr Surfacing At FW	756.00 CY	27,553	0	4,133	3,169	523	35,377	46.79
11.01.13 Drainage Systems								
11.01.13.01 Shoring - Augercast Piles								
11.01.13.01.19 Mob/Demob of Crane								
11.01.13.01.19.01 Initial Mob of Crane	2.00 DAY	20,000	0	0	0	0	20,000	10000.00
TOTAL Mob/Demob of Crane	2.00 DAY	20,000	0	0	0	0	20,000	10000.00
11.01.13.01.20 Setup Crane								
11.01.13.01.20.01 Setup Crane	1.00 EA	1,344	0	202	155	25	1,725	1725.49
TOTAL Setup Crane	1.00 EA	1,344	0	202	155	25	1,725	1725.49
11.01.13.01.21 Setup Pile Equipment								
11.01.13.01.21.01 Setup Pile Equipment	1.00 EA	3,840	0	576	442	73	4,931	4930.72
TOTAL Setup Pile Equipment	1.00 EA	3,840	0	576	442	73	4,931	4930.72
11.01.13.01.22 Set Template & Layout								
11.01.13.01.22.01 Set Template & Layout	1.00 EA	78,785	0	11,818	9,060	1,495	101,158	101158.44
TOTAL Set Template & Layout	1.00 EA	78,785	0	11,818	9,060	1,495	101,158	101158.44
11.01.13.01.23 Install Augercast Piles								
11.01.13.01.23.01 Install Augercast Piles	4800.00 LF	75,520	0	11,328	8,685	1,433	96,966	20.20
TOTAL Install Augercast Piles	4800.00 LF	75,520	0	11,328	8,685	1,433	96,966	20.20
11.01.13.01.24 Augercast Piling Material								
11.01.13.01.24.01 Augercast Piling Material	4800.00 LF	62,943	0	9,441	7,238	1,194	80,817	16.84
TOTAL Augercast Piling Material	4800.00 LF	62,943	0	9,441	7,238	1,194	80,817	16.84
TOTAL Shoring - Augercast Piles	4800.00 LF	242,432	0	33,365	25,580	4,221	305,597	63.67

** PROJECT INDIRECT SUMMARY - Assembly **

	QUANTITY	UOM	DIRECT	OVERHEAD	% OVRHD	PROFIT	BOND	TOTAL COST	UNIT COST
11.01.13.16 Gatewell - Sta 75+62									
11.01.13.16.25 Base Slab	7.00	CY	3,445	0	517	396	65	4,423	631.89
11.01.13.16.26 1st Lift (Wall)	27.41	CY	19,152	0	2,873	2,203	363	24,591	897.16
11.01.13.16.27 2nd Lift (Wall)	27.41	CY	19,039	0	2,856	2,190	361	24,446	891.86
11.01.13.16.28 3rd Lift (Wall)	20.56	CY	16,966	0	2,545	1,951	322	21,784	1059.51
11.01.13.16.29 4th Lift (Wall)	10.28	CY	9,073	0	1,361	1,043	172	11,649	1133.16
11.01.13.16.30 Elevated Slab	4.64	CY	3,423	0	513	394	65	4,395	947.14
11.01.13.16.31 Metals			71,354	0	10,703	8,206	1,354	91,617	
11.01.13.16.32 Pipe	30.00	LF	16,935	0	2,540	1,948	321	21,744	724.81
11.01.13.16.33 Cradle	11.11	CY	3,994	0	599	459	76	5,128	461.55
11.01.13.16.34 Concrete Collar	2.67	CY	1,940	0	291	223	37	2,490	932.75
11.01.13.16.35 Outlet Structure for 48" RCP									
11.01.13.16.35.01 Toe	3.47	CY	1,217	0	183	140	23	1,563	450.37
11.01.13.16.35.03 Slab	8.16	CY	3,519	0	528	405	67	4,518	553.73
11.01.13.16.35.04 Wingwall	5.30	CY	4,927	0	739	567	93	6,326	1193.39
11.01.13.16.35.05 Headwall	4.10	CY	48,120	0	7,218	5,534	913	61,785	15069.54
11.01.13.16.35.06 Riprap	15.56	CY	1,192	0	179	137	23	1,530	98.36
TOTAL Outlet Structure for 48" RCP	1.00	EA	58,975	0	8,846	6,782	1,119	75,723	75722.79
TOTAL Gatewell - Sta 75+62	1.00	EA	224,295	0	33,644	25,794	4,256	287,990	287989.70
11.01.13.20 New Pump Plant @ Sta 86+10									
11.01.13.22 GW @ Sta 88+69									
11.01.13.22.36 Base Slab	7.17	CY	3,551	0	533	408	67	4,560	635.96
11.01.13.22.37 1st Lift (Wall)	24.07	CY	17,013	0	2,552	1,956	323	21,844	907.52
11.01.13.22.38 2nd Lift (Wall)	24.07	CY	16,873	0	2,531	1,940	320	21,665	900.09
11.01.13.22.39 3rd Lift (Wall)	16.94	CY	14,087	0	2,113	1,620	267	18,087	1067.72
11.01.13.22.40 4th Lift (Wall)	8.47	CY	7,534	0	1,130	866	143	9,673	1142.02
11.01.13.22.41 Elevated Slab	3.44	CY	2,895	0	434	333	55	3,717	1080.55
11.01.13.22.42 Metals			61,473	0	9,221	7,069	1,166	78,930	
11.01.13.22.43 Pipe	30.00	LF	7,490	0	1,123	861	142	9,617	320.55
11.01.13.22.44 Cradle	11.11	CY	3,994	0	599	459	76	5,128	461.55
11.01.13.22.45 Concrete Collar	2.67	CY	1,940	0	291	223	37	2,490	932.75
11.01.13.22.46 Outlet Structure for 36" RCP									
11.01.13.22.46.01 Toe	3.47	CY	1,217	0	183	140	23	1,563	450.37
11.01.13.22.46.03 Slab	8.16	CY	3,519	0	528	405	67	4,518	553.73
11.01.13.22.46.04 Wingwall	5.30	CY	4,927	0	739	567	93	6,326	1193.59
11.01.13.22.46.05 Headwall	4.10	CY	40,163	0	6,024	4,619	762	51,568	12577.56
11.01.13.22.46.06 Riprap	15.56	CY	1,165	0	175	134	22	1,496	96.17
TOTAL Outlet Structure for 36" RCP	1.00	EA	50,991	0	7,649	5,864	968	65,472	65471.65

