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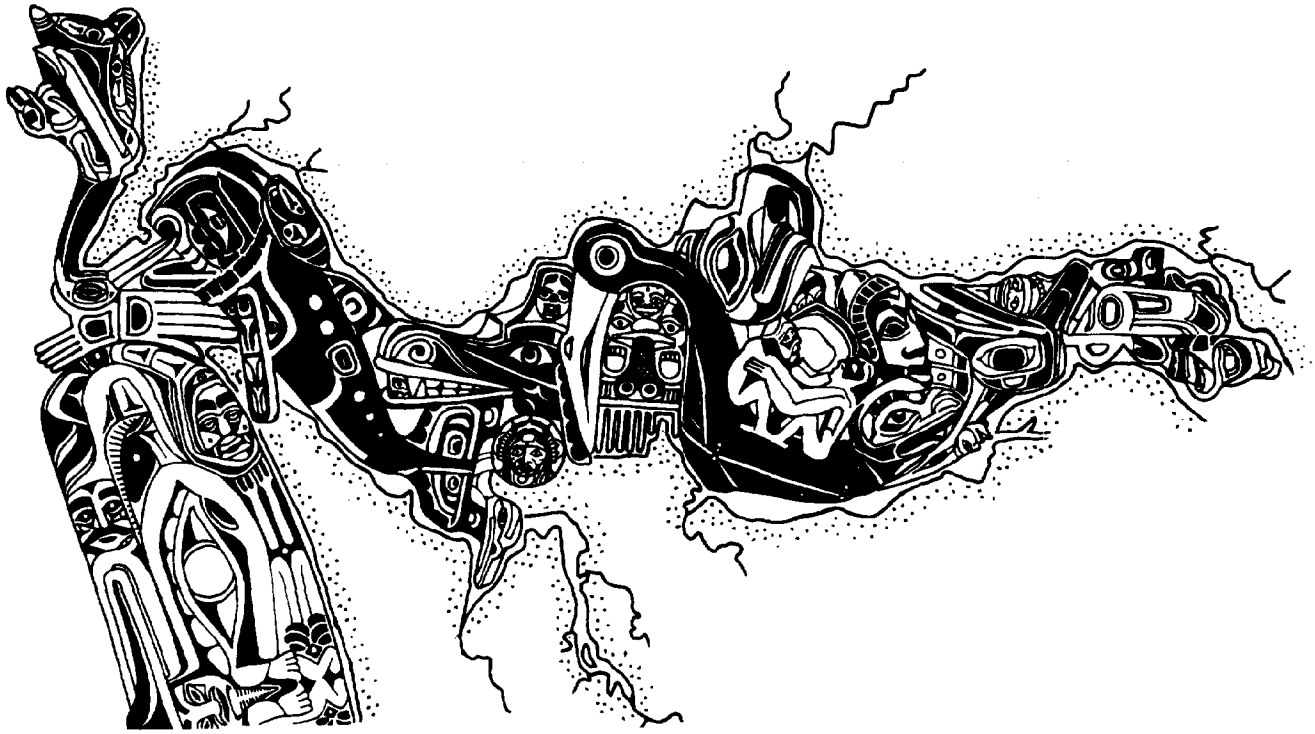
FOR THE COMPLETION OF THE

COLUMBIA RIVER ESTUARY DATA DEVELOPMENT PROGRAM



CREST

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River Spirits, by Gayle McKennon, is based on traditional Northwest Indian motifs. This graphic is projected on a map of the estuary.

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PLAN OF STUDY

For the Completion of the

COLUMBIA RIVER ESTUARY

DATA DEVELOPMENT PROGRAM

Prepared under a Cooperative Agreement between

CREST (Columbia River Estuary Study Taskforce)
P.O. Box 175
Astoria, Oregon 97103

and the

U.S. Water Resources Council
2120 L Street NW, Suite 800
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SUMMARY

The Columbia River Estuary Data Development Program

The Columbia River Estuary Study Taskforce (CREST), in cooperation with the U.S. Water Resources Council, has prepared this Plan of Study for the completion of the Columbia River Estuary Data Development Program (CREDDP). CREDDP was originally authorized in October 1978 as a 6-year, $6,204,000 interdisciplinary applied research program. It was administered by the Pacific Northwest River Basins Commission until September 30, 1981 when the Commission was abolished, and the completion of CREDDP was left in abeyance. In recognition of the regional importance of CREDDP information, Congress appropriated funds for the orderly completion of the program (in December 1981). A revised Plan of Study is needed because of changes in both the schedule and the funding available to complete the program.

On September 7, 1982, CREST entered into a cooperative agreement with the U.S. Water Resources Council to administer the completion of the program. The National Oceanic and Atmospheric Administration will assume the role of the U.S. Water Resources Council as the federal representative in this co-operative agreement.

The purpose of CREDDP is twofold: to increase understanding of the Columbia River Estuary ecosystem and to provide information in a form suitable for use in making water and related land use management decisions. The program and its products are designed with the needs of users of the information in mind. These users include resource managers, developers and other commercial interests, interested citizens, scientists, and educational institutions.

The goals and objectives of CREDDP specify the scientific research to be completed and its relation to planning needs. To assure that the technical goals and objectives are achieved, work programs are presented in detail for each of the CREDDP work units. Individual work units will be integrated in order to produce a more complete understanding of the estuary, and emphasis will be placed on the development of useable resource management documents.

CREDDP will have an information management program to provide for data archiving and for the production and distribution of final products. These respective functions will be handled by a Data Management contractor and Program management.

The Plan of Study establishes a Program Control Board consisting of CREST and the National Oceanic and Atmospheric Administration. This group will provide executive direction for the completion of the program. A Federal Advisory Panel will advise program management on policy. In addition, there will be a Users Advisory Panel consisting of federal, state, and local agency representatives and other interested parties to work with program management and advise CREST on product development. The program manager and staff will be responsible for day-to-day program management.

Program management activities, research activities, and product development are scheduled to allow for efficient completion of CREDDP. The Plan of Study presents a program budget with preliminary work unit and management allocations. The Water Resources Council has advised CREST that the amount of funding available for program activities from the Congressional appropriation will be 1.22 million dollars and that all CREDDP activities must be completed by June 30, 1984. The Plan of Study also itemizes additional work tasks that can be completed if additional funds become available.

The Plan of Study is intended to be flexible, and it may be amended by a consensus of the Program Control Board.

All program activities during the completion of CREDDP will conform to the regulations of the National Environmental Policy Act.

1. INTRODUCTION

1.1 Program History

CREDDP is an applied research program with two purposes: to increase understanding of the ecology of the Columbia River Estuary and to provide information useful in making land and water use decisions. The origin of the program can be traced to the concerns of local governments and citizens for a clearer understanding of the estuarine ecosystem. They saw a need for a better information base for use in managing natural resources and in planning development. Local governments, planning commissions, and state and federal agencies involved in making land and water use decisions were seen as the principal users. Because of these concerns, the Governors of the States of Oregon and Washington requested in 1974 that the Pacific Northwest River Basins Commission (PNRBC) undertake an interdisciplinary ecological study of the estuary. At approximately the same time, local governments and port districts formed CREST, the Columbia River Estuary Study Taskforce, to develop a regional management plan for the Estuary.

The Commission accepted the Governors' requests and in June 1976 published a "Proposal to Study" which outlined the need for an estuary study, how such a study would be organized and managed, and an estimated budget. This proposal was submitted to the Water Resources Council (WRC) as part of PNRBC's total program budget request for FY 1978, and was endorsed by the Governors of the two states and the members of CREST.

The program received an authorization for federal funding in 1979, and the proposed $6,204,000 six-year program received first year appropriated funds in the amount of $828,900. Through September 30, 1981, the Pacific Northwest River Basins Commission administered CREDDP and obligated approximately $3,600,000 to the program. The chronology of CREDDP events up to July 1982 is shown in Appendix A. A list of the former CREDDP contracts and contractors is given in Appendix B.

When PNRBC was abolished in September 1981, the completion of the program was left in abeyance. This termination of CREDDP occurred at a mid-stage of the program. Much of the field work had been carried out and some of the data analysis had been completed, but few final products had been produced. Completed products included the literature surveys, the final reports from some of the smaller work units, and reports such as the historical "Columbia's Gateway."

Otherwise, the only products from most of the major work units were the 1980 annual reports, which generally presented only raw data and a summary of the work completed with some preliminary findings (Appendix C).

In December 1981 Congress recognized that data already collected were in danger of being wasted, and provided funds for the orderly completion of the study.

1.2. The Revised Plan of Study

The original Plan of Study approved by PNRBC in March 1979 describes CREDDP as a six year effort. A new plan is needed to reorganize the program within a shorter time frame and decreased funding. The new completion date is June 1984, and the available funding is $1.22 million. During the past three months CREST, in cooperation with WRC, has drafted and revised this new Plan of Study describing the completion of CREDDP and this Plan of Study supercedes the Plan of Study dated March 1979. The Plan of Study describes program activities, staff responsibilities and organization, and presents a program budget together with time and cost estimates for the revised work units. The draft Plan of Study was circulated to the distribution list (Appendix D). Comments from numerous reviewers were received (Appendix E) and have been incorporated where appropriate.

This revised Plan of Study describes the steps necessary to bring CREDDP to an orderly conclusion. Sections 1 and 2 provide the historical, geographical and scientific background to the program, and discuss the users of the final products and their information needs.

The revised list of CREDDP goals and objectives, described in Section 3, was derived from the original Plan of Study and modified with advice from potential information users and the Data Evaluation Team consultants. General goals and specific objectives are defined in terms of information needed to make management decisions for the Estuary. A CREDDP users workshop was held to solicit suggestions from local, state and federal agencies on the most useful products needed from the program. Interested citizens and other groups also participated. These users reviewed a preliminary list of goals and objectives and made recommendations for completing data analysis and preparing maps, reports and other products. Many of the objectives in the original Plan of Study were deleted because of insufficient time and funds. The highest priority was assigned to the objectives that would lead to the most useful products within the revised time frame and budget.

CREST assembled a Data Evaluation Team of six scientists to provide technical

assistance during the drafting of the new Plan of Study, particularly with Section 4 (Work Programs). Five of the Data Evaluation Team members were former CREDDP researchers while the sixth was familiar with similar applied estuarine research programs. Two Data Evaluation Team meetings were held to review the status of program data and to recommend a plan for completing data sets. The Data Evaluation Team also recommended a method for integrating the data of different work units to complete the program. An Integration Team will be established during the completion of the program, whose duties will include a study of ecosystem level processes using the results from the program's work units. The steps necessary for completion of the program are shown in Figure 1.1.

Two other consultants assisted in preparing this Plan of Study. A Data Management Consultant reviewed the status of program data in the scientific work units and made recommendations on assembling completed CREDDP data into a data management system. Another scientific consultant reviewed the Currents and Simulation work units in CREDDP and made recommendations on the quality and future use of the physical data and related modelling. A list of the CREST and WRC staff and consultants on the Plan of Study is included in Appendix F.

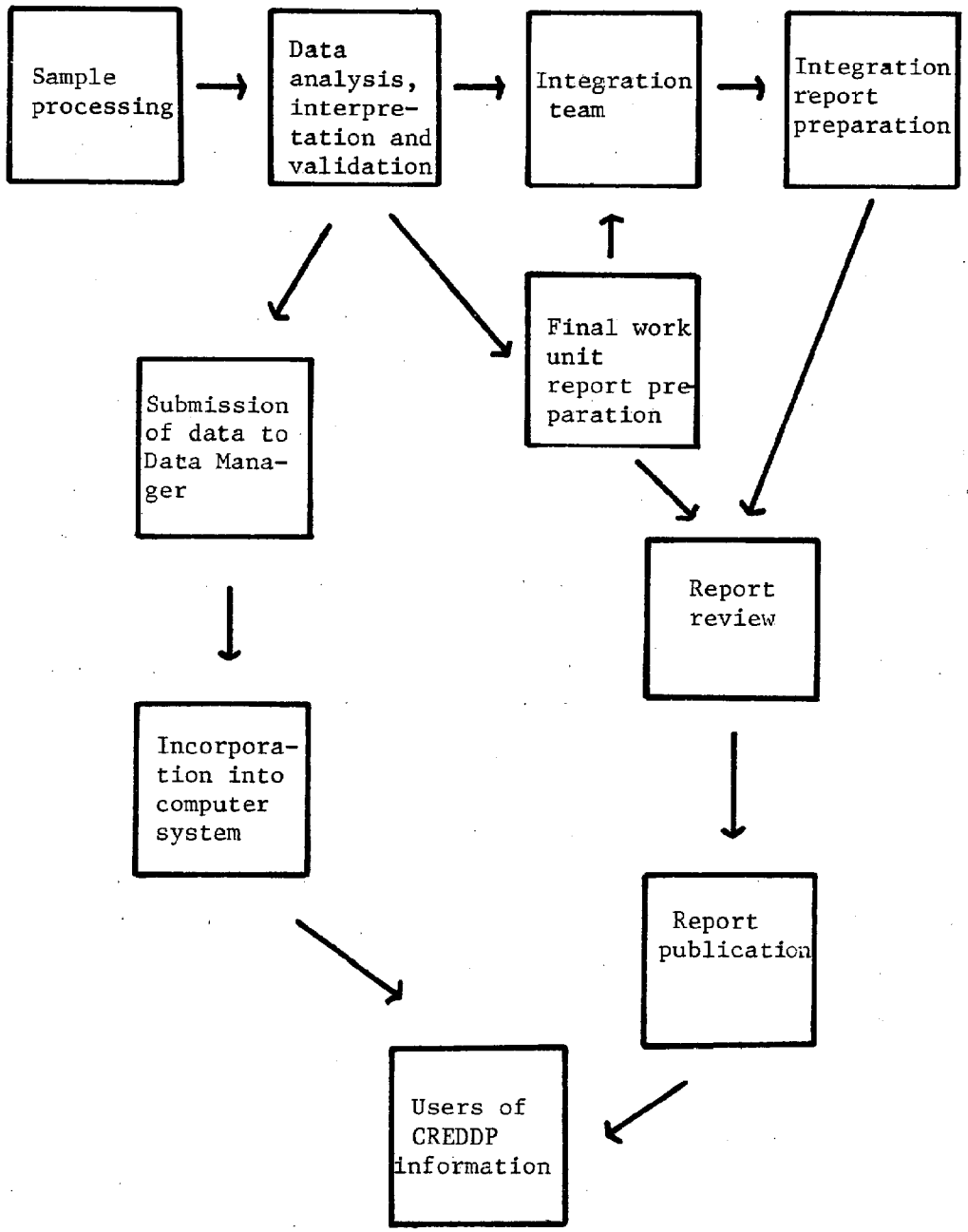
The work programs present detailed plans and schedules for the tasks requiring completion. Such tasks typically fall into the following categories:

- processing of stored samples to obtain the raw data;
- analyzing the raw data;
- filling gaps in the program's data by whatever means are feasible (mainly using information from scientific literature);
- integrating the data from different work units;
- preparing the final products.

The Work Programs Section also describes relationships between the different work units, and how they are linked to the objectives and final products.

Section 5, Information Management, describes the kinds of final products the program will produce, and how information will be disseminated and used. Section 6, Study Organization and Management, describes the management structure needed to complete the program and defines the responsibilities of program management and other agencies involved in the study. Staffing requirements and study contracting procedures are described in this section. Milestones for completing management activities are identified, and report and completion dates are scheduled. Finally, a budget is presented for completing the program.

Figure 1.1. Study Process.



1.3. Program Design and User Needs

CREDDP will develop technical reports, maps, and nontechnical interpretive summaries that can be used in making land and water use decisions. The users of this information, described in Section 2, include organizations and individuals involved in estuary planning and resource management. CREDDP's broad, ecosystem based approach will provide a basis for assessing the potential effects of developments.

Program goals and objectives for the individual work units are intended to provide this information. The goals include gathering information and developing products which describe both the structure and processes of the estuary.

In addition, the integration of data from the individual biological and physical units is a necessary step in developing useable products. Data integration is the synthesis of a multidisciplinary information base so that generalizations about ecological processes can be drawn. This will lead to a clearer understanding of the likely impact of estuarine alterations on the ecosystem.

These integration activities will give cohesion to the program and will convert the work unit products into a broader ecosystem view, providing many of the program's process-oriented products. From the users' point of view, this will be very valuable, since a major insight into the interrelatedness of the different estuarine properties will be provided. It can therefore form a basis for predicting the impacts on the ecosystem of site specific alterations.

1.4. The Columbia River and Its Estuary

The Columbia, the largest river on the Pacific Coast of North America, is approximately 1,200 miles long and drains over 250,000 square miles. Initially it was the route which opened the region to commerce and settlement, and industries developed based on the vast fisheries and timber resources. Since then, the economy has diversified. Numerous dams have provided generating capacity for hydroelectric power, and water appropriations from the river allow for the irrigation of arid lands. Forestry is the major industry over the western part of the basin, and the river continues to play an important role in log transportation and storage. Major ports have developed along the river and water-borne commerce exceeds 30 million tons annually, with a 40' navigation channel inland to Portland. Although fisheries are an important regional industry, they have

declined steadily since dam construction and large scale logging began. The salmon industry has been particularly hard hit: the lack of resource management during regional development led to the catastrophic decline of some of the world's largest salmon runs through dam building, logging practices, overfishing and wetland destruction. Dam related losses to salmon and steelhead fisheries since 1960 alone have been valued at over $300 million annually.

The need for sound management to protect natural resources during regional development is obvious, and ecosystem studies like CREDDP are necessary for informed decision making.

Like most large west coast rivers, the Columbia is characterized by very high flows during late spring and early summer, generated by melting snows in the mountainous watershed. Even with 13 mainstream and numerous tributary dams, monthly average flows in the lower river sometimes exceed 600,000 cfs during spring freshets. In addition, winter freshets are common, caused by storms concentrated in the Cascade Mountains. The flows of late summer are no longer as low as before dam construction, due to regulation for hydropower generating needs.

In the estuary, salinities are constantly changing in response to semidiurnal tides, spring/neap cycles, river flow and wind effects.

Patterns of circulation are unique in every estuary, and because of the profound effects of currents on sediment transport, water chemistry and plankton, current measurements and circulation modelling are important elements in CREDDP.

Studies of estuarine sediments, including their composition, distribution and transportation, are an important part of the Columbia River Estuary Data Development Program. Information derived from sediment studies forms an important contribution to the biological work units and is also of direct interest to estuary managers.

The stability, grain size and organic content of sediments influence the structure of the invertebrate communities which inhabit them as well as the levels of benthic primary productivity. Sediments are therefore important in determining the productivity of numerous biological communities in the estuary.

The characteristics of shoaling in the estuary are of interest to those users of the program data who are involved in maintaining navigation channels and disposing of dredge materials. It is evident that far more river-borne and bedload sediment enters the estuary than leaves it, and the effects of this shoaling on navigation and on biological resources needs to be evaluated. Comparisons should be made of present day shoaling patterns with those which occurred before the estuary was extensively altered by man. Information needed

for predicting the effects of future alterations on sediment transport will be provided by the Sedimentation, Currents, and Simulation work units.

Water chemistry has an important influence on the productivity of biological communities in the estuary. The availability of river and ocean derived nutrients is likely to be limiting to populations of planktonic organisms in particular, while salinity levels in the water play an important role in structuring communities. Since there is no single work unit in CREDDP responsible for collecting water chemistry data, close attention will be paid to this topic in integration activities.

Sources of primary productivity in the estuary need to be quantified in order to model the first trophic level and the estuary carbon budget. Primary productivity supports all the higher trophic organisms through direct grazing, detritus production or dissolved organics. The individual sources, such as tidal marshes, benthic plants, phytoplankton and river-borne detritus should be quantified in space and time so that their individual importance can be appreciated. This information is central to developing an ecosystem view of the estuary. It is also directly useful to estuary managers, who can estimate the importance of tidal marshes and tideflat areas, for example, to the carbon budget.

Invertebrates which occupy the sediments and water column of the estuary depend directly or indirectly on the primary producers. These invertebrates are of great importance to the food web, since they are the major food source for many commercially important species of fish and wildlife. Characteristics of the habitats and life cycles of important invertebrates, together with abundance and biomass data, are needed to estimate food supplies available to the higher trophic levels. This information can also be used by estuary managers to identify areas of high invertebrate productivity. Also, some species such as sand shrimp, Dungeness crab and crayfish have direct economic importance, and information on these species can be used in the management of stocks.

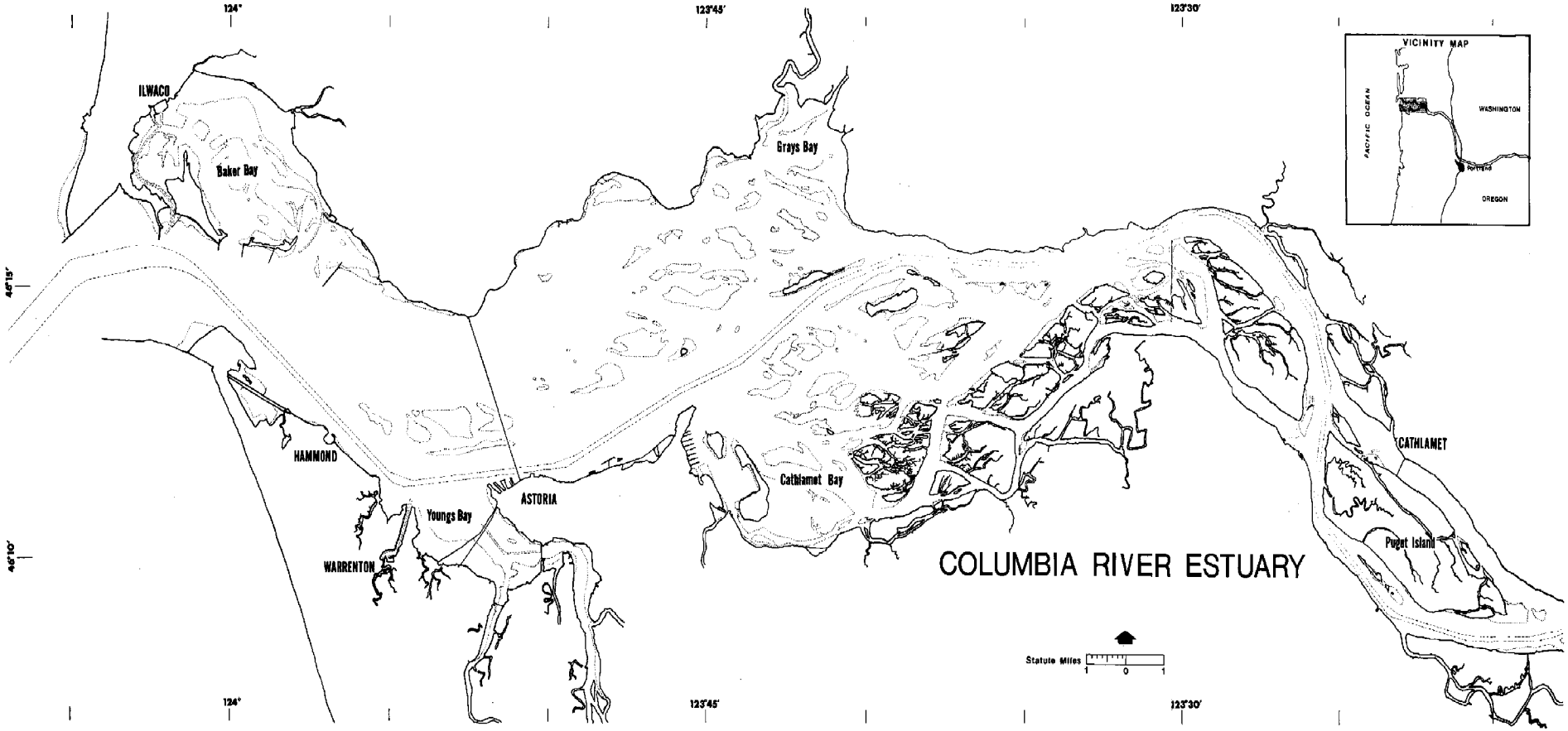
Many finfish and wildlife species found in the estuary support commercial and recreational harvest. Information on the habitats, life cycles, feeding, population sizes and migrations of these species is of prime importance to resource managers who have the responsibility for preserving stocks. Commercial fish include salmonids, starry flounder, English sole, smelt, American shad, herring and anchovy. Harvesting these species is a major part of the local economy. Economically important wildlife which depend on the estuary include many species of waterfowl and aquatic furbearing mammals. Research on higher trophic organisms will focus on the requirements of different life cycle stages, the

importance of the estuary to each species, and their interactions with organisms lower in the food chain.

1.5. The Study Area

The CREDDP study area extends from the Columbia River Bar upstream to River Mile 46 at the southeastern end of Puget Island (Figure 1.2). This includes the main body of the estuary, semi-enclosed by land, where ocean and river waters mix. It also includes a riverine, freshwater area (above RM 23) where current reversals as a result of tidal action are common. Excluded is the 100 mile tidal section of the river where current reversals are rare or absent, and the plume which extends far offshore in the form of mixed river and ocean water. These three areas are not normally encompassed by definitions of an estuary. Along the estuary shoreline, the study area extends up to the line of non-aquatic vegetation, where the tidal vegetation is replaced by upland communities, or up to mean higher high water where vegetation is absent.