** PROJECT INDIRECT SUMMARY - Assembly **

	QUANTITY	UOM	DIRECT	OVERHEAD	% OVRHD	PROFIT	BOND	TOTAL COST	UNIT COST
TOTAL GW @ Sta 88-69	1.00	EA	187,840	0	28,176	21,602	3,564	241,182	241182.24
11.01.13.24 GW @ Sta 91+02									
11.01.13.24.47 Base Slab	7.00	CY	3,445	0	517	396	65	4,423	631.89
11.01.13.24.48 1st Lift (Wall)	27.41	CY	19,147	0	2,872	2,202	363	24,584	896.91
11.01.13.24.49 2nd Lift (Wall)	27.41	CY	19,039	0	2,856	2,190	361	24,446	891.86
11.01.13.24.50 3rd Lift (Wall)	20.56	CY	16,966	0	2,545	1,951	322	21,784	1059.51
11.01.13.24.51 4th Lift (Wall)	10.28	CY	9,070	0	1,360	1,043	172	11,646	1132.83
11.01.13.24.52 Elevated Slab	4.64	CY	3,423	0	513	394	65	4,395	947.14
11.01.13.24.53 Metals			81,384	0	12,208	9,359	1,544	104,496	
11.01.13.24.54 Pipe	30.00	LF	13,750	0	2,063	1,581	261	17,655	588.49
11.01.13.24.55 Cradle	11.11	CY	3,994	0	599	459	76	5,128	461.55
11.01.13.24.56 Concrete Collar	2.67	CY	1,940	0	291	223	37	2,490	932.75
11.01.13.24.57 Outlet Structure for 54" RCP									
11.01.13.24.57.01 Toe	3.47	CY	1,217	0	183	140	23	1,563	450.37
11.01.13.24.57.03 Slab	8.16	CY	3,519	0	528	405	67	4,518	553.73
11.01.13.24.57.04 Wingwall	5.30	CY	4,927	0	739	567	93	6,326	1193.59
11.01.13.24.57.05 Headwall	4.10	CY	55,843	0	8,376	6,422	1,060	71,701	17487.93
11.01.13.24.57.06 Riprap	15.56	CY	1,165	0	175	134	22	1,496	96.17
TOTAL Outlet Structure for 54" RCP	1.00	EA	66,671	0	10,001	7,667	1,265	85,604	85604.20
TOTAL GW @ Sta 91-02	1.00	EA	238,829	0	35,824	27,465	4,532	306,650	306650.14
11.01.13.26 Inlet @ Sta 84+10									
11.01.13.26.58 Excavation									
11.01.13.26.58.24 Exc within Piles for Pump Plant	424.00	BCY	2,735	0	410	314	52	3,511	8.28
TOTAL Excavation	424.00	CY	2,735	0	410	314	52	3,511	8.28
11.01.13.26.59 Backfilling									
11.01.13.26.59.32 Backfilling	498.82	BCY	7,651	0	1,148	880	145	9,823	19.69
TOTAL Backfilling	424.00	CCY	7,651	0	1,148	880	145	9,823	23.17
11.01.13.26.60 Construct Heel Extensions									
11.01.13.26.60.01 Base Slab	1.53	CY	1,252	0	188	144	24	1,608	1051.04
11.01.13.26.60.02 Buttress	1.48	CY	2,127	0	319	245	40	2,731	1845.48
11.01.13.26.60.03 Horz Drilg Holes -2"dia X 6"Deep	40.00	EA	1,916	0	287	220	36	2,460	61.51
11.01.13.26.60.05 Grouting of holes	40.00	EA	621	0	93	71	12	797	19.92

** PROJECT INDIRECT SUMMARY - Assembly **

	QUANTITY UOM	DIRECT	OVERHEAD	? OVRHD	PROFIT	BOND	TOTAL COST	UNIT COST
11.01.13.26.69.06 Hole Layout	2.00 HR	267	0	40	31	5	342	171.13
TOTAL Construct Heel Extensions	1.00 EA	6,183	0	927	711	117	7,939	7938.92
TOTAL Inlet @ Sta 84-10	1.00 EA	16,568	0	2,485	1,905	314	21,273	21273.21
11.01.13.28 Inlet @ Sta 84-10a								
11.01.13.28.61 Excavation								
11.01.13.28.61.24 Exc within Piles for Pump Plant	424.00 BCY	2,735	0	410	314	52	3,511	8.28
TOTAL Excavation	424.00 CY	2,735	0	410	314	52	3,511	8.28
11.01.13.28.62 Backfilling								
11.01.13.28.62.32 Backfilling	498.82 BCY	7,651	0	1,148	880	145	9,823	19.69
TOTAL Backfilling	424.00 CCY	7,651	0	1,148	880	145	9,823	23.17
11.01.13.28.63 Construct Heel Extensions								
11.01.13.28.63.01 Base Slab	1.53 CY	1,252	0	188	144	24	1,608	1051.04
11.01.13.28.63.02 Buttress	1.48 CY	2,127	0	319	245	40	2,731	1844.99
11.01.13.28.63.03 Horz Drilg Holes -2"dia X 6"Deep	40.00 EA	1,916	0	287	220	36	2,460	61.51
11.01.13.28.63.05 Grouting of holes	40.00 EA	621	0	93	71	12	797	19.92
11.01.13.28.63.06 Hole Layout	2.00 HR	267	0	40	31	5	342	171.13
TOTAL Construct Heel Extensions	1.00 EA	6,183	0	927	711	117	7,938	7938.20
TOTAL Inlet @ Sta 84+10a	1.00 EA	16,568	0	2,485	1,905	314	21,272	21272.49
11.01.13.30 Inlet @ Sta 85+57								
11.01.13.30.64 Excavation for Heel #1								
11.01.13.30.64.24 Excavation for Heel Extension	265.00 BCY	2,188	0	328	252	42	2,809	10.60
TOTAL Excavation for Heel #1	265.00 CY	2,188	0	328	252	42	2,809	10.60
11.01.13.30.65 Backfilling for Heel #1								
11.01.13.30.65.32 Backfilling	311.76 BCY	3,938	0	591	453	75	5,056	16.22
TOTAL Backfilling for Heel #1	265.00 CCY	3,938	0	591	453	75	5,056	19.08

** PROJECT INDIRECT SUMMARY - Assembly **

	QUANTITY	UOM	DIRECT	OVERHEAD	% OVRHD	PROFIT	BOND	TOTAL COST	UNIT COST
11.01.13.30.66 Construct Heel Extension #1									
11.01.13.30.66.01 Base Slab	1.63	CY	1,340	0	201	154	25	1,720	1055.52
11.01.13.30.66.02 Buttress	0.37	CY	565	0	85	65	11	726	1961.66
11.01.13.30.66.03 Horz Drilg Holes -2"dia X 6"Deep	36.00	EA	1,725	0	259	198	33	2,214	61.51
11.01.13.30.66.05 Grouting of holes	36.00	EA	559	0	84	64	11	717	19.92
11.01.13.30.66.06 Hole Layout	2.00	HR	267	0	40	31	5	342	171.13
TOTAL Construct Heel Extension #1	1.00	EA	4,455	0	668	512	85	5,720	5720.10
11.01.13.30.67 Excavation for Heel #2									
11.01.13.30.67.24 Excavation for Heel Extension	180.00	BCY	1,094	0	164	126	21	1,404	7.80
TOTAL Excavation for Heel #2	180.00	CY	1,094	0	164	126	21	1,404	7.80
11.01.13.30.68 Backfiling for Heel #2									
11.01.13.30.68.32 Backfilling	211.76	BCY	3,090	0	464	355	59	3,968	18.74
TOTAL Backfilling for Heel #2	180.00	CCY	3,090	0	464	355	59	3,968	22.04
11.01.13.30.69 Construct Heel Extension #2									
11.01.13.30.69.01 Base Slab	0.97	CY	826	0	124	95	16	1,061	1093.35
11.01.13.30.69.02 Buttress	0.37	CY	554	0	83	64	11	711	1922.62
11.01.13.30.69.03 Horz Drilg Holes -2"dia X 6"Deep	26.00	EA	1,246	0	187	143	24	1,599	61.51
11.01.13.30.69.05 Grouting of holes	26.00	EA	403	0	61	46	8	518	19.92
11.01.13.30.69.06 Hole Layout	2.00	HR	267	0	40	31	5	342	171.13
TOTAL Construct Heel Extension #2	1.00	EA	3,296	0	494	379	63	4,231	4231.40
TOTAL Inlet @ Sta 85+57	1.00	EA	18,060	0	2,709	2,077	343	23,189	23188.65
TOTAL Drainage Systems	1.00	EA	944,593	0	138,689	106,328	17,544	1,207,154	1207154
TOTAL Levees	1.00	EA	1,323,550	0	195,532	149,908	24,735	1,693,725	1693725
11.02 Floodwalls									
11.02.02 Floodwalls									
11.02.02.01 Demolish Existing Floodwall									
11.02.02.01.25 Excavation for Demolition									

** PROJECT INDIRECT SUMMARY - Assembly **

	QUANTITY UOM	DIRECT	OVERHEAD	^ OVRHD	PROFIT	BOND	TOTAL COST	UNIT COST
11.02.02.01.25.03 Excavate to Base	7169.00 CY	84,769	0	12,715	9,748	1,608	108,841	15.18
TOTAL Excavation for Demolition	1.00 EA	84,769	0	12,715	9,748	1,608	108,841	108841.24
11.02.02.01.26 Demolition of Exist Floodwall								
11.02.02.01.26.01 Demolish Exist Floodwall	3667.00 CY	269,699	0	40,455	31,015	5,118	346,286	94.43
11.02.02.01.26.02 Load & Haul Demo Debris	3667.00 CY	238,373	0	35,756	27,413	4,523	306,066	83.16
11.02.02.01.26.03 Dispose of Demo Debris	3667.00 CY	42,545	0	6,382	4,893	807	54,626	14.90
TOTAL Demolition of Exist Floodwall	3667.00 CY	550,617	0	82,592	63,321	10,448	706,978	192.79
11.02.02.01.27 Backfill to New Base elevation								
11.02.02.01.27.01 Backfill to New Base Elevation	2666.00 BCY	28,574	0	4,286	3,286	542	36,688	13.76
TOTAL Backfill to New Base elevation	1.00 EA	28,574	0	4,286	3,286	542	36,688	36688.24
11.02.02.01.28 RW MH Protection (Allowance)	20.00 EA	20,000	0	3,000	2,300	380	25,680	1283.98
TOTAL Demolish Existing Floodwall	3667.00 CY	683,959	0	102,594	78,655	12,978	878,187	239.48
11.02.02.02 Place Rockfill								
11.02.02.02.29 Rockfill placed riverside of FW								
11.02.02.02.29.06 Haul/Stockpile Rockfill for Emer	5667.00 TON	76,505	0	11,476	8,798	1,452	98,230	17.33
11.02.02.02.29.07 Haul and Stockpile Rockfill	29934.00 TON	404,109	0	60,616	46,473	7,668	518,866	17.33
11.02.02.02.29.08 Place Rockfill	29934.00 TON	226,301	0	33,945	26,025	4,294	290,565	9.71
11.02.02.02.29.09 Finish Rockfill	29934.00 TON	12,312	0	1,847	1,416	234	15,808	0.53
11.02.02.02.29.10 Place Pipe Crossings (allowance)	6.00 EA	30,000	0	4,500	3,450	569	38,519	6419.87
TOTAL Rockfill placed riverside of FW	29934.00 TON	749,227	0	112,384	86,161	14,217	961,989	32.14
TOTAL Place Rockfill	29934.00 TON	749,227	0	112,384	86,161	14,217	961,989	32.14
11.02.02.03 Pipe Piles								
11.02.02.03.30 Install Pipe Piles								
11.02.02.03.30.01 Pipe Pile Materials	11137.50 VLF	642,363	0	96,355	73,872	12,189	824,779	74.05
11.02.02.03.30.02 Install Pipe Piles	9900.00 VLF	238,376	0	35,756	27,413	4,523	306,069	30.92
11.02.02.03.30.03 Install Pile Caps & Rebar	220.00 EA	39,040	0	5,856	4,490	741	50,127	227.85
11.02.02.03.30.04 Siesmic Monitoring	1.00 EA	3,800	0	570	437	72	4,879	4879.11
TOTAL Install Pipe Piles	9900.00 VLF	923,580	0	138,537	106,212	17,525	1,185,853	119.78