Fig. 1.2 - ESTUARY MAP



2. USERS AND THEIR INFORMATION NEEDS

2.1. Introduction

The original aims of CREDDP emphasized the common desire of all information users for a well designed scientific study of the physical and biological structure and processes of the estuary. An assessment of specific user needs in this Plan of Study will ensure that the products from the program are structured so as to be of greatest value.

The principal user group, specifically identified in the original Plan of Study, includes local government officials, planning commissions, CREST, state and federal agencies, and others involved with carrying out the Columbia River Estuary Regional Management Plan. These users can be divided into two categories: specialist and nonspecialist. The former includes scientists and estuary managers who would use the program's detailed technical reports. The nonspecialist user would be anyone with insufficient training or time to study the technical reports, but who needs easy access to the major findings of the program. This category includes interested citizens such as commercial and recreational fishermen, educators, planners, developers and scientists who are not specialists in all of the areas covered by CREDDP.

2.2. Land and Water Use Decisions

CREDDP's focus on providing information for land and water use decision making stems from the early involvement of CREST in the program. The major objective of CREST was to produce a regional management plan for the Columbia River Estuary under the auspices of the Oregon and Washington Coastal Zone Management Programs. The CREST Plan aims at protecting natural resources while allowing for economic development in the form of necessary water dependent projects.

These decisions can be divided into planning and permitting activities, and both involve CREST, local governments, planning commissions, and state and federal agencies. For Oregon, there is a comprehensive land use planning program, with special "Goals" which apply to the coastal zone. This is administered by the Department of Land Conservation and Development (DLCD). Relevant sections of the CREST Plan have been incorporated into local jurisdictions' land use plans. These local plans are reviewed by DLCD and other state agencies such as Oregon

Department of Fish and Wildlife for compliance with Statewide Planning Goals. Federal resource agencies such as the National Marine Fisheries Service and the U.S. Fish and Wildlife Service also comment on local plans under the state and federal consistency provision of the Coastal Zone Management Act.

In Washington, a parallel system exists in the form of the state's Coastal Zone Management Program, administered by the Washington Department of Ecology. As in Oregon, relevant parts of the CREST Plan are used by local jurisdictions and reviewed by state and federal agencies including the Washington Department of Game and the Washington Department of Fisheries. The planning processes outlined above are almost complete. There is still, however, a need for additional information on the management of natural resources, particularly fish and wildlife species, which could be used during plan implementation and incorporated into plans during future updates.

Of particular importance in planning is ecosystem level research which identifies and maps important estuarine resources. Equally important is research on the roles of the different trophic levels and identification of the linkages between sources of carbon, nutrients, detritus, detritivore populations and higher trophic levels. This information may be used to predict the effects of estuarine alterations on natural resources. Similarly, there is a need for information on currents and sediment transport which could be used in formulating dredge material disposal plans. Particularly useful would be data collected from critical areas in the estuary, such as areas designated as suitable for development.

The permit process involves two groups: the applicants, who may be citizens, corporations or a government body, and reviewers, mostly local governments and state and federal agencies together with occasional participants from the public. As with the planning process, a complicated system surrounds the permit process: estuarine permits are reviewed by local governments, either directly or through CREST, and also by state agencies. In addition, a federal section 404 permit from the U.S. Army Corps of Engineers is required. This permit is reviewed by federal agencies such as the National Marine Fisheries Service, U.S. Fish and Wildlife Service and Environmental Protection Agency, as well as by state agencies. They can recommend project modifications, mitigation or permit denial, on the grounds of impacts to fish and wildlife populations or degradation of environmental quality. The permit applicant must furnish site specific information on the impacts of the project, and may have to fund additional research. Both permit applicants and reviewers will therefore need access to the raw and processed data from CREDDP.

Information in two areas is of value here. First, ecosystem data will be needed to predict the importance of development sites to the estuary. This will be used to compare the values of different sites, and also for deciding whether or not additional research is needed. Second, any sampling carried out in the vicinity of development sites will be especially useful since it can also be used in site specific studies and will, as a result, reduce the cost of the project. Major developments are anticipated in the following areas: the main navigation channel, the Port of Astoria docks, the Skipanon River-Tansy Point area and the Tongue Point docks.

Alterations to the estuary fall into two categories: first, the filling of areas, usually intertidal flats or tidal marshes, to provide space for cargo handling and access to deeper water, and second, the dredging of areas for navigation channels with the associated problems of dredge material disposal. Resource managers will therefore need to apply CREDDP products to these kinds of problems. The Corps is likely to be a major user of data on dredging, since they are actively studying the feasibility of a deep draft coal export channel in the estuary.

Scientists conducting research on the Columbia or other estuaries will be another major group of specialist users who will need the technical reports and data from the program. Program findings published in scientific journals should also be of value to this group, and contractors are therefore encouraged to publish their research from the program.

In addition to the specialist users described above there are likely to be a large number of nonspecialist users who would need the program products presented in an edited and lucid form. These users would include the local citizens who have supported the program and who are involved in the citizen based land and water use planning activities, commercial fishermen and others who depend on natural resources for a livelihood, recreational fishermen, and local educators focusing student science and geography classes on the estuary. The relationship between the program's Goals and Objectives and the information needs of estuarine managers is discussed in the section 3.4.

3. GOALS AND OBJECTIVES OF CREDDP

3.1. Introduction

The goals and objectives of CREDDP specify the research activities to be completed and their relationships to resource management needs. In order to provide an ecological information base suitable for use in making estuarine management decisions, resource management questions and issues must be broken down into specific scientific objectives. This is necessary because resource managers tend to be confronted with multidisciplinary problems, such as assessing the impacts of dredging projects on structural and functional aspects of the estuary, while scientists usually ask specific questions within narrow disciplines. The CREDDP goals are a list of resource management information needs while the objectives are the specific research tasks which will be used to accomplish these goals. In order for the scientific results to be useful to resource managers, they must be placed in a form that is easily understood and referenced.

The process, then, consists of reducing estuarine management questions to goals and objectives (i.e., research questions), which in turn yield products useful in making management decisions. The purpose of this section is to list the goals and objectives and to describe the relationships between objectives and general questions of resource management.

3.2 Goals

The goals of CREDDP are grouped into 5 categories: 1) first trophic level, 2) higher trophic levels, 3) sedimentation and shoaling, 4) currents and simulation, and 5) integration. First trophic level and higher trophic levels goals include data interpretation and product development that describe the structure and function of the biological component of the ecosystem. Maps of abundance and production, and assessments of functional linkages among various biological groups are included. These goals include describing the relationships between physical and biological factors, critical information needed to develop predictive capabilities required by resource managers. The structure and function of the physical portion of the ecosystem are described by the sedimentation and shoaling, and currents and simulation goals. Bottom sediment distribution, sediment transport, circulation and salinity patterns, and the underlying processes accounting for these patterns are included. This information provides

an essential base upon which to support resource management decisions.

The final goal, integration, is very important because it leads to a more complete understanding of estuarine ecological structure and function. Integrating the results from all of the work units is the key to a successful interdisciplinary program, giving resource managers a better understanding of the ecosystem and improving their predictive capability. The goals of CREDDP are listed below.

A. First Trophic Level

1. Describe and map productivity and biomass patterns of Columbia River Estuary primary producers.

2. Determine to the extent possible the carbon budget of primary producers.

3. Describe the relationships among primary producers and productivity levels and physical factors.

B. Higher Trophic Levels

1. Describe and map abundance patterns of the invertebrate and vertebrate groups.

2. Determine functional relationships among higher trophic groups.

3. Describe the relationships among vertebrate and invertebrate species and physical and biological factors.

C. Sedimentation and Shoaling

1. Characterize and map bottom sediment distribution.

2. Characterize sediment transport.

3. Determine (qualitatively) the causes of historic and modern bathymetric change.

D. Currents and Simulation

1. Evaluate and model circulation patterns.

2. Evaluate and model vertical mixing and salinity patterns.

E. Integration

1. Integrate program information for a more complete understanding of biological and physical structure and processes.

3.3. Objectives

The objectives of CREDDP are designed to answer research questions and, because they depend on specific research tasks, they are classified by work unit. The objectives listed below are related to the goals in Appendix G and the specific tasks needed to achieve each objective are outlined in the work programs section.

Each of the objectives is assigned a priority on a three part scale. These priorities are based on comments received from user reviewers and the results of the Users Workshop on June 2, 1982. The major emphasis is on classifying habitats, describing abundance and distribution of organisms, describing important physical processes, and relating the biological information to physical factors. A lower emphasis is placed on biological process information as it relates to the estuarine carbon budget. Although the most effort will be expended on completing the high priority items, the intent of the program is to complete all of the objectives listed. The following list itemizes the CREDDP objectives and their priorities (H = high; M = medium; L = low).

Emergent Plant Primary Production

H 1. Describe and map emergent plant biomass and primary productivity patterns.

H 2. Relate marsh vegetation types and productivity to elevation, salinity, and other pertinent physical and chemical factors.

M 3. Estimate the export of detritus from marshes.

L 4. Determine the emergent plant carbon budget.

Benthic Primary Production

H 1. Describe and map benthic microalgal productivity, biomass, and related variable patterns.

H 2. Relate benthic microalgal productivity to sediment parameters, salinity, and other pertinent physical and chemical factors.

L 3. Determine the benthic microalgal carbon budget.

Water Column Primary Production

H 1. Describe and map phytoplankton productivity and biomass patterns.

H 2. Relate phytoplankton productivity and biomass to light, salinity, currents (null zone), nutrients, and other pertinent physical and chemical factors.

M 3. Measure or estimate phytoplankton and other organic particulate inputs and outputs.

L 4. Determine the phytoplankton carbon budget.

Zooplankton and Larval Fish

H 1. Describe and map key and selected other zooplankton and larval fish species, by principal life history stages, or assemblages in terms of occurrence, density and standing crop over time.

H 2. Quantify functional relationships among zooplankton and larval fishes and physical (salinity, temperature, tide stage) and biological (planktivorous predators) factors.

M 3. Describe population structure and dynamics and life history of *Eurytemora*.

Benthic Infauna

H 1. Describe and map key and selected other benthic infauna species or assemblages in terms of density, standing crop, and production over time.

H 2. Quantify relationships among benthic infauna and physical (salinity, sediments, depth) and biological factors.

M 3. Determine the population structure and dynamics, life history, and turnover rates of *Corophium*, *Macoma*, *Hobsonia*, and *Pseudopolydora*.

L 4. Define functional relationships of benthic infauna in the ecosystem including predator-prey linkages, population movements, and role in the estuary carbon budget.

Epibenthic Organisms

H 1. Describe and map key and selected other epibenthic species or assemblages in terms of density, standing crop, and production over time.

H 2. Quantify relationships among epibenthic organisms and physical (salinity, sediments, depths) and biological factors.

M 3. Describe the population structure, dynamics, life history, and trophic relationships of Dungeness crab, crangonid shrimp, and mysids.

L 4. Define functional relationships of epibenthic organisms in the ecosystem, including predator-prey linkages, emigration and immigration, and role in the estuary carbon budget.

Fish

H 1. Describe and map key and selected other fish species by life history stage or assemblages in terms of density and standing crop over time.

H 2. Quantify relationships among key fish species and physical (salinity, temperature, tide stage) and biological factors.

H 3. Describe and map migration routes and timing (seasons, residence time) of juvenile and adult salmon and the feeding habits of juvenile salmon in different estuarine habitats.

M 4. From the stomach analyses, tabulate composition, abundance, and biomass of prey in the diets of key fish species and life history stages, with emphasis on diel samples.

L 5. Generate estimates of growth over time of identifiable cohorts of key fish species residing within the estuary.

L 6. Estimate mean consumption rates of key fish species/life history stages and proportional contribution of principal prey taxa in different regions/habitats of the estuary. Discuss the role of a key species in the estuary's carbon budget.

Avifauna

H 1. Describe and map key avifauna species abundance and habitats.

M 2. Determine avifauna food requirements and prey composition.

Wildlife

H 1. Describe and map key wildlife species occurrence and density.

L 2. Estimate the rate of consumption of food/prey by wildlife.

H 3. Identify possible factors that limit key wildlife species use of particular habitats.

Marine Mammals

H 1. Describe and map key marine mammal species occurrence, density, and standing crop.

Sedimentation and Shoaling

H 1. Characterize and map bottom sediments.

H 2. Perform grain-size analysis of sediment samples collected by biologists.

M 3. Characterize and map bedform types and migration directions.

M 4. Characterize the estuarine suspended sediment field.

H 5. Define modern sedimentary environments and processes (including important temporal and spatial scales) in the Estuary.

H 6. Investigate causes of modern and historical bathymetric change.

Currents

H 1. Describe and analyze tidal circulation.

M 2. Incorporate NOS data into CREDDP data base and use in all analyses, as appropriate.

M 3. Describe and analyze low frequency flow, including "null zone" location and processes.

H 4. Describe and analyze salinity and temperature patterns.

H 5. Describe and analyze vertical mixing processes.

Simulation

L 1. Model circulation patterns through the use of a two-dimensional, horizontal model. Use the model to study atmospheric, freshwater and tidal forcings to analyze circulation in peripheral bays, and to assist the Sedimentation work unit in determing shoaling patterns.

L 2. Formulate and use a two-dimensional multichannel vertical model to examine tidal forcings, salinity intrusion, freshwater inflow, atmospheric forcing, vertical mixing, and residual flow processes.

Integration Objectives

M 1. Analyze effects of physical processes on key species and the taxonomic structure of communities.

L 2. Integrate program information to define functional linkages among organisms, to develop a carbon budget, and relate these to the physical processes in the Columbia River Estuary.

H 3. Classify and map habitat types in relation to appropriate physical and biological parameters (depth/elevation, salinity, sediment, emergent vegetation type).

H 4. Using information developed by work unit contractors, describe the biological communities in each habitat type.

M 5. Integrate current and salinity results and sediment results to develop an understanding of the estuarine sedimentological processes.

3.4. The Relationships Between Goals/Objectives and Estuarine Management

Because of the narrow scope of research questions, science often becomes divorced from resource management and, as a result, valuable scientific information is often overlooked in making important resource management decisions. In order to demonstrate how the information base developed by CREDDP applies to resource management, the scientific objectives are discussed in the context of

general resource management questions.

The following discussion is organized into broad areas of resource management concerns. These concerns fall into the categories of tidal marshes, salmonid fish, birds and wildlife, key species, habitat classification, dredging, shoaling, and freshwater flow alterations. Each category is headed by a series of estuary management questions followed by a discussion of how CREDDP data can lead toward answering the questions. The management questions are derived from the Columbia River Estuary Regional Management Plan.

Tidal marshes

Management Questions: What is the importance of the estuary's tidal marshes to estuarine food chains? For fish and wildlife habitat and feeding?

Key factors for answering these questions include:

a) tidal marsh distribution
b) marsh assemblage classification
c) marsh productivity measurements
d) assessment of detrital export
e) information on other food sources in the Estuary
f) fish utilization
g) bird and mammal utilization

Related CREDDP objectives include:

1. Describe and map emergent plant biomass and primary productivity patterns.

2. Relate marsh vegetation types and productivity to elevation, salinity, and other pertinent physical and chemical factors.

3. Estimate the export of detritus from marshes.

4. Determine the emergent plant carbon budget.

5. Determine the benthic microalgal carbon budget.

6. Measure or estimate phytoplankton and other organic particulate inputs and outputs.

7. Determine the phytoplankton carbon budget.

8. Describe and map key and selected other fish species by life history stage or assemblages in terms of density and standing crop over time.

9. Describe and map migration routes and timing (seasons, residence time) of juvenile and adult salmon and the feeding habits of juvenile salmon in different estuarine habitats.

10. From stomach analyses, tabulate composition, abundance, and biomass of prey in the diets of key fish species and life history stages, with emphasis on diel samples.

11. Describe and map key avifauna species abundance and habitats.

12. Determine avifauna food requirements and prey composition.

13. Describe and map key wildlife species occurrence and density.

14. Integrate program information to define functional linkages among organisms, to develop a carbon budget, and relate these to the physical processes in the Columbia River Estuary.

15. Classify and map habitat types in relation to appropriate physical and biological parameters (depth/elevation, salinity, sediment, emergent vegetation type).

16. Using information developed by work unit contractors, describe the biological communities in each habitat type.

Tidal marshes are often significantly affected by estuarine development. Resource managers on the Columbia River Estuary have little information concerning the importance of marshes to the estuarine ecosystem and are often hard pressed to make and justify decisions on tidal marsh alterations.

In order to assess the importance of tidal marshes to the estuary's food chain, the amount of "food" produced by marshes relative to other sources must be quantified. Information to be developed by CREDDP on the areal distribution and productivity of tidal marshes is the first step toward answering this question. Once the total marsh productivity for the estuary is known, estimates of the portion exported as useable food (detritus) can give an idea of the potential use of this production. Detrital export will be roughly estimated by CREDDP. In order to place this useable food into the broader context of the entire estuary, the relative contribution of other food sources must be determined. These estimates will be attained by the Benthic Primary Production and Water Column Primary production work units studying algal productivity and particulate budgets. When integrated into a carbon budget for the estuary, the relative importance of tidal marshes to the food chain can be better understood.

Beside the estimates of detrital export, another criterion which can show the importance of tidal marshes to the food chain is the proportion of the detritus feeder's diet contributed by this source. CREDDP will not have sufficient data to deal with this topic.

The importance of marshes to fish, birds and wildlife is addressed by those work units. The CREDDP fish studies are not specifically designed to show the

degree of marsh utilization so information will be sparse, depending mainly on stomach analyses which may, for example, show an abundance of marsh dwelling prey organisms. The Avifauna and Wildlife work units, on the other hand, have studied these animals' use of tidal marshes and will provide a great deal of new information concerning the importance of these areas as "habitat".

When all of the above information is integrated the importance of marshes in the Columbia River Estuary will be better understood and resource managers will begin to be able to predict some of the effects of altering these areas.

Salmonid Fish

Management Questions: How important is the estuary to juvenile salmonids? What is the carrying capacity of the estuary for juvenile salmonids and what are the limiting factors?

Key factors for answering these questions include:

a) residence time
b) feeding habits
c) prey abundance and distribution
d) timing and migration routes
e) growth rates
f) juvenile population sizes
g) transition zones

Related CREDDP objectives include:

1. Describe and map key and selected other fish species by life history stage or assemblages in terms of density and standing crop over time.

2. Quantify relationships among key fish species and physical (salinity, temperature, tide stage) and biological factors.

3. Describe and map migration routes and timing (seasons, residence time) of juvenile and adult salmon and the feeding habits of juvenile salmon in different estuarine habitats.

4. From stomach analyses, tabulate composition, abundance, and biomass of prey in the diets of key fish species and life history stages, with emphasis on diel samples.

5. Generate estimates of growth over time of identifiable cohorts of key species residing within the estuary.

6. Estimate mean consumption rates of key fish species/life history stages and proportional contribution of principal prey taxa in different regions/habitats of the estuary. Discuss the role of a key species in the estuary's carbon budget.

7. Describe and map key and selected other zooplankton and larval fish species, by principal life history stages, or assemblages in terms of occurrence, density, and standing crop over time.

8. Quantify functional relationships among zooplankton and larval fishes and physical (salinity, temperature, tide stage) and biological (planktivorous predators) factors.

9. Describe population structure and dynamics and life history of Eurytemora.

10. Describe and map key and selected other benthic infauna species or assemblages in terms of density, standing crop, and production over time.

11. Determine the population structure and dynamics, life history, and turnover rates of Corophium, Macoma, Hobsonia, and Pseudopolydora.

12. Define functional relationships of benthic infauna in the ecosystem, including predator-prey linkages, population movements, and role in the estuary carbon budget.

13. Describe and map key and selected other epibenthic species or assemblages in terms of density, standing crop, and production over time.

14. Define functional relationships of epibenthic organisms in the ecosystem, including predator-prey linkages, emigration and immigration, and role in the estuary carbon budget.

15. Analyze effects of physical processes on key species and the taxonomic structure of communities.

16. Integrate program information to define functional linkages among organisms, to develop a carbon budget, and relate these to the physical processes in the Columbia River Estuary.

17. Classify and map habitat types in relation to appropriate physical and biological parameters (depth/elevation, salinity, sediment, emergent vegetation type).

18. Using information developed by work unit contractors, describe the biological communities in each habitat type.

The management of economically important species, especially salmonids, is a major concern of local, state and federal interests. CREDDP has emphasized investigations of juvenile salmonids because their survival rate in the estuary determines the success of the returning adults and, ultimately, the value of the fishery. In order to determine the estuary's importance to juvenile salmonids several important factors must be resolved, including salmonid residence time, feeding habits, migration routes, growth rates, and the sizes of salmon populations entering the estuary.

The length of time juvenile salmonids spend in the estuary is a major factor determining its value to them. Species such as steelhead pass through the estuary

rapidly with little feeding or growth. Subyearling fall chinook, on the other hand, spend considerable time in the estuary. Their feeding success and growth appears to influence their survival in the ocean and subsequent return. The question of juvenile salmonid residence time will be addressed by CREDDP.

Juvenile salmonid feeding information, coupled with information on the abundance and distribution of prey items, gives additional information on the importance of the estuary. The feeding information will be developed from stomach analyses undertaken by CREDDP. Information on the prey organisms will be developed by the Zooplankton, Benthic Infauna, and Epibenthic Organism contractors studying the abundance and distribution of invertebrates, their life histories, and carbon budgets.

Tied directly to feeding and residence time is the growth rate of juvenile salmonids. Because residence time is generally short and hatchery releases confuse analysis of individual cohorts, CREDDP will not be able to make definitive conclusions concerning the estuary's contribution to salmonid growth.

CREDDP will describe the routes and timing of adult and juvenile migration in relation to biological and physical factors; conclusions related to these factors help to show how the physical aspects of the estuary affect salmonids.

To assess the carrying capacity of the estuary, population sizes of salmonids must be known. Since this information will not be obtained by CREDDP, the question of carrying capacity and limiting factors will only be addressed qualitatively.

Birds and Wildlife

Management Questions: Which bird species play an important role in the estuarine food chain? Which habitats are most important for resident and migrant water fowl, shorebirds, wading birds, raptors, etc.? Which habitats are most important for wildlife?

Key factors for answering these questions include:

a) bird and wildlife density by habitat
b) bird and wildlife feeding requirements
c) critical bird and wildlife habitats

Related CREDDP objectives include:

1. Describe and map key avifauna species abundance and habitats.

2. Determine avifauna food requirements and prey composition.

3. Describe and map key wildlife species occurrence and density.

4. Estimate the rate of consumption of food/prey by wildlife.

5. Identify possible factors that limit key wildlife species use of particular habitats.

6. Describe and map key marine mammal species occurrence, density, and standing crop.

7. Classify and map habitat types in relation to appropriate physical and biological parameters (depth/elevation, salinity, sediment, emergent vegetation type).

8. Using information developed by work unit contractors, describe the biological communities in each habitat type.

The management of bird and wildlife species and their habitats is important to resource agencies, sportsmen and many other citizens of the estuary area. CREDDP will indirectly assess which birds are important to the estuarine food chain by combining density estimates with food habit information derived from the literature. This, along with other information developed by the Avifauna work unit will give an approximate idea of bird species' importance to the food chain.

The important bird and wildlife habitats can be determined from density estimates, feeding information, and nesting/denning information. Because bird and wildlife research for CREDDP was undertaken in several different, well defined habitat types, the definition and mapping of important habitats will be a major outcome of the program. These maps will offer resource managers a more accurate picture of the distribution of important habitats and will facilitate prediction of the effects of estuarine alterations.

Key Species

Management Questions: What are the key plant and animal species that play a crucial role in the estuarine food chain or are particularly important for management of the estuary? What is the life cycle, habitat requirements, and ecological interactions of each?

Key factors for answering these questions include:

a) definition of key species
b) abundance and distribution of key species
c) production of key species
d) trophic relationships and carbon budget
e) life history information

Related CREDDP objectives include:

1. All objectives from the Zooplankton and Larval Fish, Benthic Infauna, Epibenthic Organisms, Fish, Avifauna, Wildlife, and Marine Mammals work units.

2. Analyze effects of physical processes on key species and the taxonomic structure of communities.

3. Integrate Program information to define functional linkages among organisms, to develop a carbon budget, and relate these to the physical processes in the Columbia River Estuary.

4. Classify and map habitat types in relation to appropriate physical and biological parameters (depth/elevation, salinity, sediment, emergent vegetation type).

5. Using information developed by work unit contractors, describe the biological communities in each habitat type.

Key species important to the food chain have already been designated by CREDDP. Where they occur and in what numbers are important resource management concerns. Development of this information and presentation in easily referenced maps is a high priority of CREDDP. Data on the feeding relationships among key species, their production levels, and the carbon budget provide information on their relative importance in the food web. This information, coupled with descriptions of the relationships between key species and physical factors, can help resource managers to predict the outcome of disturbing one or more of these species and to trace these effects to various parts of the food chain.

The integration of CREDDP information is extremely important to key species questions. The objectives addressing interrelationships among all of the key species of the estuary and between species and physical factors, the estuarine carbon budget, and habitat classification go beyond the scope of individual work units. These integration objectives are essential to achieve the predictive capabilities described above.

Habitat Classification

Management Questions: What is the distribution of the major benthic, marsh, and shoreland habitats? What is the importance to fish, birds, and wildlife?