** PROJECT INDIRECT SUMMARY - Assembly **

	QUANTITY COM	DIRECT	OVERHEAD	% OVRHD	PROFIT	BOND	TOTAL COST	UNIT COST
TOTAL Pipe Piles	9900.00 VLF	923,580	0	138,537	106,212	17,525	1,185,853	119.78
11.02.02.04 Sheetpile Cutoff Wall								
11.02.02.04.31 Mob/Demob Crane	1.00 EA	24,886	0	3,733	2,862	472	31,954	31953.52
TOTAL Mob/Demob Crane	1.00 EA	24,886	0	3,733	2,862	472	31,954	31953.52
11.02.02.04.32 Install Template								
11.02.02.04.32.01 Install Template	1.00 EA	93,185	0	13,978	10,716	1,768	119,647	119647.17
TOTAL Install Template	1.00 EA	93,185	0	13,978	10,716	1,768	119,647	119647.17
11.02.02.04.33 Install Sheetpiling								
11.02.02.04.33.01 Sheetpile Materials	48625.00 SF	678,867	0	101,830	78,070	12,881	871,648	17.93
11.02.02.04.33.02 Install Sheetpile	38900.00 SF	936,573	0	140,486	107,706	17,771	1,202,536	30.91
TOTAL Install Sheetpiling	38900.00 SF	1,615,440	0	242,316	185,776	30,653	2,074,184	53.32
TOTAL Sheetpile Cutoff Wall	38900.00 SF	1,733,511	0	260,027	199,354	32,893	2,225,785	57.22
11.02.02.05 Floodwall Base								
11.02.02.05.34 Monolith 1								
11.02.02.05.34.01 Forming (Slab)	115.00 CY	5,257	0	789	605	100	6,750	58.70
11.02.02.05.34.02 Reinforcing	115.00 CY	23,325	0	3,499	2,682	443	29,948	260.42
11.02.02.05.34.03 Concrete	115.00 CY	23,052	0	3,458	2,651	437	29,598	257.38
11.02.02.05.34.04 Finishing	115.00 CY	1,624	0	244	187	31	2,086	18.13
11.02.02.05.34.05 Misc	115.00 CY	122	0	18	14	2	156	1.36
11.02.02.05.34.06 Crane Support	115.00 CY	6,104	0	916	702	116	7,837	68.15
TOTAL Monolith 1	115.00 CY	59,484	0	8,923	6,841	1,129	76,376	664.13
11.02.02.05.35 Monolith 2 thru 23								
11.02.02.05.35.01 Forming (Slab)	2415.00 CY	102,072	0	15,311	11,738	1,937	131,058	54.27
11.02.02.05.35.02 Reinforcing	2415.00 CY	489,818	0	73,473	56,329	9,294	628,915	260.42
11.02.02.05.35.03 Concrete	2415.00 CY	484,096	0	72,614	55,671	9,186	621,568	257.38
11.02.02.05.35.04 Finishing	2415.00 CY	33,529	0	5,029	3,856	636	43,050	17.83
11.02.02.05.35.05 Misc	2415.00 CY	2,558	0	384	294	49	3,284	1.36
11.02.02.05.35.06 Crane Support	2415.00 CY	128,177	0	19,227	14,740	2,432	164,576	68.15

** PROJECT INDIRECT SUMMARY - Assembly **

	QUANTITY	UOM	DIRECT	OVERHEAD	* OVRHD	PROFIT	BOND	TOTAL COST	UNIT COST
TOTAL Monolith 2 thru 23	2415.00	CY	1,240,251	0	186,038	142,629	23,534	1,592,451	659.40
TOTAL Floodwall Base	2530.00	CY	1,299,734	0	194,960	149,469	24,662	1,668,826	659.62
11.02.02.07 Floodwall Stem									
11.02.02.07.36 Stem on Monolith 1									
11.02.02.07.36.01 Forming	17.78	CY	13,579	0	2,037	1,562	258	17,435	980.61
11.02.02.07.36.02 Reinforcing	17.78	CY	3,865	0	580	444	73	4,962	279.09
11.02.02.07.36.03 Concrete	17.78	CY	5,683	0	852	654	108	7,297	410.39
11.02.02.07.36.04 Finishing	17.78	CY	967	0	145	111	18	1,241	69.82
11.02.02.07.36.05 Misc	17.78	CY	537	0	81	62	10	690	38.79
11.02.02.07.36.06 Crane Support	17.78	CY	200	0	30	23	4	257	14.46
TOTAL Stem on Monolith 1	17.78	CY	24,831	0	3,725	2,856	471	31,882	1793.15
11.02.02.07.37 Stem on Monoliths 2 thru 65									
11.02.02.07.37.01 Forming	1137.92	CY	855,041	0	128,256	98,330	16,224	1,097,851	964.79
11.02.02.07.37.02 Reinforcing	1137.92	CY	247,319	0	37,098	28,442	4,693	317,552	279.06
11.02.02.07.37.03 Concrete	1137.92	CY	264,186	0	39,628	30,381	5,013	339,208	298.09
11.02.02.07.37.04 Finishing	1137.92	CY	60,991	0	9,149	7,014	1,157	78,311	68.82
11.02.02.07.37.05 Misc	1137.92	CY	35,269	0	5,290	4,056	669	45,285	39.80
11.02.02.07.37.06 Crane Support	1137.92	CY	12,811	0	1,922	1,473	243	16,449	14.46
TOTAL Stem on Monoliths 2 thru 65	1137.92	CY	1,475,617	0	221,343	169,696	28,000	1,894,655	1665.02
TOTAL Floodwall Stem	1155.70	CY	1,500,448	0	225,067	172,552	28,471	1,926,538	1666.99
11.02.02.08 Toe Drain									
11.02.02.08.38 Excavate for Toe Drain									
11.02.02.08.38.01 Exc Trench for Toe Drain @ FW	675.00	BCY	2,921	0	438	336	55	3,750	5.56
TOTAL Excavate for Toe Drain	675.00	BCY	2,921	0	438	336	55	3,750	5.56
11.02.02.08.39 Place Filter Fabric									
11.02.02.08.39.01 Place Filter Fabric	29205.00	SF	5,675	0	851	653	108	7,286	0.25
TOTAL Place Filter Fabric	29205.00	SF	5,675	0	851	653	108	7,286	0.25
11.02.02.08.40 Place PVC Pipe									

** PROJECT INDIRECT SUMMARY - Assembly **

	QUANTITY UOM	DIRECT	OVERHEAD	% OVRHD	PROFIT	BOND	TOTAL COST	UNIT COST
11.02.02.08.40.01 Place PVC Pipe	1945.00 LF	19,420	0	2,913	2,233	368	24,935	12.82
TOTAL Place PVC Pipe	1945.00 LF	19,420	0	2,913	2,233	368	24,935	12.82
11.02.02.08.41 Fill For Toe Drain								
11.02.02.08.41.01 Fill For Toe Drain	750.00 BCY	19,645	0	2,947	2,259	373	25,224	33.63
TOTAL Fill For Toe Drain	750.00 BCY	19,645	0	2,947	2,259	373	25,224	33.63
11.02.02.08.42 Riser protection								
11.02.02.08.42.01 Concrete Pad	6.00 EA	3,206	0	481	369	61	4,117	686.17
11.02.02.08.42.02 RCP Manhole Riser w/lid	6.00 EA	8,626	0	1,294	992	164	11,076	1845.93
11.02.02.08.42.03 Guard Post	6.00 EA	3,130	0	469	360	59	4,018	669.72
TOTAL Riser protection	6.00 EA	14,962	0	2,244	1,721	284	19,211	3201.81
TOTAL Toe Drain	1945.00 LF	62,622	0	9,393	7,202	1,188	80,405	41.34
11.02.02.12 Foundation Preparation								
11.02.02.12.43 Foundation Preparation	2495.00 SY	805	0	121	93	15	1,033	0.41
TOTAL Foundation Preparation	2495.00 SY	805	0	121	93	15	1,033	0.41
11.02.02.13 Backfill Remainder								
11.02.02.13.44 Backfill to Final Elevation								
11.02.02.13.44.01 Backfill to Final Elevation	6553.00 BCY	74,193	0	11,129	8,532	1,408	95,262	14.54
TOTAL Backfill to Final Elevation	6553.00 BCY	74,193	0	11,129	8,532	1,408	95,262	14.54
TOTAL Backfill Remainder	6553.00 BCY	74,193	0	11,129	8,532	1,408	95,262	14.54
TOTAL Floodwalls	1.00 EA	7,028,080	0	1,054,212	808,229	133,358	9,023,878	9023878
TOTAL Floodwalls	1.00 EA	7,028,080	0	1,054,212	808,229	133,358	9,023,878	9023878
TOTAL Levees and Floodwalls	1.00 EA	8,351,629	0	1,249,744	958,137	158,093	10,717,604	10717604

13 Pump Plants

13.01 Pump Plant

Mon 01 Dec 2008 Tri-Service Automated Cost Engineering System (TRACES) TIME 14:44:06
Eff. Date 10/01 PROJECT STOPK7: Feasibility Study Estimate for: - South Topeka Unit
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** PROJECT INDIRECT SUMMARY - Assembly **

	QUANTITY	UOM	DIRECT	OVERHEAD	% OVHD	PROFIT	BOND	TOTAL COST	UNIT COST
13.01.01 Modify Pump Plants									
13.01.01.01 Modify Kansas Avenue Pump Plant									
13.01.01.01.45 Wall Stiffner									
13.01.01.01.45. 1 Sand Blasting	20.00	SF	86	0	13	10	2	111	5.53
13.01.01.01.45. 3 Concrete	1.85	CY	703	0	105	81	13	902	487.62
13.01.01.01.45. 4 Forms	60.00	SF	944	0	142	109	18	1,212	20.21
13.01.01.01.45. 5 Reinforcing Steel	827.00	LB	1,058	0	159	122	20	1,358	1.64
13.01.01.01.45. 9 Horz Drilg Holes -2"diaX6"Deep	12.00	EA	575	0	86	66	11	738	61.51
13.01.01.01.45.10 Vertcl Drilg Holes -2"diaX6"Deep	12.00	EA	575	0	86	66	11	738	61.51
13.01.01.01.45.15 Grouting of holes	24.00	EA	372	0	56	43	7	478	19.92
13.01.01.01.45.30 Hole Layout	2.00	HR	267	0	40	31	5	342	171.13
TOTAL Wall Stiffner	1.00	EA	4,580	0	687	527	87	5,880	5880.03
TOTAL Modify Kansas Avenue Pump Plant	1.00	EA	4,580	0	687	527	87	5,880	5880.03
TOTAL Modify Pump Plants	1.00	EA	4,580	0	687	527	87	5,880	5880.03
13.01.02 New Pump Plant @ Sta 86+10									
TOTAL Pump Plant	1.00	EA	4,580	0	687	527	87	5,880	5880.03
TOTAL Pump Plants	1.00	EA	4,580	0	687	527	87	5,880	5880.03
TOTAL Feasibility Study Estimate for:	1.00	EA	9,120,014	0	1,250,431	958,664	158,180	11,487,289	11487289
Contingency								2,274,267	
SUBTOTAL								13,761,556	
Engineering & Design								1,376,156	
SUBTOTAL								15,137,712	
Supervision & Administration								858,509	
TOTAL INCL OWNER COSTS								15,996,221	

LABOR ID: TPKA07 EQUIP ID: TPKA07 Currency in DOLLARS CREW ID: NAT01A UPB ID: UP01EA

R2032: 0123010101	Permanent Ea	Detail item has zero quantity - no costs reported
R2032: 0123010102	Permanent Ea	Detail item has zero quantity - no costs reported

* * * END OF ERROR REPORT * * *

Mon 01 Dec 2008 Tri-Service Automated Cos' 'neering System (TRACES) IME 14:44:06
Eff. Date 10/0. PROJECT STOPK7: Feasibility Stu .stimate for: - South Topeka Unit
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No Detailed Estimate...

No Backup Reports...

* * * END TABLE OF CONTENTS * * *

Feasibility Study Estimate for:
Water Works
Topeka, Kansas

Designed By: CENWK
Estimated By: CENWK-EC-DC

Prepared By: Patrick Miramontez 816-389-3322
LATEST ESTIMATE AS OF 1 Dec 08

Preparation Date: 12/01/08
Effective Date of Pricing: 10/01/07

Sales Tax: 0.00%

01 - Lands & Damages - The costs include the acquisition of Permanent Right-of-Way, Temporary Right-of-Way, and borrow areas. Also included, where necessary, is the relocation cost of businesses that infringe on the footprint of the raised levee. These costs include Non Federal Sponsors cost to perform the Legal work, Title Work, Tract appraisals, and land surveys.