Key factors for answering these questions include:

a) habitat classification system
b) habitat type mapping

c) abundance and distribution of organisms
d) relationships between assemblages and physical factors
e) descriptions of biological communities in each habitat type

Related CREDDP objectives include:

1. Describe and map emergent plant biomass and primary productivity patterns.

2. Relate marsh vegetation types and productivity to elevation, salinity, and other pertinent physical and chemical factors.

3. Describe and map benthic microalgal productivity, biomass, and related variable patterns.

4. Relate benthic microalgal productivity to sediment parameters, salinity, and other pertinent physical and chemical factors.

5. Describe and map phytoplankton productivity and biomass patterns.

6. Relate phytoplankton productivity and biomass to light, salinity, currents, nutrients, and other pertinent physical and chemical factors.

7. Describe and map key and selected other zooplankton and larval fish species, by principal life history stages, or assemblages in terms of occurrence, density and standing crop over time.

8. Quantify functional relationships among zooplankton and larval fishes and physical (salinity, temperature, tide stage) and biological (planktivorous predators) factors.

9. Describe and map key and selected other benthic infauna species or assemblages in terms of density, standing crop, and production over time.

10. Quantify relationships among benthic infauna and physical (salinity, sediments, depth) and biological factors.

11. Describe and map key and selected other epibenthic species or assemblages in terms of density, standing crop, and production over time.

12. Quantify relationships among epibenthic organisms and physical (salinity, sediments, depths) and biological factors.

13. All Fish work unit objectives.

14. All Avifauna work unit objectives.

15. All Wildlife work unit objectives.

16. All Marine Mammals work unit objectives.

17. Classify and map habitat types in relation to appropriate physical and biological parameters (depth/elevation, salinity, sediment, emergent vegetation type).

18. Using information developed by work unit contractors, describe the biological communities in each habitat type.

Many of the CREDDP biological objectives apply to defining habitats or, more precisely, habitat types in the Columbia River Estuary. A habitat type is defined here as an area occupied by an entire community of organisms. This differs from the narrow ecological definition of a habitat as the physical space occupied by one particular species or population. Habitat types are ideally based on easily mapped physical and biological criteria; examples include low tidal marsh and intertidal soft-sediment flats.

Habitat type classification and mapping with accompanying biological descriptions are important management tools. These are used to apply generalizations about biological communities to areas where no site specific information is available. For example, if a small site is to be filled somewhere in the estuary it is probable that no direct measurements of the organisms present there are available. However, this information is essential information for managers to determine which biological resources are being lost by the filling action. A site specific study can be avoided by determining which habitat types are being affected by the fill and then going back to a description of the communities in each habitat type to assess the resource loss. This can also be applied to mitigation where the habitat types that are lost can be replaced during a restoration action.

The habitat classification system is not intended to replace site specific studies which give a much higher resolution of resources. However, the system is extremely valuable for situations where site specific studies are not possible, such as in very small alterations or in assessing the potential transformation of a non-estuarine area when restored to the estuary.

Organism abundance and distribution, organism relationships to physical factors, and the integration of these results into a habitat classification scheme with accompanying community descriptions are primary objectives of CREDDP.

Dredging

Management Question: How should the main and peripheral channel dredging and dredged material disposal be managed?

Key factors for answering this question include:

a) tidal circulation
b) vertical mixing, salinity, and null zone patterns
c) sediment distribution
d) sediment transport rates and direction
e) knowledge of organism timing and location (to determine dredging timing and disposal location)

Related CREDDP objectives include:

1. Characterize and map bottom sediments.

2. Characterize and map bedform types and migration directions.

3. Characterize the estuarine suspended sediment field.

4. Investigate causes of modern and historical bathymetric change.

5. Describe and analyze tidal circulation.

6. Describe and analyze low frequency flow, including "null zone" location and processes.

7. Describe and analyze salinity and temperature patterns.

8. Describe and analyze vertical mixing processes.

9. Model circulation patterns through the use of a two-dimensional, horizontal model. Use the model to study atmospheric, freshwater and tidal forcings, to analyze circulation in peripheral bays, and to assist the Sedimentation work unit in determining shoaling patterns.

10. Formulate a two-dimensional multichannel vertical model to examine tidal forcings, salinity intrusion, freshwater inflow, atmospheric forcing, vertical mixing, and residual flow processes.

11. Integrate current and salinity results and sediment results to develop an understanding of the estuarine sedimentological processes.

Management for dredging operations can be broken into two broad categories: the physical design of the dredging operation and the biological impacts of dredging. All CREDDP biological objectives are relevant, at least in part, to the latter category. These can help to determine the optimal time for dredging and the best locations for dredged material disposal. The physical design of the dredging operation requires information on circulation and sediment movement patterns. CREDDP will provide detailed descriptions and models of tidal circulation. The sediment transport and dynamics will be approached by the Sedimentation work unit by describing suspended and bedload sediment transport and analyzing historic shoaling patterns. Other information on the dynamics of sediment movement will come from an analysis of vertical mixing, salinity, and null zone patterns. All of the above information will be integrated to develop a more complete understanding of estuarine sedimentological processes.

Ideally, a sediment transport model should be developed to aid in planning dredging operations. CREDDP will not develop such a model, so the indirect information described above must be utilized instead.

Shoaling

Management Questions: What are the mechanisms causing shoaling and erosion in bays, sloughs, side channels, marinas, etc.? What are the effects of large scale estuarine alterations on peripheral areas?

Key factors for answering these questions include:

a) sediment transport rates and direction
b) quantification of historical shoaling
c) sediment distribution
d) tidal circulation (present and historic)

Related CREDDP objectives include:

1. Characterize and map bottom sediments.

2. Characterize and map bedform types and migration directions.

3. Characterize the estuarine suspended sediment field.

4. Define modern sedimentary environments and processes (including important temporal and spatial scales) in the estuary.

5. Investigate causes of modern and historical bathymetric change.

6. Describe and analyze tidal circulation.

7. Describe and analyze low frequency flow, including "null zone" location and processes.

8. Model circulation patterns through the use of a two-dimensional, horizontal model. Use the model to study atmospheric, freshwater, and tidal forcings, to analyze circulation in peripheral bays, and to assist the Sedimentation work unit in determining shoaling patterns.

9. Integrate current and salinity results and sediment results to develop an understanding of the estuarine sedimentological processes.

Large scale alterations have caused considerable shoaling problems in the Columbia River Estuary. In order to avoid this problem as much as possible, estuarine managers must know the mechanisms which have caused historic shoaling. To approach this, CREDDP will analyze and interpret historical shoaling patterns and the dynamics of modern sediment transport. This, integrated with information on past and present circulation, should yield substantial information on the causes of shoaling. Without a sediment transport model, these causes will only be discussed in qualitative terms. However, it will be a major step in determining the mechanisms of shoaling in the estuary. Conclusions on shoaling can help in the design of future projects which will avoid the shoaling problem.

Freshwater Flow

Management Questions: How are salinity, currents, mixing processes, sediment transport, shoaling patterns, anadromous fish transit and feeding, marsh productivity and benthic habitats influenced by the fresh water flow cycle? What have been the effects of the managed flow cycle? What would be the effects of future water withdrawals on the estuary? Should seasonal minimum flows be established to protect important ecological patterns or influence sediment movement?

Key factors for answering these questions include:

a) estuarine biological attributes and processes
b) estuarine physical attributes and processes
c) biological - physical interactions

Related CREDDP objectives include:

All CREDDP objectives.

Questions regarding freshwater flow are extremely important to resource managers on the estuary. These questions are so broad that they encompass the entire scope of CREDDP. Although the questions will never be answered completely and the program is not specifically designed to address them, CREDDP should supply a great deal of pertinent information.

In relation to physical attributes, the salinity, currents, and mixing processes will be described and modelled in the context of freshwater forcing. From this, predictions can be made concerning the alterations of freshwater flow. Sediment transport and shoaling patterns will be described in more qualitative terms but when integrated with the circulation work, the effects of altered flow will become apparent.

Conclusions concerning the biological outcome of freshwater flow alterations will be much more speculative. CREDDP will determine the relationships between biological and physical factors such as salinity and flushing characteristics. The nature of these relationships can be used to explain the effects of an altered flow on biological species and processes. Integration is the key here; when biological and physical attributes and processes are brought together and discussed in the same context, a better capability is developed to predict changes in estuarine conditions resulting from freshwater flow alterations.

4. WORK PROGRAMS

4.1 Introduction

The following section presents the work programs for completing each of the CREDDP work units. These work units will be undertaken by individual contractors or groups of contractors and, for the most part, correspond to the work units of the original program. They are classified into research and non-research work units with the former being further broken down into biological, physical, and integration elements. The work unit classification is shown below.

Research Work Units

Biological

- Emergent Plant Primary Production
- Benthic Primary Production
- Water Column Primary Production
- Zooplankton and Larval Fish
- Benthic Infauna
- Epibenthic Organisms
- Fish
- Avifauna
- Wildlife
- Marine Mammals

Physical

- Sedimentation and Shoaling
- Currents
- Simulation

Integration

- Integration work unit

Non-Research Work Units

- Data Management
- Cartographic work unit

The purpose of the work programs is to describe the research activities, products, and schedules on which the contracts will be based. The work programs assume that: 1) $1.22 million will be available for study completion; 2) the completion date set for the program is June 30, 1984; and 3) for the biological and physical work units, researchers familiar with the past CREDDP work (not nec-

essarily the same contractors) will complete their respective work units. The activities and schedules are considered flexible so that they can be altered if more than $1.22 million is available. The specific alterations are referred to in the work programs and discussed in section 6.6, Additional Work Tasks. The work programs and objectives have not been formally approved by the research contractors and therefore do not represent contracts. Changes in the work programs and objectives may have to be made for some work units during contract negotiations (see section 6.3). Because of the funding constraints it will not be possible to analyze all of the CREDDP data. Optimum sub-samples of data sets will be selected in order to ensure that the objectives will be fulfilled to the greatest extent possible.

The biological and physical work program descriptions are organized according to a standard format. First, an introduction is presented which states the purpose of the work unit, the factors being studied, and how the original sampling design relates to these factors. Following this, three sections list the work unit objectives and data sets, and show their interrelationships. The analysis steps used to achieve the objectives are summarized in the section entitled "Tasks". Additionally, the adequacy of the data for completing the objectives and the integration and data exchange requirements are described. Throughout the task sections, reference is made to the implications of increased funding. The products section describes the final and interim products and the schedule diagram depicts the objective and product time lines, assuming a contractor starting date of November 1, 1982 and a program completion date of June 30, 1984. The interim products include bimonthly progress reports to be submitted to the Program Manager. The integration and non-research work programs follow slightly different formats.

4.2 Emergent Plant Primary Production

Introduction

Emergent vegetation (tidal marshes) is a major component of the estuarine ecosystem, both as a contributor to the food web and as areas of feeding, rearing, and shelter for invertebrates, fish, avifauna, and wildlife. The majority of tidal marshes in the Columbia River Estuary are composed of freshwater assemblages and differ markedly from the east and west coast salt marshes which have been extensively studied. Information on Columbia River Estuary tidal marshes is presently scarce, leaving little to base resource management decisions regarding these commonly affected areas.

The purpose of the Emergent Plant work unit is to fill this information gap by investigating and describing some of the key functional characteristics of emergent vegetation in the Columbia River Estuary. The research is designed to determine the annual production of selected emergent plant species and assemblages using both above ground and below ground biomass data. The approximate rate of detritus export from marshes will be determined by combining the above values with results of litterbag studies and literature information. Ultimately, the emergent plant contribution to the estuarine food web will be estimated and integrated into a total estuary carbon budget.

Objectives

1. Describe and map emergent plant biomass and primary productivity patterns.
2. Relate marsh vegetation types and productivity to elevation, salinity, and other pertinent physical and chemical factors.
3. Estimate the export of detritus from marshes.
4. Determine the emergent plant carbon budget.

Data sets

a) Unprocessed samples from the May 1980 and August 1981 sampling. Variables measured include emergent plant above and below ground biomass and species identification.

b) Raw data from the May, June, and October 1980 samples. Variables measured include emergent plant above and below ground biomass and species identification.

c) Analyzed data from the April and July 1980 samples. Variables measured and analyses include above and below ground biomass, species identification, various statistical tests and correlations, and calculations of productivity.

d) Elevation data at the marsh sampling sites.

e) Raw and partially analyzed data from the litterbag samples taken from May to October 1980.

Objective/data set relationship matrix

	Data set				
Objective	a	b	c	d	e
1	x	x	x		
2	x	x	x	x	
3	x	x	x	x	x
4	x	x	x		x

Tasks

Analysis summary. To complete the mapping objective (objective 1), the remaining CREDDP emergent plant samples will be processed and the data analyzed for the purpose of describing emergent plant productivity, seasonal dynamics, and community structure. The results will be combined with the existing emergent vegetation maps to create estuary wide maps of marsh productivity and monthly/seasonal biomass levels.

The second objective requires quantitative correlations and qualitative generalizations concerning the relationship between vegetation communities, species, and productivity with factors such as salinity, sediment, and elevation. The marsh elevation data are currently being developed by CREST.

Objective 3, detrital export, will use the productivity analyses from objective 1 along with an analysis of the litter bag raw data. These, combined with literature values, will yield rate estimates for potential detrital export.

Determining the emergent plant carbon budget (objective 4) will require analyses from objectives 1 and 3. Marsh production and detrital export rates will be used to assess and "quantify" the carbon inputs and outputs. The budget will be submitted to the Integration Team to become part of an ecosystem carbon budget.

Data Adequacy. The data sets of this work unit are adequate to achieve the objectives with some limitations. For example, production estimates will not be available for all types of emergent plant communities because some were not

sampled. Additionally, the estimates of detrital export rates and, consequently, the emergent plant carbon budget will represent only rough approximations. Literature information may fill some of the gaps here. Under the probable funding situation, statistical analyses of the data sets will be severely curtailed, reducing the quantitative resolution of the objectives (see section 6.6, Additional Work Tasks).

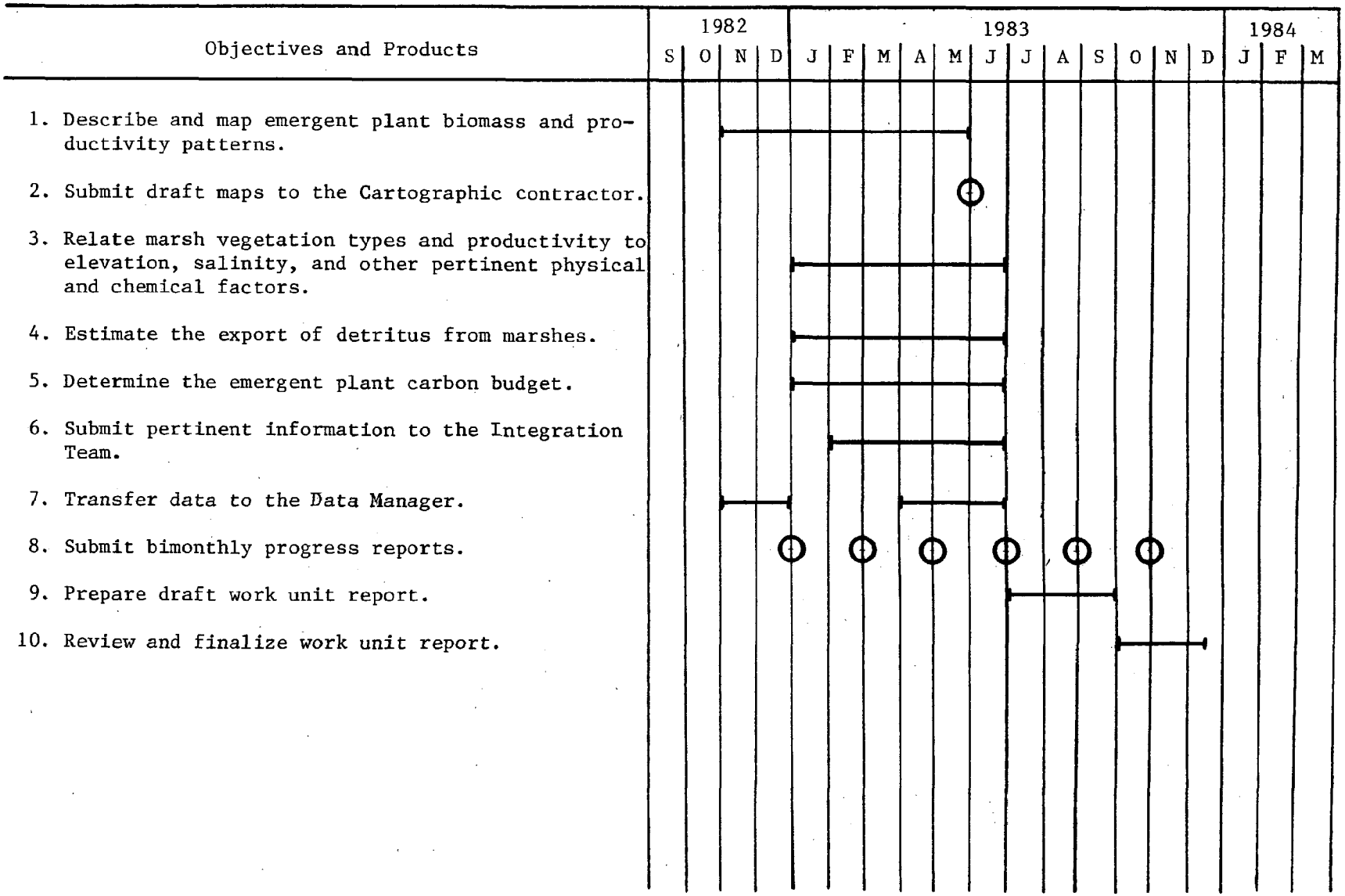
Integration and data exchange. Information such as emergent plant annual production rates, seasonal biomass dynamics, detrital export dynamics, and the emergent plant carbon budget will be submitted to the Integration Team to be used in the final integration product. This information will be used to determine functional linkages among the emergent plant system and other estuarine systems.

The most important data exchange for the Emergent Plant work unit is with CREST for the marsh vegetation community maps and the marsh elevation data. Additionally, information on salinity and sediment distribution may be required from the Currents and Sedimentation work units respectively. The Wildlife work unit can supply information on the food types and, perhaps, consumption rates of herbivorous mammals residing in marshes.

Products

The products of the Emergent Plant work unit under objective 1 will include a draft map of marsh production and monthly/seasonal biomass which will be submitted to the Cartographic contractor for final production. A final report consisting of a narrative with graphics will summarize the findings from objectives 1 through 4. Also included in the report will be background literature information, study methods, and other incidental results and conclusions not included in the objectives. The schedule for the Emergent Plant work unit is shown in Figure 4.1.

Figure 4.1. Schedule for the Emergent Plant Primary Production work unit.



4.3 Benthic Primary Production

Introduction

Benthic primary producers include microalgae (mainly diatoms), macroalgae, and submergent aquatic plants in intertidal and shallow subtidal regions of the estuary. The latter two are not conspicuous on the estuarine tidal flats; for example, eelgrass has only a sparse, patchy distribution in Baker Bay. The benthic diatoms, however, may represent a major food source to benthic invertebrates, and their dynamics need to be better understood.

The general purpose of the Benthic Primary Production work unit is to determine mechanisms which control the production dynamics of benthic plants in the Columbia River Estuary. The research is primarily concerned with the effects of chemical and physical processes on the structure and function of microalgal assemblages. This work unit is also investigating the spatial and temporal extent and productivity of microalgal assemblages. The design of the research allows for the direct integration of the results into the estuary carbon budget.

Objectives

1. Describe and map benthic microalgal productivity, biomass, and related variable patterns.

2. Relate microalgal productivity to sediment parameters, salinity, and other pertinent physical and chemical factors.

3. Determine the microalgal carbon budget.

Data Sets

a) Raw and analyzed data from sampling 5 intensive survey sites from May 1980 to April 1981. Variables measured include chlorophyll a, gross primary production, oxygen consumption, sediment organics, sediment grain size parameters, temperature, and light intensity.

b) Unprocessed samples and raw data from the sampling survey of May and June 1981 to identify validation sampling sites. Variables measured include chlorophyll a and sediment properties.

c) Unprocessed samples and raw data from the validation sampling sites. Variables measured include chlorophyll a, primary production, oxygen consumption, sediment properties, temperature, and light intensity.

d) Experimental data collected at the Oregon State University Marine Science Center with the support of the EPA. These data include measurements of gross and net primary production in assemblages of isolated benthic diatoms, measurements of primary production in relationship to light intensity and

temperature, and the examination of the ratio of microalgal biomass to the concentration of chlorophyll a.

Objective/data set relationship matrix

	Data set			
Objectives	a	b	c	d
1	x	x	x	x
2	x			x
3	x	x	x	x

Tasks

Analysis summary. The first objective will be accomplished by processing the remaining stored samples and analyzing the raw data in order to determine the spatial and temporal patterns of microalgal productivity and related variables. Productivity estimates can be expanded to the entire estuary by 1) estimating productivity levels at sites where only chlorophyll a samples were taken by using established statistical relationships between chlorophyll a and 2) productivity using sediment information developed by the Sedimentation and Shoaling work unit (either maps or raw data) in conjunction with established statistical relationships between sediment parameters and productivity.

The second objective, relating benthic microalgal productivity to physical factors, requires an examination of statistical relationships between production and selected physical and chemical variables. Much of this has been completed but the raw data from intensive samples taken after October 1980 must be added to the analyses. Additionally, laboratory data suitable for examining relationships between microalgal productivity and light intensity and temperature will be used to help meet this objective.

Estimates of the benthic microalgal carbon budget (objective 3) will be prepared by drawing on the analyses described above as well as on established ratios between chlorophyll and carbon and between net and gross primary production. These analyses and estimates will provide benthic microalgal inputs and outputs for the different regions of the estuary. The carbon budget will be submitted to the Integration Team to be incorporated into the ecosystem carbon budget.

In addition to the above, a fourth objective of mapping eelgrass beds and estimating their productivity can be added if more funding becomes available (see section 6.6, Additional Work Tasks).

Data adequacy. The data sets are adequate to describe the biological processes and structure outlined in the objectives. However, because of the limited number of samples taken, extrapolating productivity levels to produce estuary-wide maps (objective 1) will be difficult without further field work (see section 6.6, Additional Work Tasks).

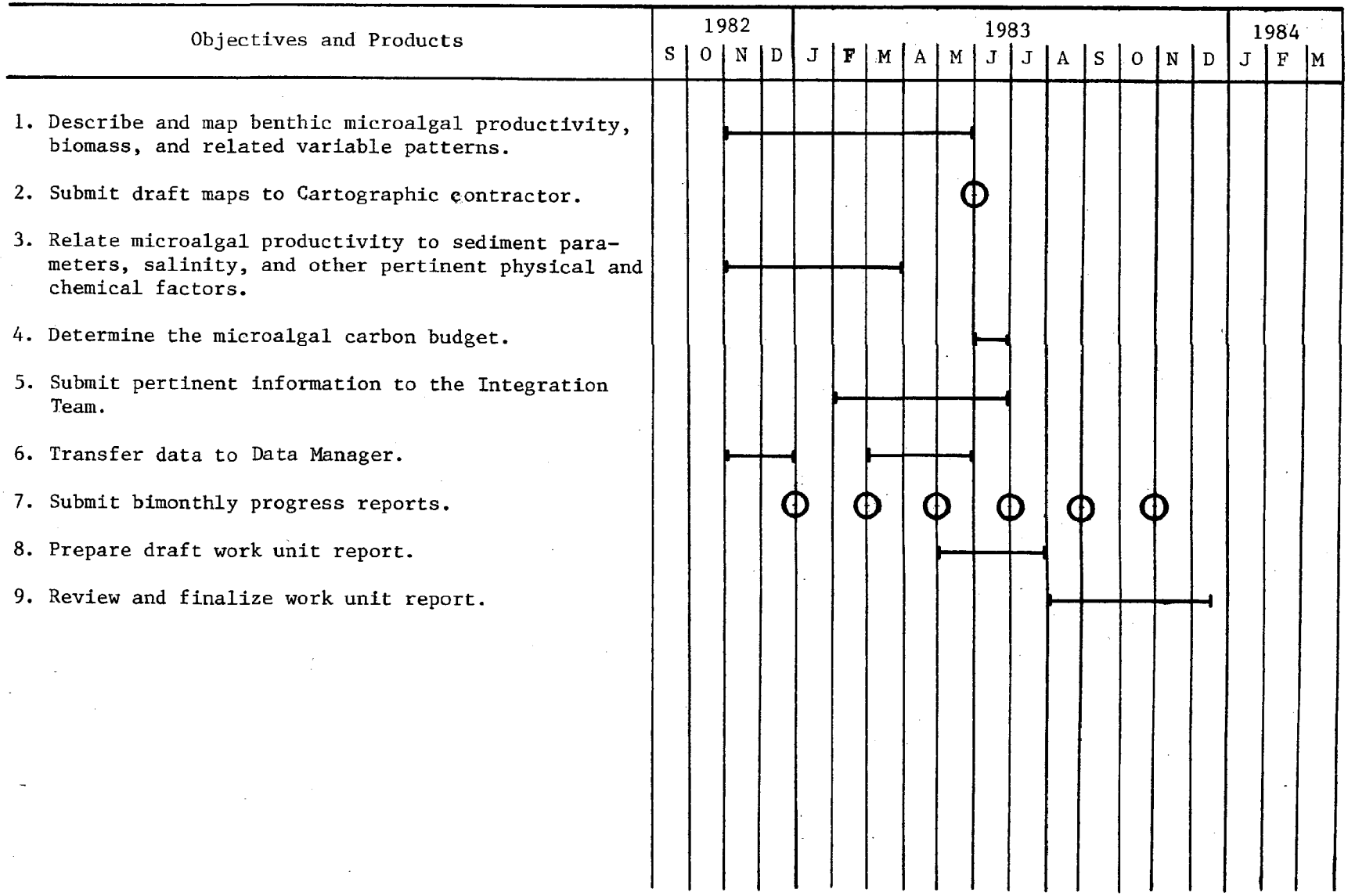
Integration and data exchange. Pertinent information developed from each data set will be submitted to the Integration Team to be used in the final integration product. This information will be used for examining some of the functional relationships among benthic primary production, benthic infauna, and emergent plants.

The most important data exchange for the Benthic Primary Production work unit is with the Sedimentation work unit. This may include sediment maps or appropriate raw data and the results of sediment grain size analyses. In addition, data on light intensity and light extinction from the Water Column Primary Production work unit and the prediction of water depth over the tidal flats from the Currents work unit will be helpful in assessing primary production in areas where direct measurements were not obtained. Any information on food consumption rates for deposit feeders from the Benthic Infauna work unit would also be useful to the Benthic Primary Production work unit.

Products

The products of the Benthic Primary Production work unit under objective 1 will include draft maps of benthic microalgal biomass, productivity, and possibly benthic oxygen consumption. These will be submitted to the Cartographic contractor for final production. A final report consisting of a narrative with graphics will summarize the findings from objectives 1, 2, and 3. Also included in the report will be study methods, background literature information, and other results and conclusions not included in the objectives, such as the ecological role of eelgrass beds, other aquatic angiosperms, and benthic macroalgae. The schedule for this work unit is shown in Figure 4.2.

Figure 4.2. Schedule for the Benthic Primary Production work unit.



4.4 Water Column Primary Production

Introduction

Water column primary producers, generally referred to as phytoplankton, may represent a significant fraction of the primary food supply in the estuary, contributing to the diets of some zooplankton, epibenthic invertebrate, and benthic infaunal populations. The latter organisms in turn supply food to many commercially important fish species. Therefore, to properly manage these commercially important species it is necessary to understand the abundance and dynamics of phytoplankton and other suspended organic particulates.

The purpose of the Water Column Primary Production work unit is to provide information on phytoplankton biomass and productivity over space and time, the concentration of other water column particulates, and physical and chemical factors such as salinity, temperature, and nutrients. This extensive data set will lead to a detailed understanding of this highly dynamic water column system and will be synthesized into a predictive model of phytoplankton productivity.

Objectives

1. Describe and map phytoplankton productivity and biomass patterns.
2. Relate phytoplankton productivity and biomass to light, salinity, currents (null zone), nutrients, and other pertinent physical and chemical factors.
3. Measure or estimate phytoplankton and other organic particulate inputs and outputs.
4. Determine the phytoplankton carbon budget.

Data sets

a) Analyzed data from the April 1980 to August 1981 sampling cruises. Variables measured include extracted chlorophyll *a*, *in vivo* fluorescence, organic seston, particulate nitrogen, particulate carbon, carbon productivity, inorganic nutrients, and phytoplankton species identification.

b) Predicted carbon productivity for full estuarine coverage approximately every other month from April 1980 to August 1981 from a model based on light input and chlorophyll biomass.

c) Analyzed data on the incoming light field.

d) Analyzed data on water transport in and out of the estuary.

e) Analyzed data from the June and July 1981 time-series zooplankton grazing experiments.

f) Estimates of particle sinking rates.

Objective/data set relationship matrix

	Data set					
Objective	a	b	c	d	e	f
1	x	x				
2	x	x	x	x		
3	x	x	x	x	x	x
4	x	x	x	x	x	x

Tasks

Analysis summary. The first objective, mapping water column primary production and biomass, requires no further data analysis. The spatial and temporal coverage of the samples allows for mapping directly from the data and analyses on hand. Draft maps will be produced showing productivity; such biomass variables as Chlorophyll a, particulate organic matter, and fluorescence; and, perhaps, nutrients.

Major work on the second objective has essentially been completed in the form of space-time plots relating physical and nutrient data to water column primary biomass and production, and a model to predict primary production from these physical and nutrient variables. Determining the relationships between phytoplankton and the null zone is an additional part of objective 2. This analysis has been partially completed but requires further identification and enumeration of phytoplankton species to better define spatial and temporal aspects of the null zone. Although a desirable task, this further processing cannot be funded under the anticipated funding level (see section 6.6, Additional Work Tasks).

The third objective will be accomplished by combining the grazing, import-export, and sinking rate information with water transport information developed by the Currents and Simulation work units. Characterizing sinking rates requires further analysis which will be curtailed under the anticipated funding level (see section 6.6, Additional Work Tasks). The input and output rates will be incorporated into a predictive model of phytoplankton dynamics.

The carbon budget will be determined from the results of objectives 1, 2, and 3. This budget will be completed by the contractor and used by the Integration Team in characterizing the total estuarine carbon budget.

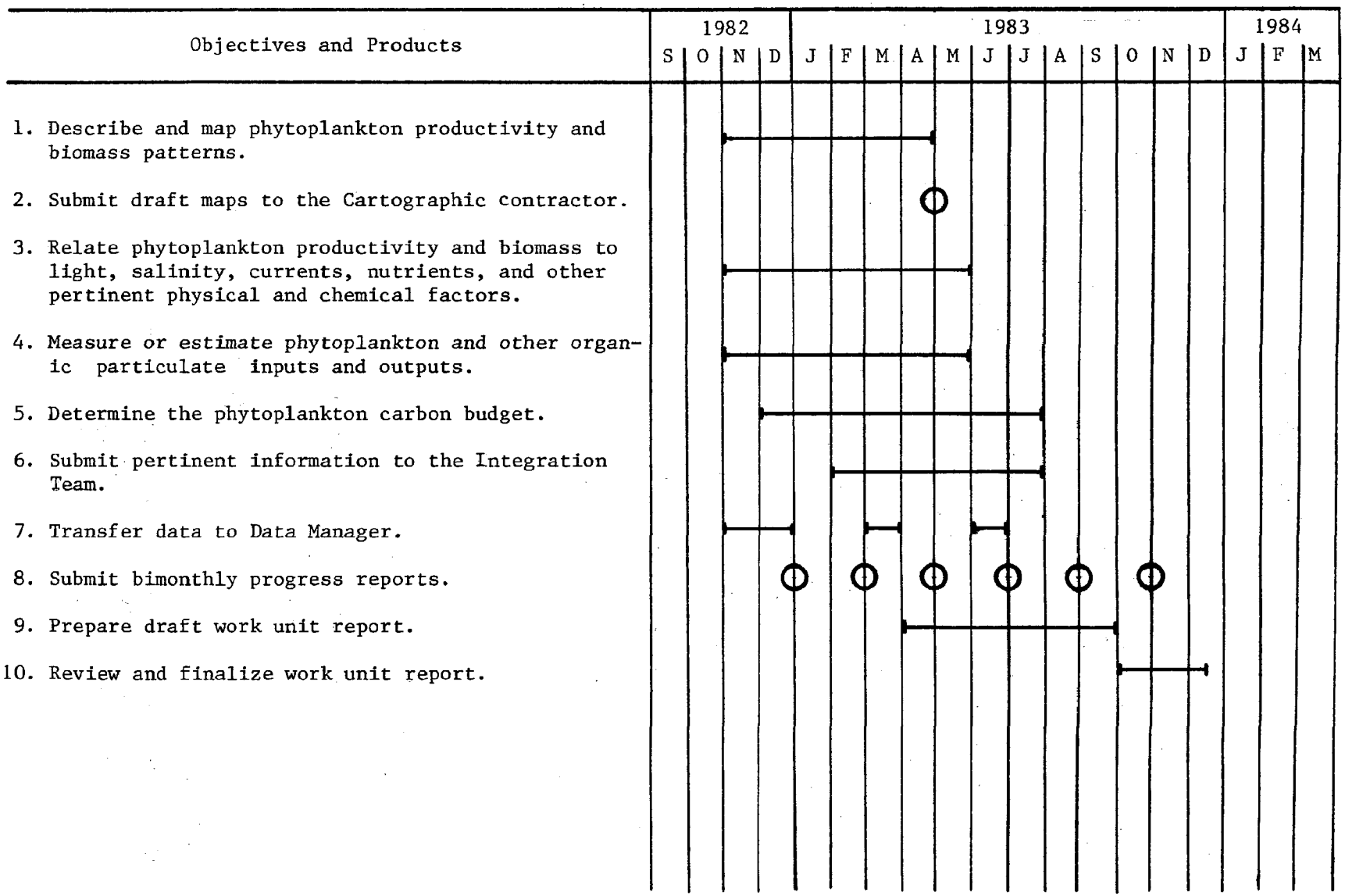
Data adequacy. All of the data sets are adequate to fulfill the objectives with some limitations. Grazing and sinking rate information needed for objective 3 are sparse, and rate information on the carbon loss due to phytoplankton respiration is nonexistent. Additionally, the importance of the null zone (under objective 2) will be difficult to determine without further identification of phytoplankton species.

Integration and data exchange. Information required by the Integration Team, such as phytoplankton input and output rates and carbon budget calculations will be submitted as it becomes available. The major data exchange required by the Water Column Primary Production work unit is with the Currents and Simulation work units for water transport information. The latter will be used to better understand phytoplankton import, export, and dynamics within the estuary. Calculations of the surface area at various depth intervals in the estuary (funded under another project) are needed in order to compute estuary-wide production and biomass levels. In addition, the Water Column Primary Production work unit may require information on abundance and distribution from the Zooplankton and Larval Fish work unit to better interpret the grazing rate determinations.

Products

The products of the Water Column Primary Production work unit under objective 1 will include draft maps of phytoplankton productivity, biomass, and, perhaps, nutrients. These will be submitted to the Cartographic contractor for final production. A final report consisting of a narrative with graphics will summarize the findings from objectives 1, 2, 3, and 4. Also included in the report will be study methods, background literature information, and other incidental results and conclusions not included in the objectives. The schedule for the Water Column Primary Production work unit is shown in Figure 4.3.

Figure 4.3. Schedule for the Water Column Primary Production work unit.



4.5 Zooplankton and Larval Fish

Introduction

Pelagic zooplankton are small water column animals that drift with water currents. They represent a major food source to commercially important fish and are therefore a concern of resource managers. Prior to CREDDP, only cursory studies of zooplankton populations had been undertaken on the Columbia River Estuary. The purpose of the Zooplankton and Larval Fish work unit is to examine the abundance, distribution, and population dynamics of important pelagic zooplankton species. Because larval fish are sampled with the same gear and techniques, this work unit also examines their abundance and distribution. The research is primarily focused on spatial and temporal population distributions, on relationships with physical factors, and on life histories of key species.

The sampling strategy of this work unit was such that temporal variations of the zooplankton assemblages could be examined on a biweekly time scale in the main channel from the mouth of the estuary to Cathlamet Bay. Additional samples were taken to define the depth distribution of Eurytemora in relation to tidal and diel cycles. The results from this work unit will enable the functional relationships of zooplankton and larval fish in the ecosystem to be defined, including predator-prey linkages, emigration and immigration, and their role in the estuary's carbon budget.

Objectives

1) Describe and map key and selected other zooplankton and larval fish species by principal life history stages, or assemblages, in terms of occurrence, density, and standing crop over time.

2) Quantify functional relationships among zooplankton and larval fishes and physical (salinity, temperature, tide stage) and biological (planktivorous predators) factors.

3) Describe population structure and dynamics, and life history of Eurytemora.

Data sets

a) Unprocessed samples, raw data, and partially analyzed data from the biweekly April 1980 to April 1981 samples. Variables measured include species identification, life history stage, abundance, sex, and maturity, and physical factors such as temperature, salinity, and water transparency.

Objective/data set relationships

Data set (a) is used in all objectives.

Tasks

Analysis summary. To accomplish the mapping objective (objective 1), the work unit contractor will use data from the April to October 1980 processed samples. The maps will show zooplankton and larval fish abundance and standing crop in the main channel to Cathlamet Bay during spring and summer seasons only. To expand the temporal coverage of the maps to an annual cycle, additional samples will need to be processed (October 1980 to April 1981). This can be accomplished only if additional funding is available (see section 6.6, Additional Work Tasks).

The second objective requires relating zooplankton density to physical factors using statistical analyses. The second part of the objective, relationships with biological factors, will require information on zooplankton species which are consumed by fishes and on fish standing stock. This will be supplied by the Fish work unit in order to define predator-prey relations with zooplankton.

The detailed description of Eurytemora life history and population dynamics (objective 3) will be accomplished by interpreting the data sets and results from objectives 1 and 2 to generate estimates of Eurytemora growth, duration of development by life history stage, fecundity, and production. As in objectives 1 and 2, the temporal coverage will be limited to the spring and summer seasons under present anticipated funding (see section 6.6, Additional Work Tasks).

In addition to the above objectives, a fourth objective, describing vertical and horizontal variation in Eurytemora populations over diel and tidal cycles, can be completed if samples from the depth/tidal/diel surveys are processed and analyzed. Information from these analyses would also augment objective 1. Analysing these samples would require funding beyond the anticipated level (see section 6.6, Additional Work Tasks).

Data adequacy. The data are adequate to complete the objectives listed; however, coverage will be limited to the main shipping channel from the mouth of the estuary to the western portion of Cathlamet Bay during the spring and summer seasons only. As discussed above, the temporal coverage can be increased to an entire annual cycle with increased funding for this work unit.

Integration and data exchange. The combined data sets, reports, and other products generated in meeting objectives 1 - 3 will provide the basis for the Integration Team's synthesis of the functional relationships of pelagic zooplankton and larval fish in the estuary's ecosystem. Included will be an

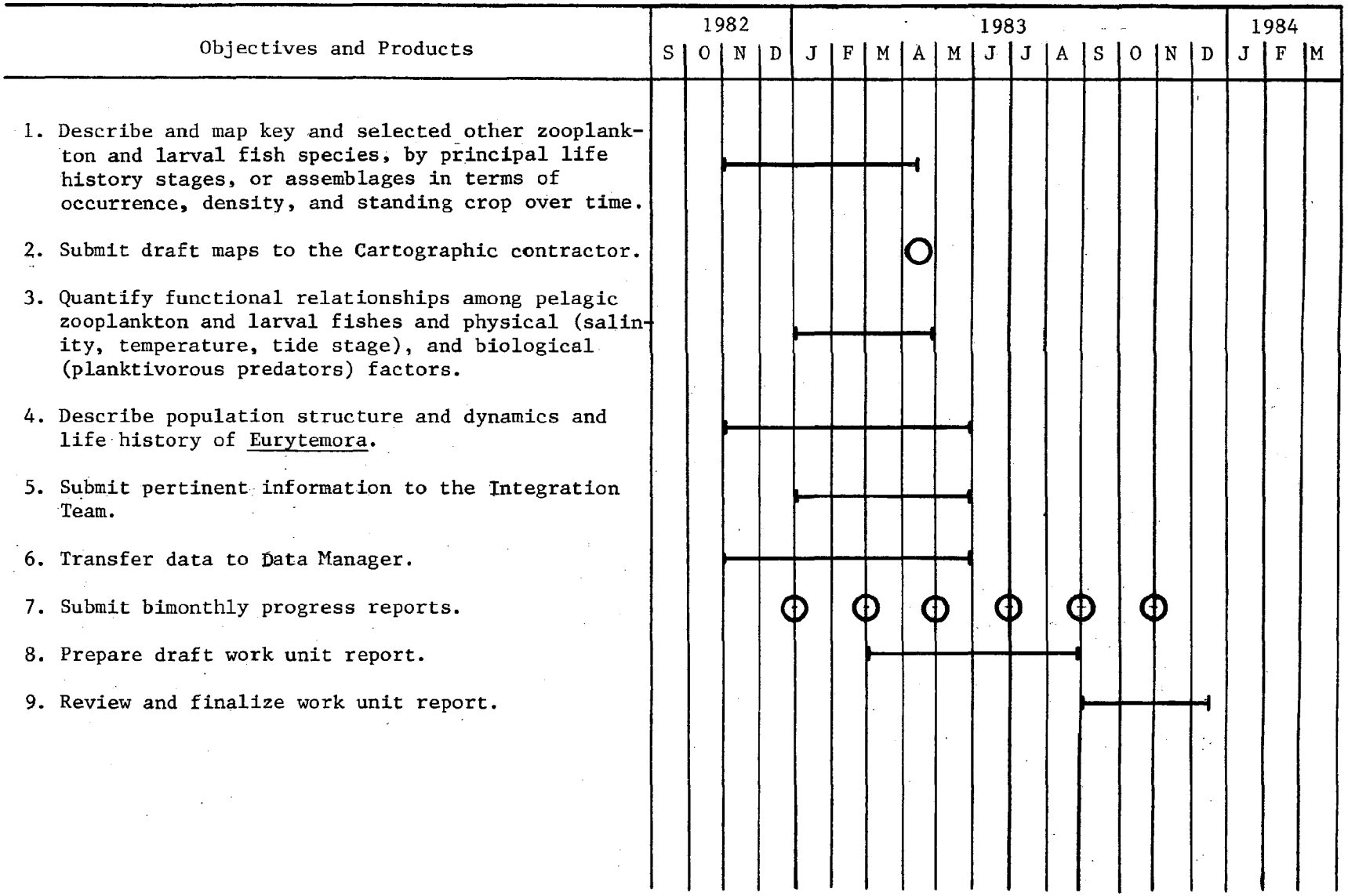
analysis of predator-prey linkages, emigration and immigration, and the role of zooplankton and larval fish in the estuary's carbon budget.

The primary data exchange required by this work unit is information about predation on zooplankton and fish standing stock from the Fish work unit. Information on salinity distribution and circulation will also be required from the Currents work unit.

Products

The products of the zooplankton and larval fish work unit under objective 1 will include draft maps of key species density and standing crop. These will be submitted to the Cartographic contractor for final production. A final report including a narrative with graphics will summarize the findings from objectives 1, 2, and 3. Also included in the report will be study methods, background literature information, and other results and conclusions not included in these objectives, such as the results of the fourth objective (discussed above), if funded. The work unit objectives and products are scheduled in Figure 4.4.

Figure 4.4. Schedule for the Zooplankton and Larval Fish work unit.



4.6 Benthic Infauna

Introduction

Benthic infauna are important as food organisms for many fish and bird species and are commonly studied as indicator organisms of ecosystem change. Although infauna have been studied intensively in some areas of the estuary, there have been few life history/production studies and no estuary-wide studies. The purpose of the Benthic Infauna work unit is to fill this gap by describing the temporal and spatial distribution of infauna and determining the life histories and production of key species. In the first phase of research, intensive field investigations were set up at a few selected sites to acquire life history information and to describe the seasonal changes in benthic infaunal assemblages. The second phase was the collection of an estuary-wide sample set upon which the mapping of infaunal density will be based. The combination of the data sets from these two research phases allows for an understanding of seasonal changes in benthic infauna over the entire estuary.

Site-specific information from past studies on benthic infauna will be incorporated into the CREDDP results. After all of the results have been integrated with other work units, a more complete understanding of processes associated with benthic infauna will be attained.

Objectives

1. Describe and map key and selected other benthic infauna species or assemblages in terms of density, standing crop, and production over time.

2. Quantify relationships among benthic infauna and physical (salinity, sediments, depth) and biological factors.

3. Determine the population structure and dynamics, life history, and turnover rates of *Corophium*, *Macoma*, *Hobsonia*, and *Pseudopolydora*.

4. Define functional relationships of benthic infauna in the ecosystem, including predator prey linkages, population movements, and role in the estuary carbon budget.

Data sets

a) Unprocessed samples from the September 1981 distributional survey. Variables measured include species density and biomass and sediment samples for standard grain size analysis.

b) Raw and partially analyzed data from the October 1979 and April 1980 preliminary samples. Variables measured include species identification and density.

c) Data from National Marine Fisheries Service studies.

d) Data from past studies of infauna in Youngs Bay.

e) Unprocessed samples and raw data from the August 1980 to September 1981 monthly (or biweekly) intensive studies. Variables measured include species density, biomass, and life history information on Corophium, Macoma, Hobsonia and Pseudopolydora.

Objective/data set relationship matrix

	Data set				
Objective	a	b	c	d	e
1	x	x	x	x	x
2	x	x			x
3					x
4	x	x	x	x	x

Tasks

Analysis summary. To complete the mapping objective, the estuary-wide survey samples will be processed and species density and biomass statistically correlated with sediment parameters. This information may be combined with the sediment distribution maps to expand the point data to cover the entire estuary. The results will then be combined with the seasonal dynamics data from the intensive studies to expand the fall survey data to cover an annual cycle. CREDDP cannot fund processing the entire distributional survey under the present funding assumptions (see section 6.6, Additional Work Tasks). Data from the preliminary survey (data set b) and past studies (data sets c and d) will aid in the mapping.

After the samples from the estuary-wide and intensive surveys are processed infauna density and standing stock will be correlated with physical factors such as sediment grain size (discussed above), salinity, and depth (objective 2). The relationships among infauna species and biological factors will come mainly from correlations with other species and inferences from other work units, particularly Fish and Avifauna.

The third objective requires completing the processing and analysis of the intensive survey data set. From this information, life history and turnover estimates can be generated for Corophium, Macoma, Hobsonia, and Pseudopolydora.

To complete objective 4, literature information on feeding rates, respiration, and food requirements of benthic infauna will be gathered. Coupled with standing stock estimates for benthic assemblages in the estuary, these will allow estimation of energy flow passing through this portion of the estuarine community which will, in turn, allow for carbon budget formulation by the Integration Team.

Data adequacy. The data sets are adequate to complete the objectives with a few constraints. First, because biomass was not measured in all samples, producing biomass maps will require converting density to biomass. Additionally, production can only be calculated for a few species (see data set e) so mapping the production of the entire infaunal assemblage will depend on indirect estimates based on biomass. Objective 4 also depends on the production estimates as well as other estimates such as food consumption and respiratory loss rates. If additional funding becomes available, the resolution of all the results will be increased by processing additional samples, such as the quarterly survey and vertical distribution samples. (see section 6.6, Additional Work Tasks).

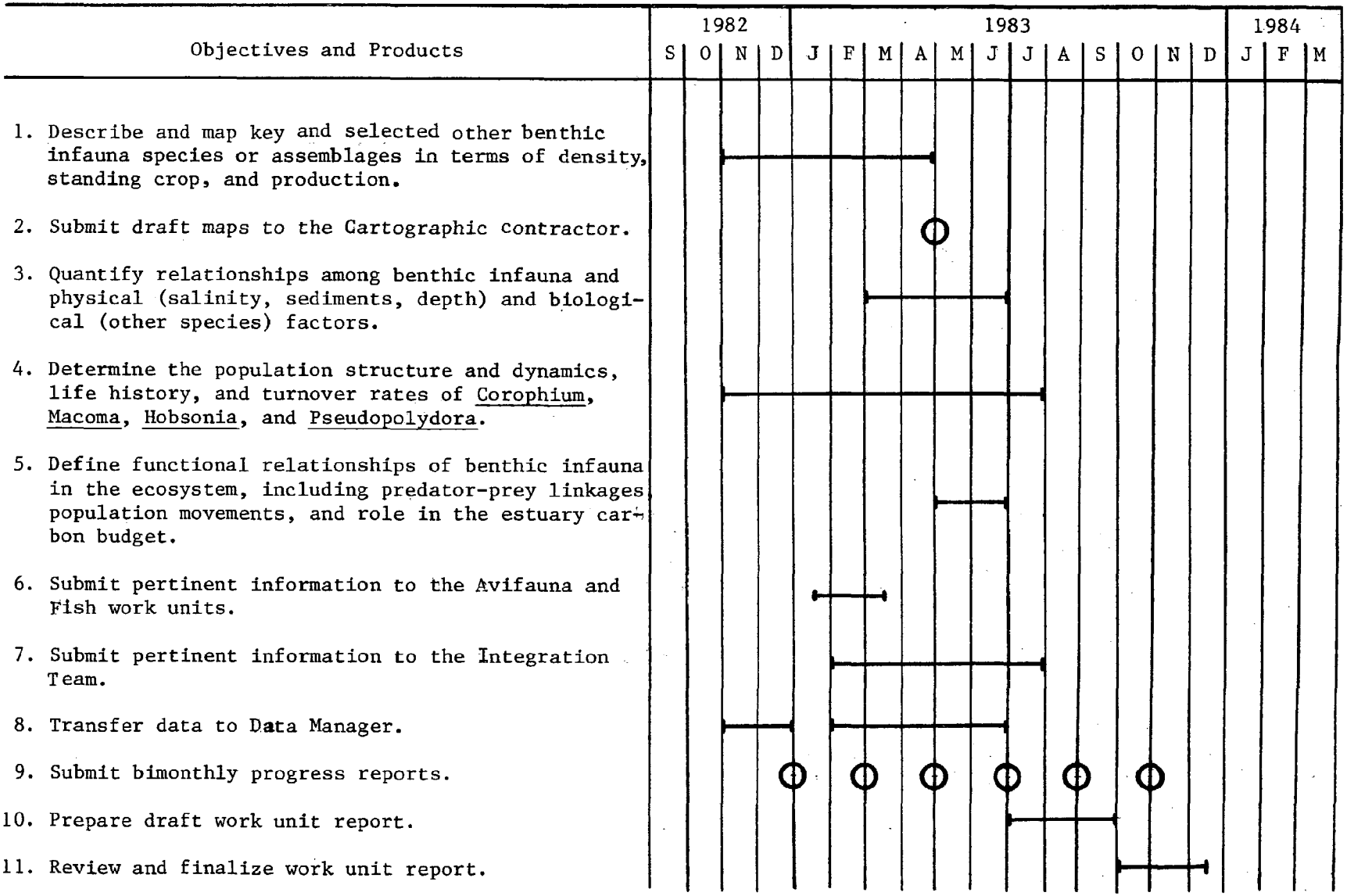
Integration and data exchange. The Benthic Infauna contractor will submit pertinent information to the Integration Team as it is produced. The information required to complete objective 4 is especially important.