02 - Relocations - This item currently includes only the relocation of 2 sheds that are at the toe of the floodwall. These are construction costs. These costs are not part of LERRD.

06 - Fish & Wildlife Facilities - N/A

11 - Levees & Floodwalls- The levees cost consists of 4 different components. These components include: 1) Borrow Site Preparation, 2) Stripping, 3) Underseepage Berm, 4) Replacement of strippings, and 5) Seeding and Mulching.

- Borrow Site - It is currently assumed one borrow site will be utilized. It is assumed 100% of the material will come from the borrow sites located approx. 1 mile away. The costs include the preparation of the borrow site, and the final grading of the borrow site when completed.

- Strippings - Quantities for the strippings were based on the removal of the topsoil from the landside of the existing FW. It was assumed this material will be dozed off and windrowed next to the FW. The stripped material will be placed on top of the underseepage berm to facilitate seed.

- Underseepage Berms - Quantities for the levee raise was calculated by hand. It is assumed the Haul distances is 1 mile. The material is to be excavated, loaded, and hauled using on-highway dump trucks over the existing roads . A cost is also included for seeding and mulching.

- Floodwalls - None in this contract.

30 - Estimated Engineering & Design Cost = 10% of project implementation (less lands & damages) cost. Percentage is based on historical data and adjusted for the size of the project.

31 - Estimated Construction Supervision & Administration = 6.5% of project implementation (less lands & damages) cost. Percentage is based on historical data.

Areas of Cost Sensitivity

- Estimate does not include any costs for sampling/testing for HTRW.
- Estimate does not include any costs for the hauling and disposal of HTRW.
- Estimate does not include O&M costs. Only project implementation (construction, real-estate and associated) costs.
- Estimate based on borrow source located approximately 1 mile away. If this borrow is not available for use additional costs will have to be considered.

General Cost Information

- The quantities have been calculated by EC-GD, EC-DC, and EC-DS. A contingency determination meeting will be held with all of the designers to apply the appropriate amount of contingency to each line item.
- No tax has been included for the state of Kansas.
- The source for the labor rates used in the estimate is the Jan 2008 Department of Labor Wage rates for Wyandotte County, Kansas.
- The national 2001 Unit Price Book is used to price minor items. Material prices for minor items were taken from the 2008 RS Means Cost Books. Quotes were received for major cost items. An adjustment factor is added to bring the rates to the appropriate price level date.
- 2007 equipment rates were used.
- Once all of the databases are normalized to the appropriate price level date an escalation factor will be added to the owner level to bring the estimate to the appropriate price level date. The escalation factors used were derived from the Civil Works Construction Cost Index System (CWCCIS) EM1110-2-1304. NOTE: Estimate was originally prepared in March 2006. The databases and materials were updated to Oct 2007 price levels. The price level date is now Oct 2007.

CONTINGENCY DETERMINATION REPORT - The reasons for final contingency development and assignment must be included in the cost estimate as part of the project narrative. When then contingency factors shown in Table 13-1 of EI 01D010 are applied to any portion of the cost estimate up to the feature level, the statement "Normal design variances are expected - Normal contingency values used" is acceptable in addressing that specific portion. For this estimate, 25% contingency is considered normal.

*****NOTE*****

Bid item numbers correspond to the summary sheet Bid Item Level WBS identifier. For example:

09.01.30.02.3 Excavation, Common

The "3" at the end of the number string corresponds to Bid Item No. 3 on this Contingency Determination Report.

*****END NOTE*****

01 Account - LANDS AND DAMAGES
-LAND VALUES
Bid Item Nos. 01 -Typical 15% contingency factor used for Real Estate.
Bid Item Nos. 02 thru 13 - NOT USED.

NON-FEDERAL SPONSORS COSTS -
Bid Item Nos. 14 - Typical 15% contingency factor used for Real estate.

FEDERAL COSTS - NOT USED

02 ACCOUNT - RELOCATIONS
SEEDS
Bid Item No. 16 - 25% - Typical contingency factor was used.

06 ACCOUNT - FISH & WILDLIFE FACILITIES - NOT USED

11 ACCOUNT - LEVEES AND FLOODWALLS

BORROW SITES
Bid Item No. 18 thru 19 - Typical 25% contingency factor used.

STRIPPING
Bid Item No. 20 - Typical 25% contingency factor used.

LEVEES
Bid Item No. 21 - Typical 25% contingency factor used.

REPLACE STRIPPINGS
Bid Item No. 22 - Typical 25% contingency factor used.

SEEDING & MULCHING
Bid Item No. 23 - Typical 25% contingency factor used.

** PROJECT OWNER SUMMARY - Feature **

	QUANTITY UOM	CONTRACT	CONTING	ESCALATN	E&D	S&A	TOTAL COST	UNIT COST	NOTES
01 Lands and Damages	1.00 EA	1,284	193	0	148	0	1,624	1623.67	
02 Relocations	1.00 EA	4,352	1,088	0	544	353	6,338	6337.71	
11 Levees and Floodwalls	1.00 EA	28,657	7,164	0	3,582	2,325	41,729	41728.56	
TOTAL Feasibility Study Estimate for:	1.00 EA	34,293	8,445	0	4,274	2,678	49,690	49689.95	

** PROJECT OWNER SUMMARY - Assembly **

	QUANTITY UOM	CONTRACT	CONTING	ESCALATN	E&D	S&A	TOTAL COST	UNIT COST	NOTES
01 Lands and Damages									
01.23 Land Values									
01.23.01 Land Values									
01.23.01.01 Land Values									
01.23.01.01.01 Tract 1	0.06 ACR	404	61	0	46	0	510	8637.46	
TOTAL Land Values	1.00 EA	404	61	0	46	0	510	510.47	
01.23.01.02 Non Federal Sponsors Costs									
01.23.01.02.14 NFS Costs	1.00 EA	880	132	0	101	0	1,113	1113.20	
TOTAL Non Federal Sponsors Costs	1.00 EA	880	132	0	101	0	1,113	1113.20	
01.23.01.03 Federal Costs (included in PED)									
TOTAL Land Values	1.00 EA	1,284	193	0	148	0	1,624	1623.67	
TOTAL Land Values	1.00 EA	1,284	193	0	148	0	1,624	1623.67	
TOTAL Lands and Damages	1.00 EA	1,284	193	0	148	0	1,624	1623.67	
02 Relocations									
02.01 Utility Relocations									
02.01.03 Cemetery, Utilities, & Structure									
02.01.03.20 Sheds									
02.01.03.20.16 Sheds									
02.01.03.20.16.01 Relocate Existing Sheds	2.00 EA	2,176	544	0	272	177	3,169	1584.43	
02.01.03.20.16.02 Relocate Sheds back to Orig Loc	2.00 EA	2,176	544	0	272	177	3,169	1584.43	
TOTAL Sheds	1.00 EA	4,352	1,088	0	544	353	6,338	6337.71	
TOTAL Sheds	1.00 EA	4,352	1,088	0	544	353	6,338	6337.71	
TOTAL Cemetery, Utilities, & Structure		4,352	1,088	0	544	353	6,338		
TOTAL Utility Relocations	1.00 EA	4,352	1,088	0	544	353	6,338	6337.71	
TOTAL Relocations	1.00 EA	4,352	1,088	0	544	353	6,338	6337.71	

** PROJECT OWNER SUMMARY - Assembly **

	QUANTITY	UOM	CONTRACT	CONTING	ESCALATN	E&D	S&A	TOTAL COST	UNIT COST	NOTES
06 Fish & Wildlife Facilities										
11 Levees and Floodwalls										
11.01 Levees										
11.01.01 Borrow Site										
11.01.01.05 Site Prep Borrow Site										
11.01.01.05.18 Site Prep New Borrow Site	1.00	EA	3,762	940	0	470	305	5,478	5477.89	
TOTAL Site Prep Borrow Site	1.00	EA	3,762	940	0	470	305	5,478	5477.89	
11.01.01.10 Final Grade Site										
11.01.01.10.19 Final Grade Site	1.00	EA	1,996	499	0	250	162	2,907	2907.15	
TOTAL Final Grade Site	1.00	EA	1,996	499	0	250	162	2,907	2907.15	
TOTAL Borrow Site	1.00	EA	5,758	1,440	0	720	467	8,385	8385.05	
11.01.02 Stripping										
11.01.02.07 Stripping										
11.01.02.07.20 Strip Material										
11.01.02.07.20.01 Strip Material & Windrow	235.00	BCY	808	202	0	101	66	1,176	5.00	
TOTAL Strip Material	235.00	BCY	808	202	0	101	66	1,176	5.00	
TOTAL Stripping	235.00	BCY	808	202	0	101	66	1,176	5.00	
TOTAL Stripping	235.00	BCY	808	202	0	101	66	1,176	5.00	
11.01.03 Levees										
11.01.03.13 Place Fill at LS Toe of FW										
11.01.03.13.21 Place Fill at LS Toe of FW										
11.01.03.13.21.01 Place Fill at LS Toe of FW	766.00	BCY	19,358	4,839	0	2,420	1,570	28,187	36.80	
TOTAL Place Fill at LS Toe of FW	766.00	BCY	19,358	4,839	0	2,420	1,570	28,187	36.80	

** PROJECT OWNER SUMMARY - Assembly **

	QUANTITY UOM	CONTRACT	CONTING	ESCALATN	E&D	S&A	TOTAL COST	UNIT COST	NOTES
TOTAL Place Fill at LS Toe of FW	766.00 BCY	19,358	4,839	0	2,420	1,570	28,187	36.80	
TOTAL Levees	1.00 EA	19,358	4,839	0	2,420	1,570	28,187	28187.39	
11.01.04 Replace Strippings									
11.01.04.07 Replace Strippings									
11.01.04.07.22 Replace Strippings									
11.01.04.07.22.01 Replace Strippings	235.00 BCY	808	202	0	101	66	1,176	5.00	
TOTAL Replace Strippings	235.00 BCY	808	202	0	101	66	1,176	5.00	
TOTAL Replace Strippings	235.00 BCY	808	202	0	101	66	1,176	5.00	
TOTAL Replace Strippings	235.00 BCY	808	202	0	101	66	1,176	5.00	
11.01.05 Seeding & Mulching									
11.01.05.01 Seeding & Mulching									
11.01.05.01.23 Seeding & Mulching									
11.01.05.01.23.01 Seeding & Mulching	1.00 ACR	1,926	481	0	241	156	2,804	2804.44	
TOTAL Seeding & Mulching	1.00 ACR	1,926	481	0	241	156	2,804	2804.44	
TOTAL Seeding & Mulching	1.00 ACR	1,926	481	0	241	156	2,804	2804.44	
TOTAL Seeding & Mulching	1.00 ACR	1,926	481	0	241	156	2,804	2804.44	
TOTAL Levees	1.00 EA	28,657	7,164	0	3,582	2,325	41,729	41728.56	
TOTAL Levees and Floodwalls	1.00 EA	28,657	7,164	0	3,582	2,325	41,729	41728.56	
TOTAL Feasibility Study Estimate for:	1.00 EA	34,293	8,443	0	4,274	2,678	49,690	49689.95	

Thu 04 Dec 2008 | Tri-Service Automated Cost Engineering System (TRACES) | TIME 09:55:50
Eff. Date 10/01/07 | PROJECT WATER7: Feasibility Study Estimate for: - Water Works | SUMMARY PAGE 5

** PROJECT INDIRECT SUMMARY - Feature **

	QUANTITY UOM	DIRECT	OVERHEAD	% OVRHD	PROFIT	BOND	TOTAL COST	UNIT COST
01 Lands and Damages	1.00 EA	1,284	0	0	0	0	1,284	1283.54
02 Relocations	1.00 EA	3,390	0	508	390	64	4,352	4352.45
11 Levees and Floodwalls	1.00 EA	22,319	0	3,348	2,567	424	28,657	28657.27
TOTAL Feasibility Study Estimate for:	1.00 EA	26,993	0	3,856	2,957	488	34,293	34293.25
Contingency							8,445	
SUBTOTAL							42,738	
Engineering & Design							4,274	
SUBTOTAL							47,012	
Supervision & Administration							2,678	
TOTAL INCL OWNER COSTS							49,690	