Work unit data exchange will consist primarily of sediment maps or appropriate habitat maps, raw data from sediment analyses, and salinity distribution information to be supplied by the Sedimentation and Currents work units respectively. The Benthic Infauna contractor will submit information on the distribution of infauna species to the Fish and Avifauna work units. The benthic infauna information will be used to analyze feeding relationships between infauna and their predators.

Products

The products of the Benthic Infauna work unit under objective 1 will include draft maps of benthic infaunal density, biomass, and production. These will be submitted to the Cartographic contractor for final production. A final report consisting of a narrative with graphics will summarize the findings from objectives 1-4. Also included in the report will be study methods, background literature information, and other results and conclusions not included in the objectives, such as the vertical distribution of benthic infauna in the sediment and the effects of the Mt. St. Helens eruption on benthic infauna. The schedule for the Benthic Infauna work unit is shown in Figure 4.5.

Figure 4.5. Schedule for the Benthic Infauna work unit.



4.7 Epibenthic Organisms

Introduction

Epibenthic organisms are animals that exist on or just above the estuary's bottom. These organisms include epibenthic zooplankton and mobile macroinvertebrates such as Dungeness crab and sand shrimp. Many of these organisms are important links between primary production and fish, yet they are rarely studied adequately. The purpose of the Epibenthic Organisms work unit is to describe key species distribution and population dynamics, secondary production, life histories, and predator-prey interactions.

The sampling of the work unit was habitat-stratified so that species density and standing crop information could be extrapolated to cover the entire estuary. Four types of sampling gear were used to assure representative catches of most of the organisms in the diverse epibenthic assemblage. The information generated by this work unit should be easily integrated with other work units for formulating the estuary-wide carbon budget.

Objectives

1. Describe and map key and selected other epibenthic species or assemblages in terms of density, standing crop, and production over time.

2. Quantify relationships among epibenthic organisms and physical (salinity, sediments, depths) and biological factors.

3. Describe the population structure, dynamics, life history, and trophic relationships of Dungeness crab, crangonid shrimp, and mysids.

4. Define functional relationships of epibenthic organisms in the ecosystem, including predator-prey linkages, emigration and immigration, and role in the estuary carbon budget.

Data sets

a) Unprocessed samples, raw data, and analyzed data from the March 1980 to July 1981 sampling. Variables measured include species identification, life history stages, abundance, weight, carapace length, sex, and maturity with corresponding data on tidal elevation, temperature, salinity, tidal stage, and sediment grain size.

Objective/data set relationships

Data set (a) is used in all of the objectives.

Tasks

Analysis summary. To complete the first objective, the remaining raw data must be analyzed and tabulated to give information on density, standing crop, and production for an annual cycle. Because the sampling was habitat-stratified, the data can be easily extrapolated over the total estuary on either the habitat-type maps produced by the Integration Team or a sediment map used in conjunction with bathymetric and salinity distribution information.

Various statistical analyses on the biological and physical data collected in data set (a) must be performed in order to relate epibenthic assemblages to physical factors (objective 2). The relationships among epibenthic organisms and biological factors will originate from correlations with other taxa and from inferences from work units studying their predators, particularly Fish, Avifauna, Wildlife, and Marine Mammals.

Objective 3 will be completed using the life history and population information developed from the data set. Describing trophic relationships of Dungeness crab, crangonid shrimp, and mysids cannot be completed, because stomach analyses of macroinvertebrates cannot be funded under the present assumptions (see section 6.6, Additional Work Tasks). Literature information may help to fill this gap.

Completing objective 4 requires information on macroinvertebrate feeding and literature information on respiration and food requirements of epibenthic zooplankton. Direct or metabolic measures of consumption rates, coupled with standing stock estimates for epibenthic assemblages, will allow estimation of energy flow. This will be incorporated into the estuary-wide carbon budget by the Integration Team.

Data Adequacy. The data are adequate to complete all of the objectives except objective 3. The trophic relationships portion of objective 3 requires further analysis of macroinvertebrate stomachs which, as discussed above, will not be funded under current assumptions. If funding becomes available, the stomach analysis data will be adequate to complete this objective. The resolution of objective 4 may be limited because literature information related to epibenthic zooplankton is sparse and quantitative data on macroinvertebrate feeding are lacking.

Integration and Data Exchange. The Epibenthic Organisms contractor will submit pertinent information to the Integration Team. Of particular importance is the information required to formulate the carbon budget.

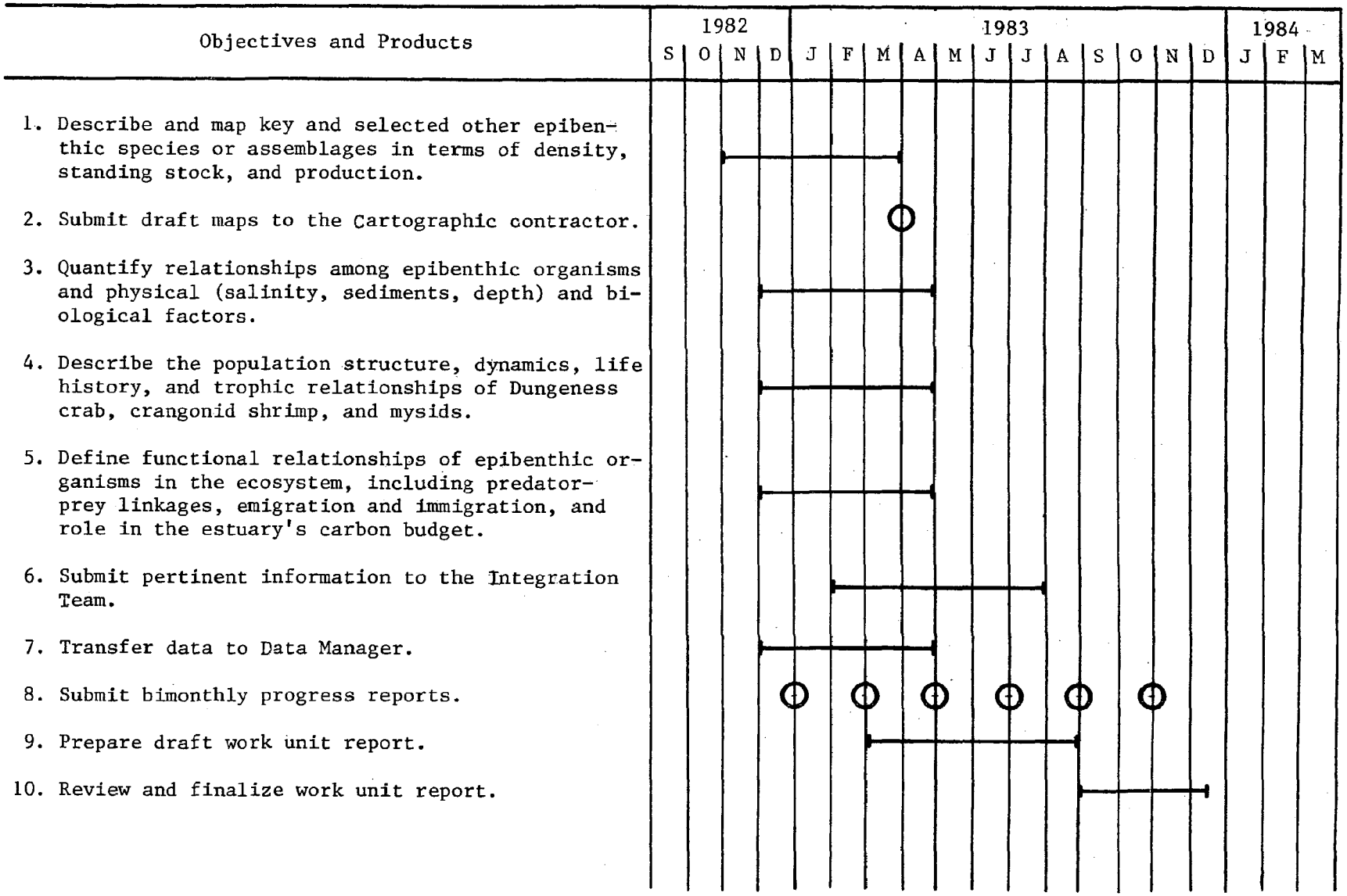
The Epibenthic Organisms work unit will require sediment and salinity maps or

appropriate habitat type maps and also the data from analysis of some of its sediment samples. Additionally, the Epibenthic work unit will exchange data with the Fish, Avifauna, Wildlife, and Marine Mammal work units for the purpose of analyzing predator-prey relationships.

Products

The products of the Epibenthic Organisms work unit under objective 1 will include draft maps of epibenthic organism density, standing crop, and secondary production. These will be submitted to the Cartographic contractor for final production. A final report consisting of narrative with graphics will summarize the findings from objectives 1-4. Also included in the report will be study methods, background literature information, and other results and conclusions not included in the objectives, such as a qualitative assessment of the importance of the estuary to Dungeness crab and crangonid shrimp. The schedule for the Epibenthic Organisms work unit is shown in Figure 4.6.

Figure 4.6. Schedule for the Epibenthic Organisms work unit.



4.8 Fish

Introduction

Fish, because of their commercial and recreational value, are one of the most important concerns of resource management agencies. In order to properly manage fisheries, the seasonal abundance and distribution of fish species must be known along with the interaction of these species and other aspects of the ecosystem. The purpose of the Fish work unit is to determine the spatial and temporal distribution of salmonid and non-salmonid fish in the estuary. The research is focused on distributional studies and temporal population changes using both estuary-wide and diel sampling. Four types of sampling gear were used to assure sampling of as many fish species as possible. In addition to distributional data, the fish contractor collected extensive data on feeding habits and growth rates. The work unit will be able to generate extensive distributional information and, upon integrating the data with other work unit results, define the functional relationships among fish and other trophic levels. Moreover, the relationships between fish species and physical factors will be described. Because the Fish work unit has collected a vast amount of data, and some of the data may have been biased by the Mt. St. Helens eruption, extreme care will be used to select only those data sets for processing which will allow the objectives to be achieved.

Objectives

1. Describe and map key and selected other fish species by life history stage or assemblages in terms of density and standing crop over time.

2. Quantify relationships among key fish species and physical (salinity, temperature, tide stage) and biological factors.

3. Describe and map migration routes and timing (seasons, residence time) of juvenile and adult salmon and the feeding habitats of juvenile salmon in different estuarine habitats.

4. From stomach analyses, tabulate composition, abundance, and biomass of prey in the diets of key fish species and life history stages, with emphasis on diel samples.

5. Generate estimates of growth over time of identifiable cohorts of key species residing within the estuary.

6. Estimate mean consumption rates of key fish species/life history stages and proportional contribution of principal prey taxa in different regions/habitats of the estuary. Discuss the role of a key species in the estuary's carbon budget.

Data sets

a) Raw and partially analyzed data from the February 1980 to July 1981 distributional surveys. Variables measured include species identification, life history stage, abundances, weights, lengths, and physical factors (temperature, salinity, depth).

b) Raw and partially analyzed data from the April to September 1980 diel surveys. The same variables were measured as in data set (a).

c) Unprocessed samples, raw data, and partially analyzed data from the fish stomach samples taken during the distributional and diel surveys.

d) Non-CREDDP data and reports involving juvenile salmonid catches, mark-recapture of tagged juvenile salmonids, and commercial salmon catches.

Objective/data set relationship matrix

	Data set			
Objective	a	b	c	d
1	x			
2	x	x		
3	x	x	x	x
4			x	
5	x			x
6		x	x	x

Tasks

Analysis summary. To complete the first objective, the relative abundance and weight data must be converted to density and standing crop estimates. This requires standardized effort computations for each type of sampling gear. Seasonal maps can then be produced directly from the converted data. Because of the large number of key fish species (17), information on several species or an assemblage may have to be displayed on a single map. Although fish population sizes in the estuary cannot be estimated, the density and standing crop estimates will allow for approximations and descriptions of the functional relationships between fish and their predators and prey.

Relating fish species to physical factors (objective 2) will require combining the biological and physical data from the surveys and performing various statistical analyses in order to examine the relationships. The second part of

this objective will be based on analytical correlations of fish and other estuarine organisms as well as inferences on the results of the Zooplankton, Benthic Infauna, Epibenthic Organisms, Avifauna and Marine Mammals work units.

The third objective requires a synthesis of both CREDDP and non-CREDDP data on distribution and feeding ecology of salmonids. Integrating these will permit a detailed description of salmon movement, timing, and feeding.

Analyzing key fish species feeding habits (objective 4) will require additional processing of fish stomach samples. About 200 selected stomachs will be processed with emphasis placed on the diel surveys so that the 24 hour feeding chronologies can be quantified. If additional funding is available, more stomachs can be analyzed resulting in a better understanding of feeding habits (see section 6.6, Additional Work Tasks). Adequate time and money will not be available to process all of the thousands of fish stomach samples taken under CREDDP so care must be taken to select a representative sub-sample of stomachs for processing. Because the eruption of Mt. St. Helens may have temporarily changed feeding habits of fish species, stomach samples collected before the May 18, 1980 eruption will be selected for processing.

The growth rates of key fish species (objective 5) will be generated for those species where data are complete enough to identify specific cohorts. Both length and weight data will be used in these analyses.

Consumption rates (objective 6) will be estimated by using the diel stomach analyses combined with information from the literature. The diel feeding chronologies will be quantified and gastric evacuation rates estimated. This information will be used by the Integration Team to determine the role of fish in the estuary's carbon budget.

Data adequacy. The data are adequate to achieve all of the objectives with some constraints. For example, the sampling design of the surveys do not adapt easily to estimating and mapping fish density and standing crop and, because of the lack of replication, sampling variability cannot be interpreted. Additionally, the eruption of Mt. St. Helens severely biased the catches and other samples from May to July 1980. The feeding habit data set is only complete for juvenile salmonids; therefore, as many non-salmonid stomach samples as possible should be processed.

Integration and data exchange. All pertinent results will be submitted to the Integration Team as they are produced. The major submission will be the results of objective 6 to be integrated into the estuary's carbon budget.

The main data exchange will be with those work units studying fish prey

species and predators to further define trophic linkages.

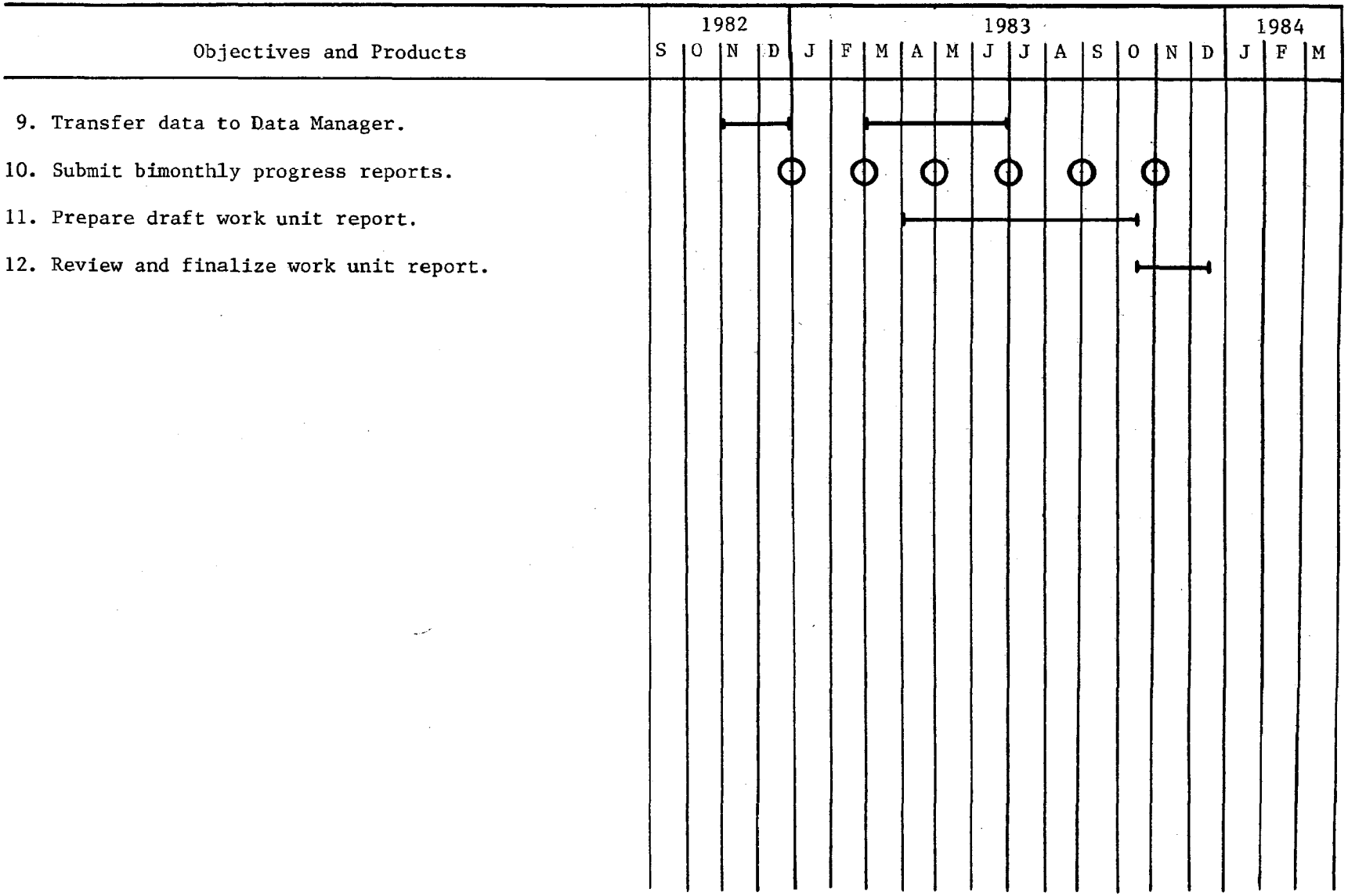
Products

The products of the fish work unit under objective 1 will include draft maps of key fish species density and standing crop. These will be submitted to the Cartographic contractor for final production. A final report consisting of a narrative with graphics will summarize the findings from objectives 1 through 6. Also included in the report will be study methods and background literature information. The schedule for the Fish work unit is shown in Figure 4.7.

Figure 4.7. Schedule for the Fish work unit.

Objectives and Products	1982				1983												1984		
	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M
1. Describe and map key and selected other fish species (by life history stage) or assemblages in terms of density and standing crop.			─	─	─	─	─	─	─										
2. Submit draft maps to the Cartographic contractor.									O										
3. Quantify relationships among key fish species and physical (salinity, temperature, tide stage) and biological factors.				─	─	─	─	─	─	─									
4. Describe and map migration routes and timing (seasons, residence time) of juvenile and adult salmon and the feeding habits of juvenile salmon in different estuarine habitats.			─	─	─	─	─	─	─	─									
5. From stomach analyses, tabulate composition, abundance, and biomass of prey in the diets of key fish species and life history stages with emphasis on diel samples.			─	─	─	─	─	─	─										
6. Generate estimates of growth over time of identifiable cohorts of key species residing within the estuary.			─	─	─	─	─	─	─										
7. Estimate mean consumption rates of key species/life history stages and proportional contribution of principal prey taxa in different regions/habitats of the estuary. Discuss the role of key species in the estuary's carbon budget.					─	─	─	─	─	─									
8. Submit pertinent information to the Integration Team.						─	─	─	─	─	─								

Figure 4.7. Schedule for the Fish work unit (continued).



4.9 Avifauna

Introduction

The Columbia River Estuary supports a diverse assemblage of resident and migratory birds. While information is available on the diversity of avifauna in the estuary and on the numbers of waterfowl in particular, there has been no concerted effort to determine the use of estuarine habitats by bird species and to link avifauna with the estuarine carbon budget. Key avifauna for CREDDP include some of the most abundant, and economically important, and endangered species.

The purpose of this work unit is to gather information on the role of these avifauna in the estuary and to assess their abundance and distribution through habitat stratified sampling. The avifauna data are relatively well processed, and a draft final report has already been submitted by the previous contractor. The inclusion of this work unit in the revised Plan of Study is intended to re-evaluate and reformat the data and make them more useful to the Integration Team and to product users.

Objectives

1. Describe and map key avifauna species abundance and habitats.

2. Determine avifauna food requirements and prey composition.

Data sets

a) Raw line census and point census data taken twice seasonally from spring 1980 to winter 1981. Variables measured include number of birds/km by species, distance from the observer and activities.

b) Partially analyzed variable circular plot data taken twice seasonally from spring 1980 to winter 1981. Variables measured include species densities, species diversity (richness and eveness), and consuming biomass.

c) Raw data from incidental bird sightings and nesting survey.

Objective/data set relationship matrix

	Data sets		
Objectives	a	b	c
1	x	x	x
2	x	x	

Tasks

Analysis summary. Objective 1, describe and map key species abundance and habitats, will be achieved using the variable plot density data and the line transect abundance data converted to densities for each habitat type. These habitat/density data will be directly comparable to a habitat type map produced by CREDDP. Critical areas identified in data set (c) will also be included on the maps.

Objective 2, estimate food requirements and prey composition of key species, will be achieved by apportioning consuming biomass for each key species according to prey composition values from the literature. A review of existing literature will be used to obtain inferences about food requirements and food composition for selected key species. Additionally, information from the Benthic Infauna, the Epibenthic Organisms, and the Fish work units will be needed to complete this objective. Feeding rates and probable prey consumption will be described, and this information will be combined with the avifauna densities from objective 1.

If additional funding becomes available, new objectives may be added which describe 1) possible factors that limit bird use of particular habitats and 2) the importance of the Columbia River Estuary within the Pacific Flyway as an overwintering and migration route (see section 6.6, Additional Work Tasks).

Data adequacy. Although the avifauna data and the findings expected from literature searches are adequate to achieve the objectives, many results will be approximations at best. The variable circular plots density data are more accurate than those derived from the line transects. These data give approximate densities for habitat types, and further extrapolation of these data with feeding habits to predict impacts on prey species will be even more approximate.

Integration and data exchange. The data from the Avifauna contractor on prey items and consuming biomass will be submitted to the Integration Team. Good co-ordination between the Avifauna contractor and the persons responsible for drafting habitat type maps is essential to the success of objective 4. The habitat types for which avifauna densities are calculated must correspond to those drafted on the habitat-type maps, so that the information can be overlayed. A second area where data exchange is needed is objective 2, estimates of food requirements. Work units studying potential avifauna prey species must submit distribution/density information on these before the avifauna food sources in the estuary can be predicted. These work units include Benthic Infauna, Epibenthic Organisms, and Fish.

Products

The products from objective 1 will be data on key species densities in habitat types which can be overlayed on a habitat type map. Also, the locations of critical feeding and nesting areas for rare, threatened and endangered species will be mapped. Objective 2 will yield a report summarizing the likely prey species and consuming biomass of key species. The work unit's objectives and products are scheduled in Figure 4.8.

Columbia River Estuary Data Development Program

Post Office Building, Room 214 P.O. Box 175 Astoria, Oregon 97103 [503] 325-0405

8 February 1983

RICHARD M. MORSE
FEDERAL REPRESENTATIVE
COLUMBIA RIVER ESTUARY DATA DEVELOPMENT PROGRAM

U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NATIONAL OCEAN SERVICE - OFFICE OF THE CHIEF SCIENTIST
1801 FAIRVIEW AVENUE EAST
SEATTLE, WASHINGTON 98102 (206) 442-4567

MEMORANDUM

TO: CREDDP Users Advisory Panel
FROM: Jack Damron, Michael DeLapa
SUBJ: Interim progress report

Five months have passed since CREST and the U.S. Water Resources Council signed a cooperative agreement to resume the Columbia River Estuary Data Development Program (CREDDP), and the program is well underway. The attached Proposal Review Schedule shows our progress (attachment 1). Except for the Fish and Avifauna work units, all other contractors have begun work following work programs structured after those established in the final Plan of Study. We would like to tell you about our progress and future plans, and solicit your help in developing reports, maps, charts and other products that will meet your needs.

User and Integration Meetings

On November 18, 1982, twenty-three representatives of local, state and federal agencies, citizen groups, and other parties interested in estuarine management attended the first CREDDP Users Advisory Panel meeting. In the morning, CREDDP technical coordinators reviewed the progress in issuing contracts. In the afternoon, David McIntire, O.S.U. Estuarine Botanist and a member of the Integration Team, presented some preliminary thoughts on our data integration effort and responded to participants' comments. Brad Harvey, from Northwest Cartography, presented his proposal for a program atlas, and participants discussed this and other ideas for final products. It became clear that no consensus was possible on which final products were best, and that the Program should seek to develop a mix of different products to meet the varied needs of estuary managers and citizens.

On December 2, 1982, users met with the CREDDP Integration Team members. The purpose of this meeting was to allow interested users to communicate their needs directly to the team of scientists responsible for analyzing and synthesizing the multidisciplinary data base. Seventeen persons attended the session which began with a discussion of different approaches to final products. The Integration Team responded to specific questions about work progress and the application of research results. Several users requested a more detailed conceptual modelling scheme. The Users Panel and Integration Team met separately in the afternoon with the users attempting to better define their needs and the Integration Team working on the conceptual model.

On December 3, the Integration Team met in the CREST office where they continued to discuss the conceptual approach. The biological members of the Integration Team (Simenstad, Small and McIntire) met again on January 12-14, 1983 and the entire team will meet again on Feburary 14-16 to refine their ideas. The Team plans to develop an outline of the final integration report late February to distribute to CREDDP users. Anyone interested in following the progress of the team more closely should contact Jack.

Delays and Problems

The Fish work unit is several months behind schedule due to problems in agreeing to a Scope of Work, but we are hopeful that work can begin by the second week in February.

The Cartography work unit contract has been let and it is structured with substantial flexibility to define and revise the mix of final products.

The Avifauna work unit proposal has not yet been finished but this poses no problem at this time.

User Needs and Final Products

Although there have been no major changes to the Plan of Study, some of our ideas about final products have changed and we expect them to continue to change. For CREDDP products to be fully responsive to user needs we will need your assistance. Attachment 2 is a preliminary listing of possible products, and we would appreciate your views. Which products do you feel are important and useful? Are there other things you would like to see? Please call or write and let us know your ideas.

The Integration Team has suggested that users provide potential development scenarios (e.g. river flow levels, possible dredging projects, etc.) to test the numerical and other models. The users guide could be designed to show how CREDDP data might be used to assess the impacts of these activities.

In late February, you will be receiving a draft outline of the final integration report. Before then, we would appreciate any comments or questions you might have.

Future Activities

The next scheduled User Advisory Panel meeting is in May when we plan to have a two day symposium of research results on May 24-25, 1983. We could schedule another users meeting in March or April if there is a sufficient demand for one. Otherwise, we will report our accomplishments in another progress report next month. Thank you for your interest in CREDDP.

Attachments

Attachment 1

PROPOSAL
REVIEW
SCHEDULE

February 8,1983

	RFP Mailed	Proposal Received	Initial Review by Technical Coordinator	Full Staff Review	Staff Comments Mailed	Revised Proposal Received	Proposal Mailed to FAP	FAP Review Complete	PCB Authority to Negotiate	Specimen Contracts Mailed	Specimen Contract Accepted by Contractor	Final SOW Prepared	Contract signed & SOW mailed to contractor	Notice of Intent mailed	Finalized Contracts received by CREST
Benthic Primary Production	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Water Column Primary Production	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Benthic Infauna	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Emergent Plant	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Epibenthic	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Zooplankton & Larval Fish	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Fish	X	X	X	X	–	X	X	X	X	X					
Avifauna	X	X	X	X						X					
Wildlife	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Marine Mammals	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Sedimentation/ Shoaling	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Currents	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Simulation	X	X	X	X	X	X	X	X	X	X	X	X	X	–	X
Cartography	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Data Mgmt. 2 mo.	X	X	X	X	X	X	X	X	X	X	X	X	X	–	X
Data Mgmt. 10 mo.	–	X	X												
Integration: 1 (DJ)	X	X	X	X	X	X	X	X	X	X	X	X	X	–	X
2 (DM)	X	X	X	X	X	X	X	X	X	X	X	X	X	–	X
3 (CSh)	X	X	X	X	X	X	X	X	X	X	X	X	X	–	X
4 (CSi)	X	X	X	X	X	X	X	X	X	X	X	X	X	–	X
5 (LS)	X	X	X	X	X	X	X	X	X	X	X	X	X	–	X

Attachment 2

POSSIBLE CREDDP PRODUCTS (not in any particular order)

Program Data Archive

- -Inventory of data sets and formats from each work unit (index to the archive)
- -Storage of non-machine readable data
- -Storage of machine readable data at Portland office of the U.S. Army Corps of Engineers

Work unit reports

- -8½" x 11" format reports from each work unit with black and white graphics

Integration report

- -Same format as work unit reports

Users Guide(s)

- -8½" x 11" format report referring to management issues and the use of CREDDP information
- -(Possibly some shorter summary reports)

Atlas

- -Large-format atlas with color maps and summaries of all work unit reports
- -Additional flat copies of all color maps.
- -8½" x 11" copy of text from atlas

Other Products

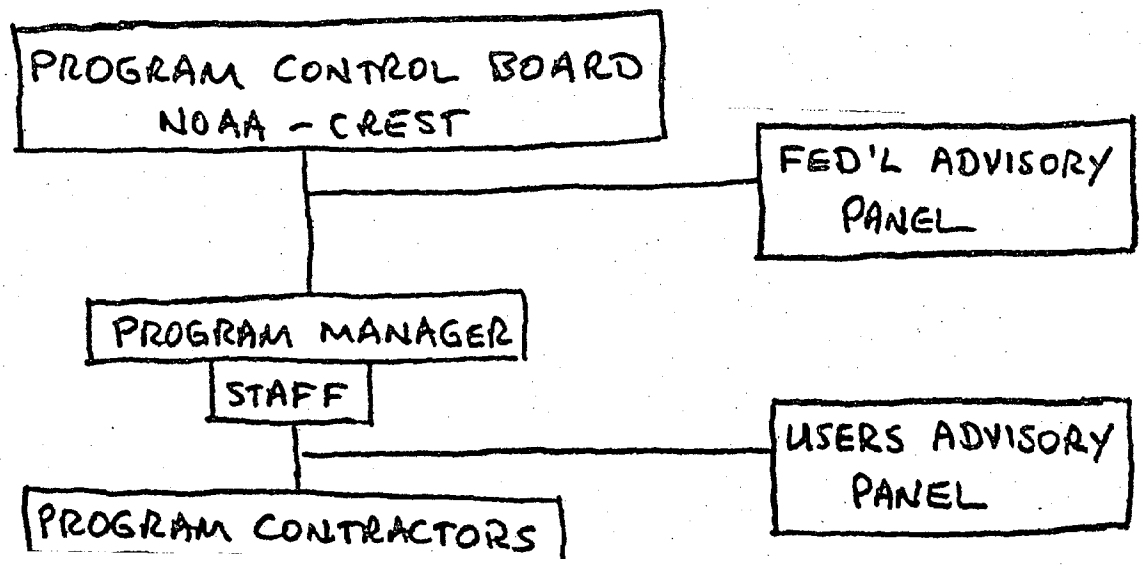
- -Copies of 1:12,000 orthophotos of the estuary (should be available at a moderate cost)
- -Possibly, a 1:12,000 base map made from these orthophotos showing the line of aquatic vegetation, 3 vegetation types (low marsh, high marsh, swamp), and bathymetric contours. (should be available at a moderate cost)
- -Estuary base maps:
  1:40,000 (7 segment orthophoto based) produced from the 1:12,000 map above.
  1:160,000 and 1:320,000 reductions of 1:40,000 map.
- -Volume/surface area/historical bathymetry data.
  - -computer printouts of raw data in 8½" x 11" tabulated format in 5 volumes:
    1. Estuary Bathymetry for 1868, 1935, 1958, and 1982
    2. Bathymetric Differences for 1868 vs. 1935, 1935 vs. 1958, and 1958 vs. 1982
    3. Surface Areas by Depth Regimes for 1868, 1935, 1958, and 1982
    4. Estuary Volumes for 1868 vs. 1935, 1935 vs. 1958, and 1958 vs. 1982
    5. Similar information as in volumes 1-4 for the special studies at the river mouth in 1852, 1868, 1855, 1895, 1902, and 1935
  - -above data on magnetic tape

COLUMBIA RIVER ESTUARY DATA DEVELOPMENT PROGRAM (CREDDP)

10 BIOLOGICAL RESEARCH ELEMENTS
3 PHYSICAL RESEARCH ELEMENTS
INTEGRATION ELEMENT
CARTOGRAPHIC SUPPORT ELEMENT
MANAGEMENT ELEMENT
(INCLUDES DATA MANAGEMENT)

FORMERLY A PROGRAM OF THE WATER RESOURCES COUNCIL/NORTHWEST RIVER BASIN COMMISSION

WRC PASSED FEDERAL OVERSIGHT TO NOAA (C.A.)
PRIME CREDDP CONTRACTOR ($1.22 M) IS CREST



CREST

Post Office Building, Room 202 P.O. Box 175, Astoria, Oregon 97103 (503) 325-0435

7 October 1982

MEMORANDUM

TO: Distribution

FROM: Norman Brateng, CREST Chairman

SUBJ: Columbia River Estuary Data Development Program (CREDDP) Plan of Study

On September 7, 1982 CREST signed a cooperative agreement with the U. S. Water Resources Council to administer the Columbia River Estuary Data Development Program (CREDDP) in accordance with the enclosed Plan of Study. This Plan describes how research efforts will be designed to meet the program's goals and objectives, which are defined in terms of user needs. Program management and organization, including the roles of advisory panels, are also described. The National Oceanic and Atmospheric Administration (NOAA) has succeeded the U. S. Water Resources Council in this cooperative agreement.

A Program Control Board consisting of CREST and NOAA will oversee the management of CREDDP. CREST director Michael D. DeLapa will represent the CREST Council on this Board and Richard Morse will represent NOAA. John Damron will be the Program Manager.

We have begun contract preparations and have requested proposals with the objective of resuming the program as soon as possible. $1.22 million will be available to complete the program and all activities must be completed by June 30, 1984. Emphasis will be placed on producing useful final products by thorough analysis of existing data and by processing selected portions of previously acquired sample sets. New field work will not be possible given the constraints of time and money.

The interdisciplinary nature of CREDDP will be stressed. Contractors' work will be closely coordinated so that exchanges of data and ideas can occur, allowing individual researchers to obtain needed information to complete their investigations. Moreover, as one of the final products, the program will publish an integration document that summarizes research results in the context of the entire ecosystem. This product will be directed toward resource managers and planners on the estuary. The final technical reports submitted by each contractor will also be important products, together with the machine-readable data in a CREDDP data archive.

If you are interested in following the progress of CREDDP, please contact the CREST office and we will add your name to our mailing list.

CREST MEMBERS—WASHINGTON: Pacific County, Port Dist. #2 (Wahkiakum Co.), Port of Ilwaco, Town of Ilwaco
OREGON: Clatsop County, City of Astoria, Town of Hammond, City of Warrenton, Port of Astoria

an essential base upon which to support resource management decisions.

The final goal, integration, is very important because it leads to a more complete understanding of estuarine ecological structure and function. Integrating the results from all of the work units is the key to a successful interdisciplinary program, giving resource managers a better understanding of the ecosystem and improving their predictive capability. The goals of CREDDP are listed below.

A. First Trophic Level

1. Describe and map productivity and biomass patterns of Columbia River Estuary primary producers.

2. Determine to the extent possible the carbon budget of primary producers.

3. Describe the relationships among primary producers and productivity levels and physical factors.

B. Higher Trophic Levels

1. Describe and map abundance patterns of the invertebrate and vertebrate groups.

2. Determine functional relationships among higher trophic groups.

3. Describe the relationships among vertebrate and invertebrate species and physical and biological factors.

C. Sedimentation and Shoaling

1. Characterize and map bottom sediment distribution.

2. Characterize sediment transport.

3. Determine (qualitatively) the causes of historic and modern bathymetric change.

D. Currents and Simulation

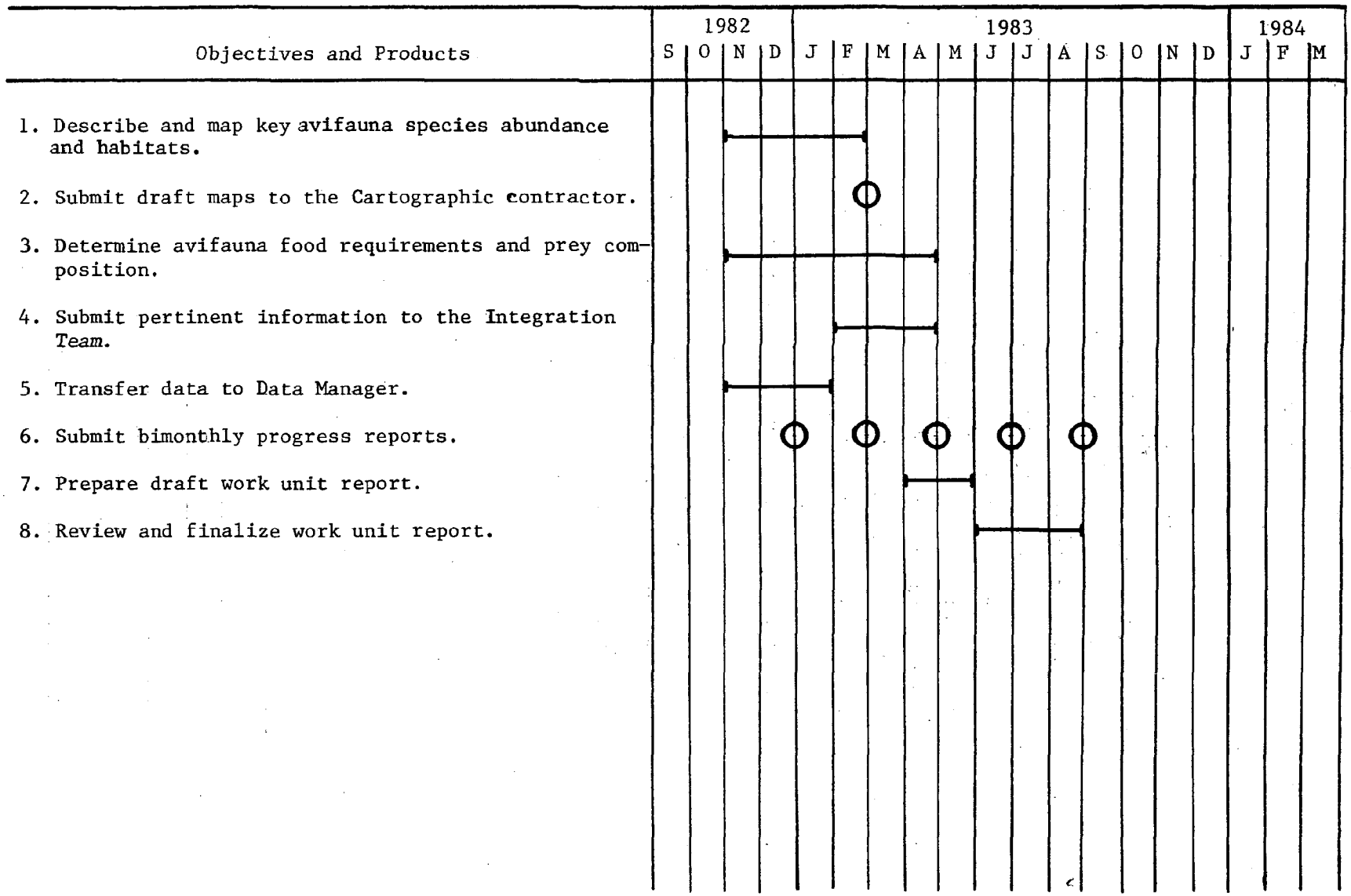
1. Evaluate and model circulation patterns.

2. Evaluate and model vertical mixing and salinity patterns.

E. Integration

1. Integrate program information for a more complete understanding of biological and physical structure and processes.

Figure 4.8. Schedule for the Avifauna work unit.



4.10 Wildlife

Introduction

Terrestrial and aquatic mammals associated with the estuary are recreationally and, to some extent, commercially important and are a major concern of many resource management agencies. Prior to CREDDP, there was little information on the non-endangered mammals of the Columbia River Estuary. The Wildlife work unit studied mammalian distribution and feeding habits in intertidal marsh and swamp habitats. The work unit was completed as of September 1981 and produced a final report summarizing, in detail, results and data analyses. However, to fulfill the integration objective concerning the estuarine carbon budget and to conform with the mapping format of other work units, some additional work must be done. An additional objective which addresses the identification of possible factors that limit key species use of particular habitats is added to address some of the concerns of resource management agencies.

Objectives

1. Describe and map key wildlife species occurrence and density.
2. Estimate the rate of consumption of food/prey by wildlife.
3. Identify possible factors that limit key species use of particular habitats.

Data sets

a) Analyzed data on species distribution and density collected under the former Wildlife contract.

b) Vegetation type maps of the Columbia River Estuary.

c) Analyzed data on wildlife food habits collected under the former Wildlife contract.

Objective/data set relationship matrix

	Data set		
Objectives	a	b	c
1	x	x	
2	x		x
3	x	x	x

Tasks

Analysis summary. The mapping objective will be completed by extrapolating the species occurrence data on the existing vegetation type maps. Occurrence of all species and relative density of a few species will be mapped.

Estimating consumption rates requires that literature information be combined with the qualitative feeding habits data collected by the Wildlife work unit to give approximate consumption rates of some prey items by some species.

The third objective can be accomplished using the data analyses already produced by the Wildlife contractor. The objective is basically a restatement of some of the information in the Wildlife final report.

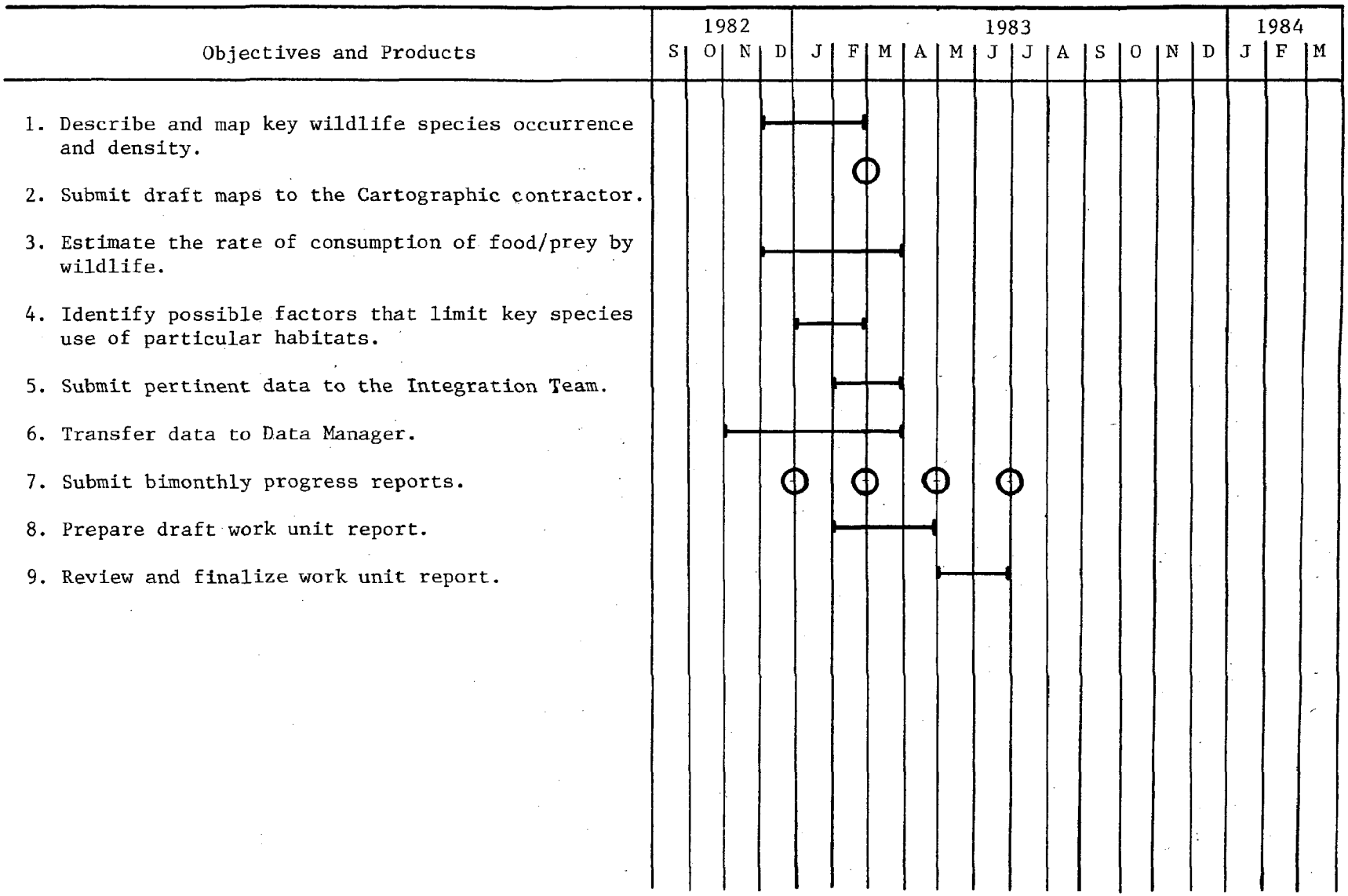
Data adequacy. The data are adequate to fulfill the objectives listed with limitations. For example absolute species density cannot be calculated or mapped and relative density can only be mapped for a few wildlife species. The estimates of consumption rates will be approximate and will be limited to only a few species of wildlife and prey items.

Integration and data exchange. Pertinent information from the Wildlife work unit will be submitted to the Integration Team, particularly the consumption rate information as it relates to the estuarine carbon budget. Also, the feeding habits information already produced will be essential for describing predator-prey interactions and grazing effects. Information from the Emergent Plant, Epibenthic Organisms, Fish, and Avifauna work units will be required to accomplish objective 3.

Products

The products of the Wildlife work unit under objective 1 will include draft maps of wildlife species occurrence and relative density. These maps will be submitted to the Cartographic contractor for final production. A report supplementing the September 1981 final report already submitted to the program and consisting of a narrative presentation with graphics will summarize the results of objectives 1, 2, and 3. The schedule for this work unit is shown in Figure 4.9.

Figure 4.9. Schedule for the Wildlife work unit.



4.11 Marine Mammals

Introduction

Marine mammals are of special concern to fishermen and fisheries management agencies because of their high position in the food chain. This makes them potential competitors with man for the estuary's food resources. Information on the distribution of marine mammals in time and space, their prey requirements, and their consuming biomass is therefore important in evaluating the role of marine mammals in the ecosystem, and their impacts on fisheries.

The most important marine mammals using the Columbia River Estuary have been identified as harbor seals and sea lions. The objective of the Marine Mammals work unit has been to study the populations, feeding, seasonal distribution and migration of these species, and their interaction with commercial fisheries. The Marine Mammals work unit obtains most of its funds from other sources and is included here principally for the purpose of producing abundance maps compatible with the CREDDP mapping format.

Objective

1. Describe and map marine mammal species occurrence, density and standing crop.

Data sets

a) Partially analyzed data from monthly or biweekly aerial censuses from September 1980 to September 1981.

b) Partially analyzed mark and relocate or recapture data from marked or radio-tagged animals.

Objective/data set relationships

Objective 1 involves the use of data sets (a) and (b).

Tasks

Analysis summary. Objective 1 will be accomplished through the analysis of data sets (a) and (b). The data sets include raw and processed information on marine mammal distribution in the estuary and along the adjacent coast. These data will be analyzed to provide seasonal density maps, and will be converted to standing crop for further mapping. Seal haulout areas and other critical habitat will be identified and mapped.

Additional objectives can be added to this work unit if additional funding becomes available. These objectives include 1) analyzing tagging data to des-

cribe marine mammal activity patterns, 2) estimating the consumption rates of marine mammals, and 3) analyzing methods of avoiding marine mammal/fisheries interaction (see section 6.6, Additional Work Tasks).

Data adequacy. Good quantitative data are available for haulout areas; data are less reliable for non-haulout areas. Estimates of the percentage of the population in the water can be obtained from the tagging data, and these can be combined with counts of haulout areas to give overall densities. Adequate data exist in processed and unprocessed form to achieve this objective.