** PROJECT INDIRECT SUMMARY - Assembly **

	QUANTITY UOM	DIRECT	OVERHEAD	% OVRHD	PROFIT	BOND	TOTAL COST	UNIT COST
01 Lands and Damages								
01.23 Land Values								
01.23.01 Land Values								
01.23.01.01 Land Values								
01.23.01.01.01 Tract 1	0.06 ACR	404	0	0	0	0	404	6808.03
TOTAL Land Values	1.00 EA	404	0	0	0	0	404	403.54
01.23.01.02 Non Federal Sponsors Costs								
01.23.01.02.14 NFS Costs	1.00 EA	880	0	0	0	0	880	880.00
TOTAL Non Federal Sponsors Costs	1.00 EA	880	0	0	0	0	880	880.00
01.23.01.03 Federal Costs (included in PED)								
TOTAL Land Values	1.00 EA	1,284	0	0	0	0	1,284	1283.54
TOTAL Land Values	1.00 EA	1,284	0	0	0	0	1,284	1283.54
TOTAL Lands and Damages	1.00 EA	1,284	0	0	0	0	1,284	1283.54
02 Relocations								
02.01 Utility Relocations								
02.01.03 Cemetery, Utilities, & Structure								
02.01.03.20 Sheds								
02.01.03.20.16 Sheds								
02.01.03.20.16.01 Relocate Existing Sheds	2.00 EA	1,695	0	254	195	32	2,176	1088.11
02.01.03.20.16.02 Relocate Sheds back to Orig Loc	2.00 EA	1,695	0	254	195	32	2,176	1088.11
TOTAL Sheds	1.00 EA	3,390	0	508	390	64	4,352	4352.45
TOTAL Sheds	1.00 EA	3,390	0	508	390	64	4,352	4352.45
TOTAL Cemetery, Utilities, & Structure		3,390	0	508	390	64	4,352	
TOTAL Utility Relocations	1.00 EA	3,390	0	508	390	64	4,352	4352.45
TOTAL Relocations	1.00 EA	3,390	0	508	390	64	4,352	4352.45

** PROJECT INDIRECT SUMMARY - Assembly **

	QUANTITY	UOM	DIRECT	OVERHEAD	% OVRHD	PROFIT	BOND	TOTAL COST	UNIT COST
06 Fish & Wildlife Facilities									
11 Levees and Floodwalls									
11.01 Levees									
11.01.01 Borrow Site									
11.01.01.05 Site Prep Borrow Site									
11.01.01.05.18 Site Prep New Borrow Site	1.00	EA	2,930	0	439	337	56	3,762	3761.97
TOTAL Site Prep Borrow Site	1.00	EA	2,930	0	439	337	56	3,762	3761.97
11.01.01.10 Final Grade Site									
11.01.01.10.19 Final Grade Site	1.00	EA	1,555	0	233	179	30	1,996	1996.50
TOTAL Final Grade Site	1.00	EA	1,555	0	233	179	30	1,996	1996.50
TOTAL Borrow Site	1.00	EA	4,485	0	673	516	85	5,758	5758.47
11.01.02 Stripping									
11.01.02.07 Stripping									
11.01.02.07.20 Strip Material									
11.01.02.07.20.01 Strip Material & Windrow	235.00	BCY	629	0	94	72	12	808	3.44
TOTAL Strip Material	235.00	BCY	629	0	94	72	12	808	3.44
TOTAL Stripping	235.00	BCY	629	0	94	72	12	808	3.44
TOTAL Stripping	235.00	BCY	629	0	94	72	12	808	3.44
11.01.03 Levees									
11.01.03.13 Place Fill at LS Toe of FW									
11.01.03.13.21 Place Fill at LS Toe of FW									
11.01.03.13.21.01 Place Fill at LS Toe of FW	766.00	BCY	15,076	0	2,261	1,734	286	19,358	25.27
TOTAL Place Fill at LS Toe of FW	766.00	BCY	15,076	0	2,261	1,734	286	19,358	25.27

** PROJECT INDIRECT SUMMARY - Assembly **

	QUANTITY	UOM	DIRECT	OVERHEAD	? OVRHD	PROFIT	BOND	TOTAL COST	UNIT COST
TOTAL Place Fill at IS Toe of FW	766.00	BCY	15,076	0	2,261	1,734	286	19,358	25.27
TOTAL Levees	1.00	EA	15,076	0	2,261	1,734	286	19,358	19357.81
11.01.04 Replace Strippings									
11.01.04.07 Replace Strippings									
11.01.04.07.22 Replace Strippings									
11.01.04.07.22.01 Replace Strippings	235.00	BCY	629	0	94	72	12	808	3.44
TOTAL Replace Strippings	235.00	BCY	629	0	94	72	12	808	3.44
TOTAL Replace Strippings	235.00	BCY	629	0	94	72	12	808	3.44
TOTAL Replace Strippings	235.00	BCY	629	0	94	72	12	808	3.44
11.01.05 Seeding & Mulching									
11.01.05.01 Seeding & Mulching									
11.01.05.01.23 Seeding & Mulching									
11.01.05.01.23.01 Seeding & Mulching	1.00	ACR	1,500	0	225	173	28	1,926	1925.96
TOTAL Seeding & Mulching	1.00	ACR	1,500	0	225	173	28	1,926	1925.96
TOTAL Seeding & Mulching	1.00	ACR	1,500	0	225	173	28	1,926	1925.96
TOTAL Seeding & Mulching	1.00	ACR	1,500	0	225	173	28	1,926	1925.96
TOTAL Levees	1.00	EA	22,319	0	3,348	2,567	424	28,657	28657.27
TOTAL Levees and Floodwalls	1.00	EA	22,319	0	3,348	2,567	424	28,657	28657.27
TOTAL Feasibility Study Estimate for:	1.00	EA	26,993	0	3,856	2,957	488	34,293	34293.25
Contingency								8,445	
SUBTOTAL								42,738	
Engineering & Design								4,274	
SUBTOTAL								47,012	
Supervision & Administration								2,678	
TOTAL INCL OWNER COSTS								49,690	

R2032: 0123010101 Permanent Ea Detail item has zero quantity - no costs reported

* * * END OF ERROR REPORT * * *

Thu 04 Dec 200: Tri-Service Automated Cos ineering System (TRACES) TIME 09:55:50
Eff. Date 10/0. PROJECT WATER7: Feasibility y Estimate for: - Water Works
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No Detailed Estimate...

No Backup Reports...

* * * END TABLE OF CONTENTS * * *