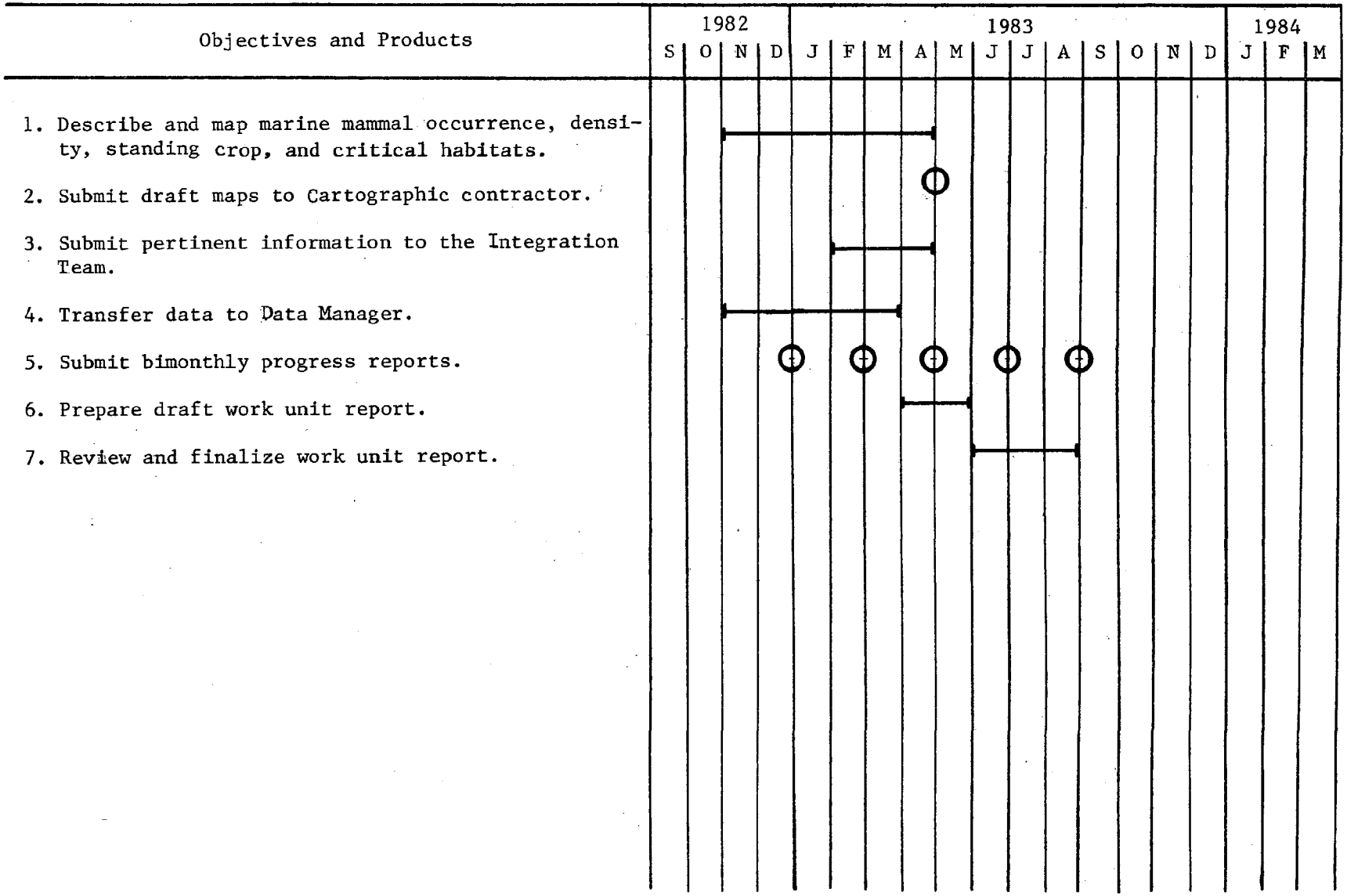
Integration and data exchange. Information concerning the standing crop and seasonal movements of marine mammals is important to the Integration Team. In order to draw a quantitative link between marine mammals and their prey, the Integration Team requires estimates of marine mammal consumption rates. As discussed above, the latter estimates require additional funding.

Understanding seal movements requires information on prey (fish) abundance in the estuary from the Fish work unit.

Products

The products of the Marine Mammals work unit will be draft maps of key species critical habitat, density, and standing crop for the Columbia River Estuary, accompanied by an explanatory narrative. The draft maps will be submitted to the Cartographic contractor for final production. The schedule for this work is shown in Figure 4.10.

Figure 4.10. Schedule for the Marine Mammals work unit.



4.12 Sedimentation and Shoaling

Introduction

The general purpose of the Sedimentation work unit is to develop an understanding of the sedimentological processes in the estuary by describing 1) the distribution of sediments in the estuary along with the processes accounting for this observed distribution, 2) sediment transport, and 3) shoaling patterns. The sampling strategy of this work unit involved extensive sampling of bottom sediments throughout the estuary which, when analyzed statistically, will yield a detailed characterization of bottom sediment distribution. The sediment transport work included field studies of bedform and suspended sediment movement. The results of these studies should yield a characterization of bedform types and migration directions and a characterization of the suspended sediment field. The description of historical shoaling patterns will rely heavily on information from the literature and estuarine volume calculations which have been funded under another project.

Because the Columbia River Estuary differs markedly from other more extensively studied estuaries, characterizing the sedimentary environment has required innovative research and will require careful and extensive integration with the Currents and Simulation work units. The results of the Sedimentation and Shoaling work unit will be invaluable to the U.S. Army Corps of Engineers in assessing the feasibility and impacts of deepening the Columbia River Navigation Channel.

Objectives

1. Characterize and map bottom sediments.
2. Perform grain size analysis of sediment samples collected by biologists.
3. Characterize and map bedform types and migration directions.
4. Characterize the estuarine suspended sediment field.
5. Define modern sedimentary environments and processes (including important temporal and spatial scales) in the estuary.
6. Investigate causes of modern and historical bathymetric change.

Data sets

a) Unprocessed samples, raw data, and partially analyzed data from the October 1979 through October 1980 bottom sediment samples. Variables measured in-

clude sediment grain size distribution and analyses include statistical analysis of the data.

b) Unprocessed bottom sediment samples provided by biological contractors for sediment grain size analysis.

c) Raw and partially analyzed data from the October 1979 sampling cruise and seven Columbia River tributaries. Variables measured include light, heavy, magnetic mineral percentages, mineral composition of sediments (spray diffraction), and the physical structure of sediment and mineral grains (photomicrographs).

d) Analyzed data from the October 1979 through October 1980 cruises. Variables measured include bedforms (side-scan sonar data) and bathymetry.

e) Unprocessed samples, raw data, and partially analyzed data from the profiling current meter cruise and instruments mounted on the Astoria-Megler Bridge. Variables measured include turbidity (depth series and long term time series), suspended sediment grain size, and salinity and current profiles.

f) Analyzed data from the August 1980 fluorescent tracer study of bedload sediment transport from a point near the mouth of the estuary.

g) Bathymetric and bathymetric differencing information (maps and volume calculations) already produced or currently funded under another project.

Objective/data set relationship matrix

	Data set					
Objective	a	b	c	d	e	f
1	x		x			
2		x				
3				x		x
4					x	
5	x		x	x	x	x
6	x		x	x	x	x

Tasks

Analysis summary. The first objective, mapping of bottom sediment distribution, requires processing about 350 additional sediment samples in areas where variability in grain size distribution was too great to map properly. Some additional samples beyond the 350 may be processed if additional funding becomes available (see section 6.6, Additional Work Tasks). The grain size data, along with mineralogical data, will be statistically analyzed in order to group sediment types and delineate and map sedimentary environments.

Processing sediment samples for biological contractors, the second objective, requires analyzing grain sizes of approximately 80 samples from the Benthic

Primary Production, Benthic Infauna, and Epibenthic Organisms work units. These data will take the form of computer printouts of grain size distribution and associated statistical parameters.

Objectives 3 and 4 have been completed and the results are included in a June 1982 U.S. Army Corps of Engineers report. These results will be used in other analyses of this work unit and will be incorporated into the final CREDDP products.

To accomplish the fifth objective of defining the modern sedimentary environments and processes in the estuary, information from the bottom sediment, bedform, and suspended sediment data sets will be combined and integrated with current and salinity measurements and the output from the Simulation work unit.

The sixth objective requires integrating several data sets with information obtained from the literature. In order to investigate the causes of historical bathymetric change, this work unit will interpret historical bathymetric and bathymetric differencing information along with the results of objective 6 and literature descriptions of climatic, geologic, tectonic, and human influences on the formation and evolution of the estuary.

In addition to the above objectives, a seventh objective which involves estimating suspended sediment fluxes can be added if additional funding becomes available (see section 6.6, Additional Work Tasks). This objective would involve combining the current profile data and the suspended sediment data (from both profiling and bridge-mounted instruments).

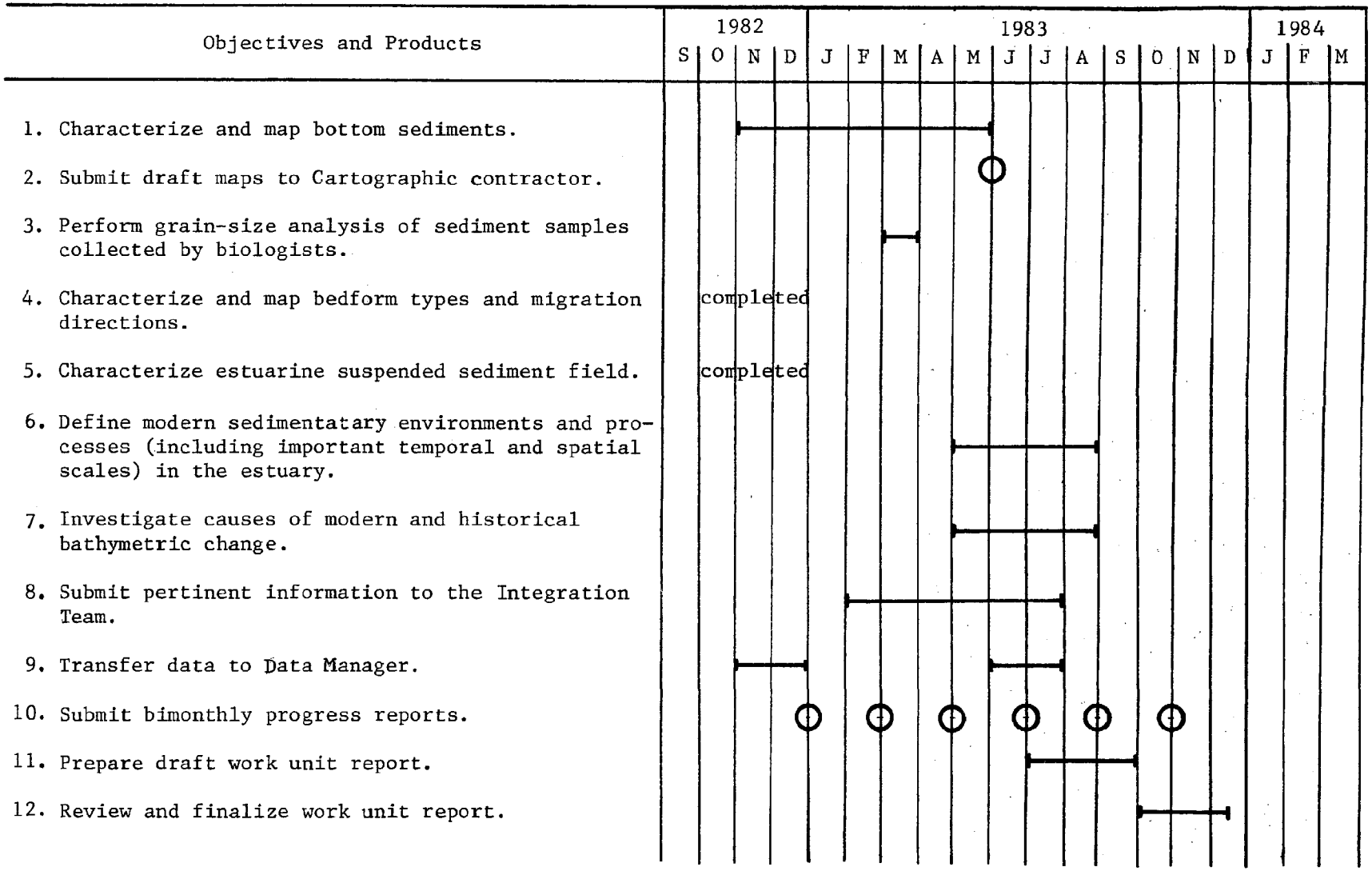
Data adequacy. Although the data sets are adequate to complete the work unit objectives, there are some limitations and constraints. The characterization and mapping of bottom sediments is difficult because of the spatial variability of grain size in the estuary. However, processing additional samples, performing further statistical analyses, and combining these results with the mineralogical data should allow for a characterization of bottom sediments on which to base mapping. The suspended sediment profile data used in the calculation of suspended sediment fluxes only covered the low river discharge period and will therefore limit the scope of this objective, if funded.

Integration and data exchange. The primary integration and data exchange of this work unit will be with the Currents work unit. Both profiling and moored current meter data are needed to formulate an integrated picture of sedimentological processes. Also historical bathymetric and bathymetric differencing information will be obtained from another project in order to complete objective 6. The results of processing sediment samples from biological

contractors along with maps of sediment distribution will be provided to the appropriate work units. Products

The product from objective 1 will be a draft map or set of maps of sediment distribution or sedimentary environments. These will be submitted to the Cartographic contractor for final production. A final report consisting of a narrative with graphics will summarize the results of objectives 1 - 6. Also included in the report will be study methods, background literature information, and other incidental results and conclusions not covered by the objectives. Additional products include a set of captioned photomicrographs of estuarine minerals and the results of the analyses of sediment samples from the biological contractors. The schedule for the Sedimentation work unit is shown in Figure 4.11.

Figure 4.11. Schedule for the Sedimentation and Shoaling work unit.



4.13 Currents

Introduction

The work to be carried out in the Currents work unit is designed to provide both descriptive and process oriented physical information, with a strong emphasis on understanding the functioning of the system. This work unit will focus on analyzing tidal circulation and low frequency flow processes. Emphasis will also be placed on describing and analyzing vertical mixing processes and salinity and temperature patterns. In addition to being individually important, the Currents work is essential in understanding biological and all other physical processes in the Columbia River Estuary. The Columbia River Estuary is sufficiently different from other estuaries that an innovative combination of modelling, analytical, and theoretical work is required to describe and understand the physical estuarine processes.

The sampling scheme of this work unit was designed to describe physical processes (currents, vertical mixing, etc.) in the main channels of the estuary rather than in peripheral bays. The main body of the estuary has to be understood before processes in the bays can be described. Information from the National Ocean Survey (NOS) data base, once incorporated into the CREDDP data base, will help to increase the understanding of the bays. The Currents work unit also compliments the Simulation work unit, which emphasizes modelling the circulation field.

Objectives

1. Describe and analyze tidal circulation.
2. Incorporate NOS data into CREDDP data base and use in all analyses, as appropriate.
3. Describe and analyze low frequency flow, including "null zone" location and processes.
4. Describe and analyze salinity and temperature patterns.
5. Describe and analyze vertical mixing processes.

Data sets

a) Current meter data from 1980 CREDDP sampling and 1975, 1977, and 1978 Corps of Engineers sampling. The data include current velocity and direction, temperature, salinity, and pressure.

b) Tidal height data from 1980 CREDDP sampling; 1977 and 1978 Corps of Engineers sampling; 1977-80 NOS sampling; and 1977-81 USGS sampling. The data include tidal height and temperature.

c) Current meter data from the 1981 NOS sampling. The data contain the same information as described in (a).

d) Tidal height data from the 1981 NOS sampling. The data contain the same information as described in (b).

e) Anemometer data from the 1981 NOS sampling. The data include wind velocity and direction.

f) Geostrophic wind and surface pressure data from NOAA.

g) Riverflow data from USGS.

Objective/data set relationship matrix

	Data set						
Objective	a	b	c	d	e	f	g
1	x	x	x	x			
2			x	x	x		
3	x	x	x	x	x	x	x
4	x	x	x	x			x
5	x	x	x	x			x

Tasks

Analysis summary. The first objective, tidal circulation analysis, will be accomplished by performing harmonic analyses on the CREDDP and NOS current meter and tidal height data. From these analyses will come descriptions of the velocity, direction, and phasing of tidal currents.

Incorporating the NOS data base into the CREDDP system (objective 2) will require similar processing as described under objective 1. The data will be used extensively in describing low frequency flow (objective 3), analyzing vertical mixing processes (objective 5), and describing the tidal circulation in peripheral bays (part of objective 1). Processing NOS data will be curtailed under the present funding assumptions (see section 6.6, Additional Work Tasks).

The purpose of objective 3 is to quantitatively analyze the estuary's low frequency response to forcing by tides, river flow, density structure, local winds, and continental shelf sea level fluctuations. The forcing functions will be quantified by performing time series analyses and various statistical routines

on the tidal current, tidal height, atmospheric, and freshwater flow information.

The fourth objective, analysis of salinity and temperature patterns, requires time series and various statistical analyses to relate the current meter data to forcing functions such as river flow, tides, and atmospherically driven coastal circulation. This is also closely related to the 5th objective on vertical mixing.

The purpose of the 5th objective is to describe the processes related to vertical mixing, essential information in analyzing currents, salinity, and other physical and biological processes. This objective requires analysis of the vertical profile data (included in data set a) to describe and classify the density and velocity structure in terms of hydrodynamic parameters. The analysis of the vertical profile data cannot be funded by CREDDP under the present funding assumptions (see section 6.6, Additional Work Tasks). Without the vertical profiling data the objective can only yield cursory and qualitative information on vertical mixing processes.

Data adequacy. For objectives 1-4, the CREDDP data combined with the NOS data are adequate to describe physical process during low river flow, high river flow, and storm periods in the main body of the estuary and, to a lesser extent, in the peripheral bays. The vertical profiling data (objective 5) are adequate to describe the vertical mixing processes over a tidal-monthly cycle during low river flow only. The level of statistical and descriptive analysis of the vertical profile, salinity, and residual flow data will be increased if more funding becomes available (see section 6.6, Additional Work Tasks).

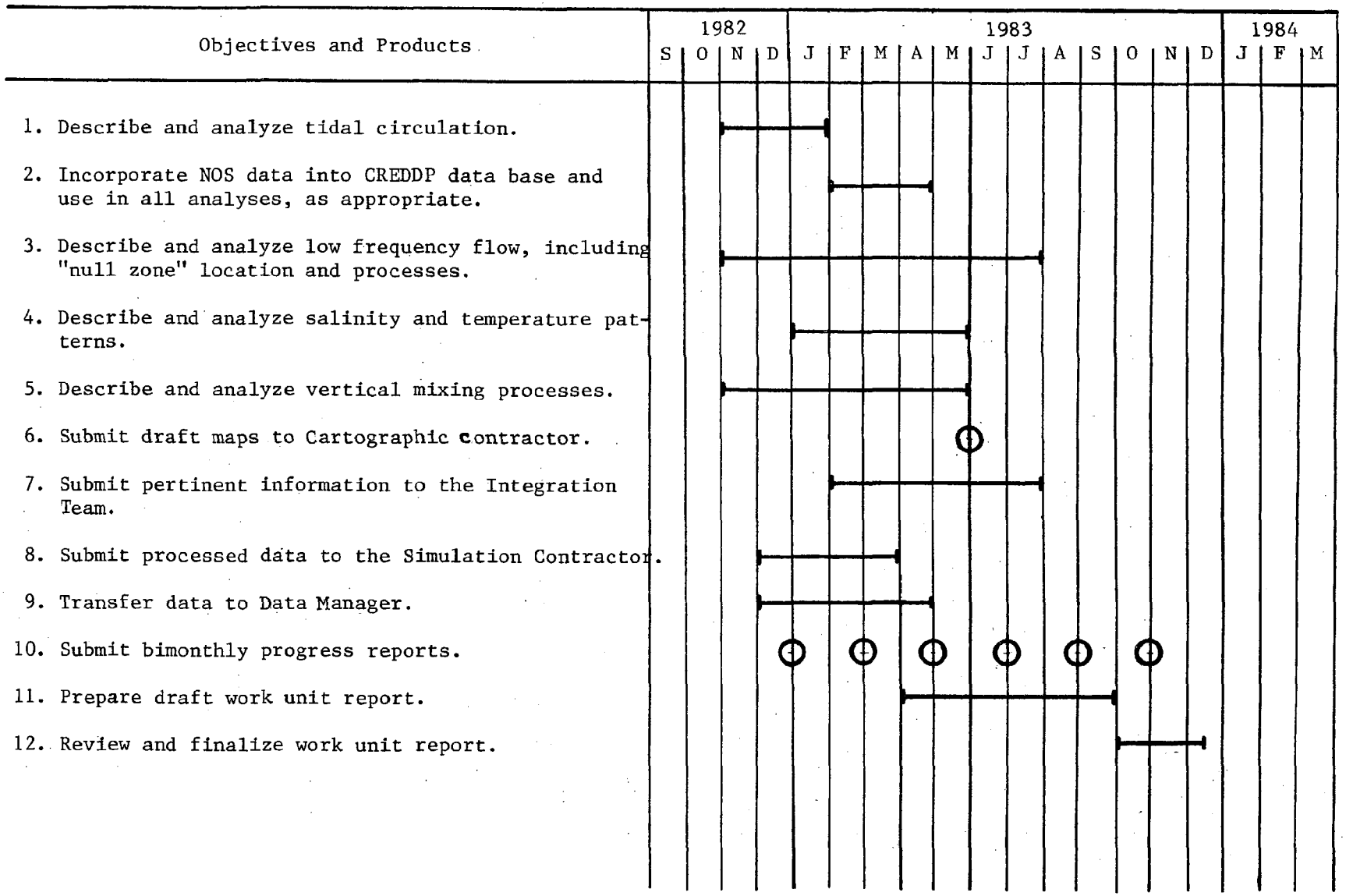
Integration and data exchange. Information essential to the Integration Team and other contractors includes salinity and temperature distribution, which will be related to biological communities and processes. Tidal circulation, null zone information, and vertical mixing processes will be related to the transport of suspended and bedload sediment, and to the transport of water column organisms such as phytoplankton and zooplankton. Additionally, the Currents work unit will provide all the analyzed data to run and verify the models produced by the Simulation work unit.

Products

The main product of this work unit will be a final report containing detailed discussions of the results of all of the objectives. Graphics will be included showing various physical oceanographic factors in relation to depth, longitudinal and lateral position in the estuary, and time. Appropriate information will be

submitted to the Cartographic contractor for drafting and final production. Also included in the final report will be background literature information and study methods. The schedule for the Currents work unit is shown in Figure 4.12.

Figure 4.12. Schedule for the Currents work unit.



4.14 Simulation

Introduction

The purpose of the Simulation work unit is to produce a horizontal tidal and storm surge numerical model to define circulation patterns and examine the effects of atmospheric forcing, and a two-dimensional vertical model to examine vertical current structure and the salinity intrusion processes in the deeper channels. The circulation models proposed here are excellent descriptive and analytical tools. Once verified, they can predict estuarine circulation over wide areas and under conditions not observed in the field and can be used to investigate estuarine dynamics. It is the role of CREDDP to verify the models, provide appropriate descriptive output, and use the models to answer dynamical questions posed by the Simulation, Circulation, Sedimentation and Integration work units. The results will be applicable to resource management concerns, such as circulation in the peripheral bays, the causes of shoaling, the effects of channel deepening, and the effects of restricting freshwater flow. The data used to verify and run the models will be provided by the Currents work unit.

Objectives

1. Model circulation patterns through the use of a two-dimensional, horizontal model. Use the model to study atmospheric and tidal forcing, to analyze circulation in peripherial bays, and to assist the Sedimentation work unit in determining shoaling patterns.

2. Formulate and use a two-dimensional multichannel vertical model to examine tidal forcings, salinity intrusion, freshwater inflow, atmospheric forcing, vertical mixing, and residual flow processes.

Data sets

The Simulation work unit does not produce data but uses selected portions of the data sets supplied by the Currents work unit. Therefore, the data sets listed represent those from the currents work.

a) Current meter data from 1980 CREDDP sampling and 1975, 1977, and 1978 Corps of Engineers sampling. The data include current velocity and direction, temperature, salinity, and pressure.

b) Tidal height data from 1980 CREDDP sampling; 1977, 1978 Corps of Engineers sampling; 1977-80 NOS sampling; and 1977-81 USGS sampling. The data include tidal height and temperature.

c) Current meter data from the 1981 NOS sampling. The data contain the same information as described in (a).

d) Tidal height data from the 1981 NOS sampling. The data contain the same information as described in (b).

e) Anemometer data from the 1981 NOS sampling. The data include wind velocity and direction.

Objectives/data set relationship matrix

	Data set				
Objective	a	b	c	d	e
1	x	x	x	x	x
2	x	x	x	x	x

Tasks

Analysis summary. The first objective will be accomplished by refining the already existing two-dimensional horizontal model and verifying it using CREDDP, NOS, and Corps of Engineers data. The model's resolution in the bays and other peripheral areas will be improved. The primary purpose of the model is to illustrate the water transport patterns in the estuary and to test the dynamics of the estuary using numerical experiments with the model. Tests to be carried out include the estuarine system's response to various tidal forcing conditions, coastal sea level changes, direct wind stress, and various riverflow conditions.

The second objective will be accomplished by modifying an existing two-dimensional vertical model to include both the north and south channels. This will be used to examine salinity intrusion, freshwater flow, atmospheric forcing, residual flows, and vertical mixing processes. The model will be verified using the CREDDP moored and profiling current meter data base (data set a). The latter cannot be funded by CREDDP under present funding assumptions (see section 6.6, Additional Work Tasks). As with the horizontal model, numerical experiments will be performed once the model is verified. The purpose of these experiments will be to graphically display salinity and current patterns and to investigate vertical mixing and salinity intrusion processes. The results of these experiments will augment the work of the Currents work unit.

Both the level of model refinement and the number of numerical experiments can be significantly increased if additional funding is available (see section 6.6, Additional Work Tasks).

Data adequacy. For objective 1, the data from CREDDP, NOS, and the Corps of

Engineers are adequate to simulate circulation in the estuary including all peripheral areas except Grays Bay. The CREDDP vertical profiling data, along with the NOS data, are adequate for completing objective 2.

Integration and data exchange. The Simulation work unit will contribute to the Integration work unit in several ways. The horizontal tidal model will be used to resolve problems regarding the circulation and distribution of planktonic organisms in the estuary's main stem and peripheral bays. The vertical model will play an important role in tying together circulation, sedimentation, and biological information related to null zone processes and salinity distribution. The numerical experiments described above will be important in resolving these integration problems.

The main data exchange required by the Simulation work unit is processed data from the Currents work unit which will be used in model verification.

Products

The main product of the Simulation work unit will be a final report containing extensive graphics representing estuarine currents, the results of the numerical experiments, and a narrative summary. The schedule for the Simulation work unit is shown in Figure 4.13.

Figure 4.13. Schedule for the Simulation work unit.

Objectives and Products	1982				1983												1984		
	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M
1. Model circulation patterns through the use of a two-dimensional, horizontal model. Use the model to study atmospheric, freshwater, and tidal forcings; to analyze circulation in peripheral bays; and to assist the Sedimentation work unit in determining shoaling patterns.																			
2. Formulate and use a two-dimensional, multi channel vertical model to examine tidal forcings, salinity intrusion, freshwater inflow, atmospheric forcing, vertical mixing, and residual flow processes.																			
3. Submit pertinent information to the Integration Team.																			
4. Submit bimonthly progress reports.																			
5. Prepare draft work unit report.																			
6. Review and finalize work unit report.																			

4.15 Integration

Introduction

The purpose of the Integration work unit is to synthesize the results of the various biological and physical work units and to produce a report describing the structural and functional attributes of the estuarine ecosystem. Satisfactory integration is particularly crucial for the successful completion of CREDDP, as most of the important management concerns are related to the complex interactions among the individual subsystems under examination by the work units. Most management questions cannot be answered from information generated by an individual work unit without a good knowledge of how that information couples with the results of other work units. The Integration work unit will consist of a team of five CREDDP researchers, each responsible for work units in his/her area of expertise. These areas include the first trophic level, higher trophic levels, circulation, sedimentation, and general estuarine ecology. These researchers will work in close cooperation with each other and with program management to accomplish the objectives of the Integration work unit.

Throughout the work unit programs section, reference is made to data and analyses that will be submitted to the Integration Team. This work program will present the strategy for synthesizing these work unit results. The schedule of this work unit (Figure 4.14) represents the timing of the steps in this strategy rather than individual objectives.

Objectives

1. Analyze effects of physical processes on key species and the taxonomic structure of communities.

2. Integrate program information to define functional linkages among organisms, to develop a carbon budget, and relate these to the physical processes in the Columbia River Estuary.

3. Classify and map habitat types in relation to appropriate physical and biological parameters (depth/elevation, salinity, sediment, emergent vegetation type).*

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* A habitat type is defined here an an area occupied by a community of organisms. This differs from the narrow ecological definition of a habitat as the physical space occupied by one particular species or population. Habitat types are ideally based on easily mapped physical and biological criteria, examples include low tidal marsh and intertidal soft-sediment flats.

4. Using information developed by work unit contractors, describe the biological communities in each habitat type.

5. Integrate current and salinity results and sediment results to develop an understanding of the estuarine sedimentological processes.

Data sets

Information developed by the physical and biological work units.

Tasks - Strategy for Integration.

Integration activities can be divided into two phases: 1) development of a plan or conceptual structure for integration and 2) integrating results and report writing. To accomplish the first phase, the Integration Team along with will meet early in the program with program management to develop a conceptual structure for synthesizing CREDDP information and producing the final integration document. One suggested structure is a hierarchical process model which identifies linkages among biological components (processes) and represents physical processes as ecosystem driving and control variables. This, and other conceptual structures such as the one presented in U.S. Fish and Wildlife Service's Ecological Characterization of the Pacific Northwest Coastal Region, will be carefully evaluated during the planning phase. Moreover, there is a need during this phase to begin defining exactly which work unit data sets and analyses are required by the Team and which team member is responsible for each data set. This is necessary so that the formidable logistics of data exchange and integration can be overcome as early as possible. During phase 1, the Integration Team and program management will also develop a habitat type classification system and associated maps which will be used by other work units in their mapping. This is directly applicable to integration objectives 3 and 4.

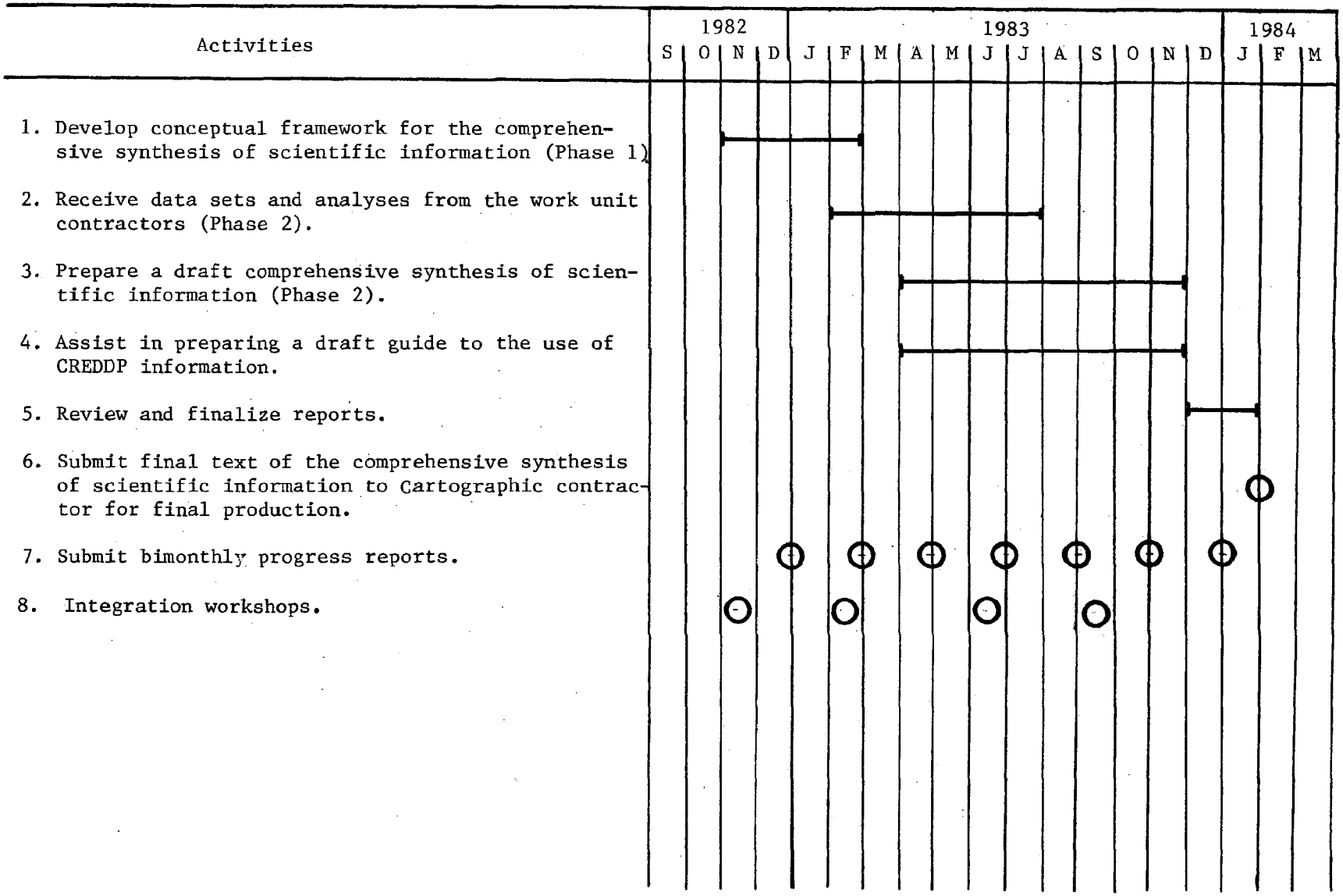
The second phase, integrating the work unit results and report writing, will require periodic workshops involving the Integration Team and program management with individual Team members working independently in the interim. A total of four workshops will be held during phases 1 and 2. There will be continuous interaction among the Integration Team, program management, the Cartographic contractor, and other work unit contractors to assure the timely completion of the final products.

Data adequacy. The adequacy of data sets used in integration varies widely among the work units (see work unit programs). It is the responsibility of the Integration Team, in conjunction with other work unit contractors, to ensure that data are adequate and also to identify data gaps in the final integration product.

Products

The primary product of the Integration work unit is a comprehensive synthesis of CREDDP information. This will contain a narrative summary with accompanying maps of the work unit results and integration objectives presented within a conceptual ecosystem framework. A second product which the Integration Team will produce with program management is a guide to the use of CREDDP information. These products are described in detail in section 5.3, Final Products. The schedule for Integration activities is shown in Figure 4.14.

Figure 4.14. Schedule for the Integration work unit.



4.16 Cartographic Work Unit

Introduction

One of the important products of CREDDP will be the final integration report synthesing the program's scientific information and illustrated with high quality maps and other graphics. Developing final maps from the draft maps submitted by the various work unit contractors requires experienced cartographers with production facilities. Moreover, because the narrative text of the final integrated product will be combined with the maps, it is time and cost efficient to have the Cartographic contractor lay out and produce the entire integration report. Other reports, such as the final work unit reports and the guide to the use of CREDDP information (see section 5.3, Final Products), can be printed and reproduced by either the Cartographic contractor or program management.

An additional function of the Cartographic contractor will be to produce a standard set of base maps for the work unit contractors to use in their draft mapping. These maps will have the same scales as used in the final integration document.

Mapping Products

The maps produced by the work units will probably follow three formats: (a) a 1:40,000 scale 7 segment map set, (b) 1:160,000 scale 1 segment map, and (c) a 1:320,000 scale set of maps to display seasonal data (4 maps per page). The 1:40,000 scale is a standard scale used on National Oceanographic and Atmospheric Association navigation charts and was used previously in the program. The other scales are selected because they are the most appropriate given the amount of information portrayed, the shape of the estuary, and the physical dimensions of the final integration report. The maps will be either 1, 2, 3, or 4 color depending on the optimal design for the amount of information portrayed. Table 4.1 gives a preliminary assignment of the number and types of maps by work unit. This is a preliminary list; the total number of maps and plates will not change appreciably under the present funding assumptions but the distribution of maps among the work units may be altered. If more funding becomes available, the number of maps may be increased (see section 6.6, Additional Work Tasks).

The estuary base maps will be produced using the most economical method and will be distributed to the work unit contractors as early in the program as possible.

Table 4.1. Preliminary list of number and type of maps by work unit.

Work Unit	#colors	format	#maps	#plates
Emergent Plants	4	b	1	1
Benthic Primary Production	2	b	3	3
Water Column Primary Production	2	c	6	6
Zooplankton and Larval Fish	3	c	3	3
" "	2	c	4	4
Benthic Infauna	3	b	1	1
" "	2	b	2	2
" "	1	b	1	1
Epibenthic Organisms	3	b	2	2
" "	2	b	3	3
Fish	4	b	3	3
" "	4	c	3	3
Avifauna	2	b	2	2
Wildlife	2	b	1	1
Marine Mammals	2	b	2	2
Sedimentation and Shoaling	3	a	1	7
" "	3	b	6	6
" "	1	b	1	1
Currents	2	b	4	2
Integration - habitat classification	4	a	1	7
Additional maps:				
Bathymetric differencing maps	3	a	3	21
Bathymetric maps	2	b	2	2
TOTALS			53	83

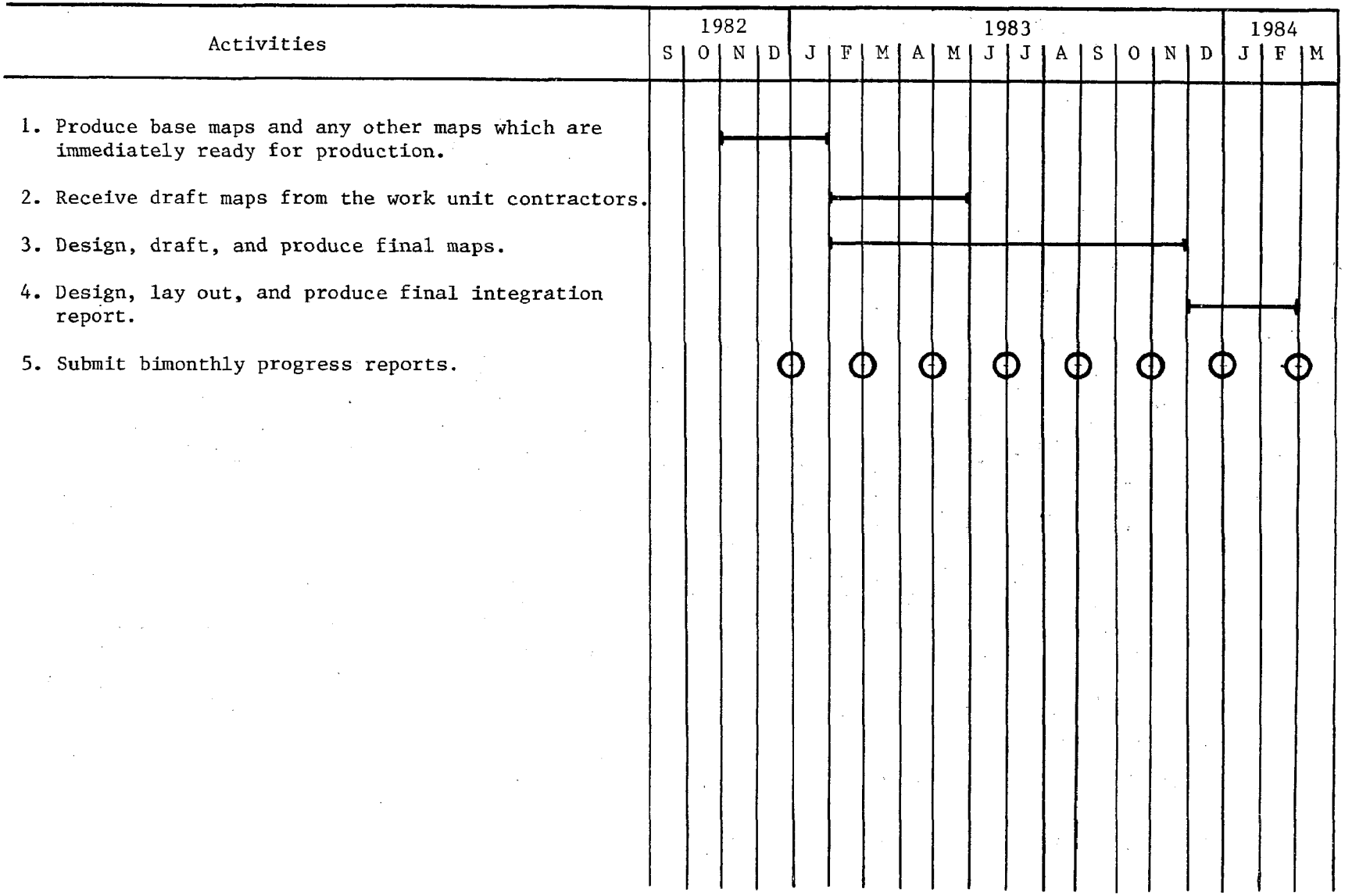
Final integration product

The final integration report (see section 6.6, Final Products) will contain the maps listed above plus narrative text and other graphics such as charts and graphs. The design, lay out, and printing of the final product will be the responsibility of the Cartographic contractor.

Other products

The final work unit reports and the guide to the use of CREDDP information (see section 5.3, Final Products) will be reproduced by the most economical method by either the Cartographic contractor or program management. The schedule for Cartographic work unit activities is shown in Figure 4.15.

Figure 4.15. Schedule for the Cartographic work unit.



4.17 Data Management

Introduction

The original CREDDP Plan of Study identified a Data Systems work unit, responsible for developing data storage and management systems. Little progress was made on this work unit up to September 1981. The CREST review of CREDDP and the assessment of program user needs show that an easily accessed data archive at a central location, containing most of the data from the work units, will be an important final product of the program.

This section therefore describes the establishment of a data archive for the program. The work unit contract will include a Data Manager, responsible for compiling, archiving, and documenting the data base. Arrangements may be made through an agreement to locate the collection and storage facility at the U.S. Army Corps of Engineers (Corps) North Pacific Division Computer Services facility in Portland. A data base will be produced during the program composed of data files structured for convenient user access. An index will be prepared listing the data files and their contents. Arrangements will probably be made with the Corps for retrieving and copying data sets.

Meeting data management needs for the program

The data collection site. The Computer Services facility in Portland would be the most suitable location for the collection and archiving of CREDDP data. There are several reasons for this choice:

- Location. Portland is a central location for data users in Oregon and Washington; it is very convenient for those organizations concerned with the Columbia River based in and around Portland, and is relatively accessible to users from the estuary area, the Willamette Valley and the Puget Sound area;

- Equipment. The Corps' AMDAHL 470 computer is a large, high speed processer with the necessary peripherals and software to accomodate many of the media on which data will be submitted.

- Interest. The Corps is engaged in a study to deepen the Columbia River navigation channel for coal export. They are very interested in some of the CREDDP data and are likely to be a major user. They have indicated that their facilities might be used (without charge) for the purpose of collecting, initially processing, and archiving CREDDP data.

- CROHMS. The Columbia River Operational Hydromet System (CROHMS), operated by the Corps, is currently being revised to handle additional kinds of ecological data. Revision should be completed in FY 84 and CROHMS should then be capable of handling much of the physical and biological data from CREDDP.

Possible interagency agreement for use of Corps facilities. The use of Corps facilities for the collection, initial processing and archiving of CREDDP data will be secured through an interagency agreement between CREST and the Corps. The agreement, if made, will address the following points:

- the Corps will provide adequate computer time during normal working hours.
- the Corps will provide office space and use of their telephone system for one CREDDP person.
- the CREDDP work will be coordinated with the Corps computer system managers so that activities can be accomplished efficiently and with minimum impact on Corps operations.
- the agreement will be active from September 1, 1982 through June 30, 1984.
- CREDDP will provide documentation to the Corps to facilitate retrieving data following program completion.
- the Corps will outline their policies regarding future user access to the archived data.

Possible use of the Corps facility as a repository. The Corps' policies should be adequate to permit access at nominal cost to a wide range of potential users and to store CREDDP data following program completion. These arrangements would be discussed between CREST and the Corps as part of an interagency agreement. Documentation of the contents of the data bank and methods of retrieval will be prepared by CREDDP and distributed to potential users, particularly those who have expressed an interest in incorporating data into their data base management systems. These include but are not limited to the Corps, the Environmental Protection Agency, the U.S. Fish and Wildlife Service, the National Oceanographic and Atmospheric Administration and the Washington Department of Natural Resources.

The data collection process

Contract provisions for data submission. Most CREDDP contracts will contain provisions for the orderly submission of machine readable data. Work units will coordinate with the Data Management contractor and will submit samples of all data

sets to be included in the data base as soon as possible. A specific date will be negotiated with each contractor for the submission of 1979, 1980, and 1981 data. The medium of transfer of the machine readable data sets will also be negotiated and specified in each contract.

Devising data transfer plans for each contractor. Data management activities will begin with the development of plans for the transfer of data from each work unit to the collection site. In this way, problems with incompatible media may be avoided or, if necessary, conversion plans adopted in a timely manner. Travel to meetings with contractors will be necessary during the initial phase of data management to elicit exact information on the status of data sets and media.

Preparing data for archiving. Some work units have prepared their data in ways suitable for their own uses, without consideration of its ultimate inclusion in a data base. These files will need reformatting before being included in the data base. To achieve better data consistency, any necessary reformatting will be the responsibility of the data management contractor. The work units' obligations to provide sample data sets will enable the size of the reformatting effort to be estimated early in the program and a schedule with priorities will be developed. Following an interagency agreement, the Data Management contractor will coordinate with the Corps CROHMS data base administrator to determine the suitability of including each data set in CROHMS. Whenever possible, data preparations will be conducted in ways that will assist the transfer of data into CROHMS, when that system is ready.

Archiving and documenting the data base. Depending upon an interagency agreement, the active data base will be at the Corps facility on magnetic tape and possibly also on disk. Documentation of the type of tape and disk structures and automated procedures for retrieving and copying files would be provided to the Corps by the Data Management contractor.

An index to the data base will be compiled, printed, and distributed to potential users of the CREDDP data. This document will describe the available data and list the contents of the files. Procedures for requesting copies of the data files will be determined in cooperation with the Corps and contained in the index. The index will also contain information on the source of each data set. Since work unit contractors will retain copies of their own data, alternative sources for the data will be given to these contractors if they desire.

The Data Management contractor's responsibilities and products.

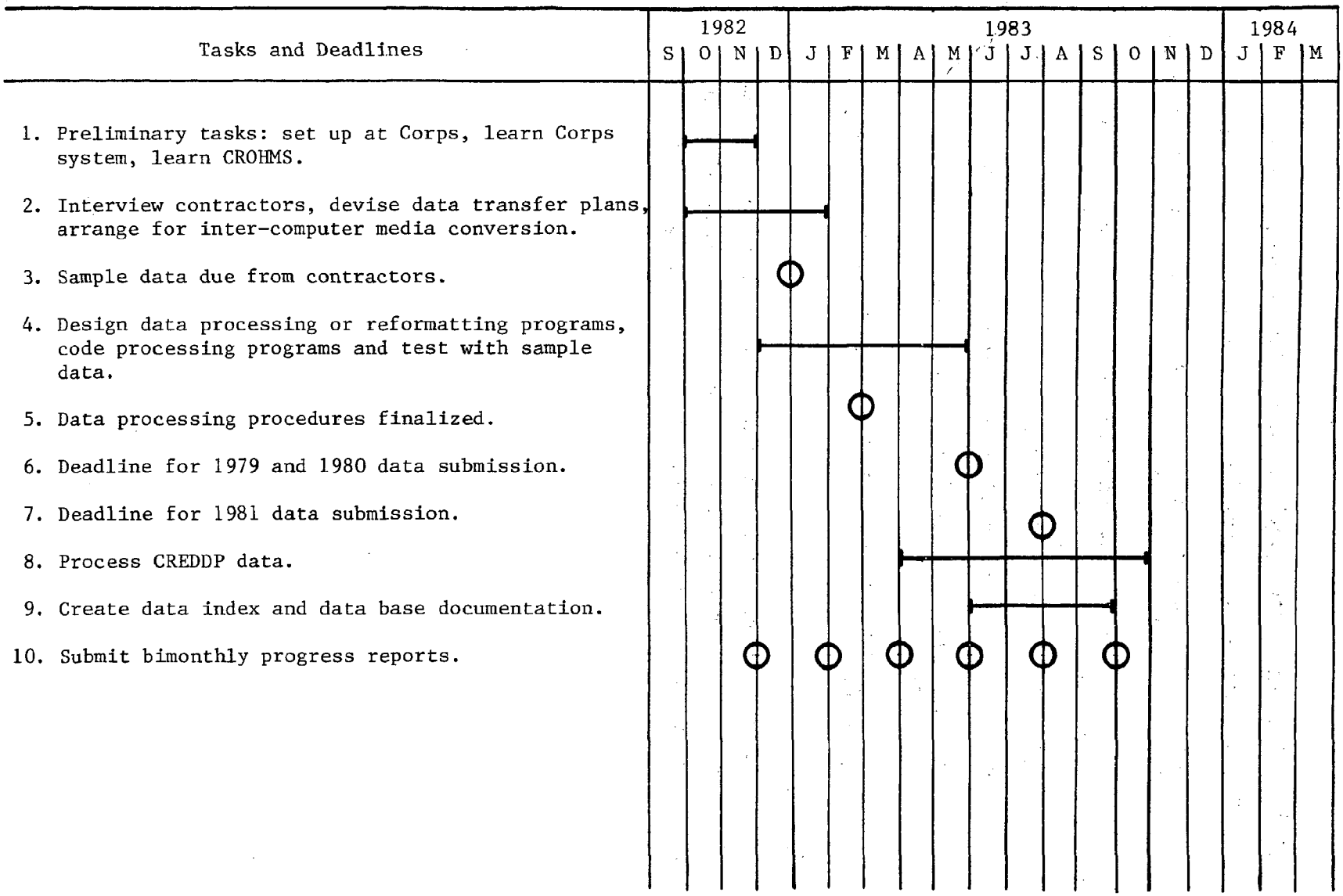
The Data Manager will have the following responsibilities:

- working with individual work units to devise plans and procedures for the orderly transfer of data to the Corps facility,
- compiling and reformatting the data sets to create a consistent collection of data files suitable for future use,
- producing an index to the data,
- producing documentation of the data structures for the Corps,
- reviewing work unit data quality assurance activities as they relate to data handling.
- providing computer tapes and other supplies necessary for establishing the data archive.

Work schedule

A proposed schedule for the Data Management tasks is presented in Figure 4.16. The time required to accomplish some of the tasks is uncertain at present, since precise information on the number and structure of the data sets is lacking.

Figure 4.16. Schedule for Data Management



5. INFORMATION MANAGEMENT

5.1 Introduction

CREDDP is an applied research program whose products, though intended for a wide audience, will be particularly useful to those people involved in making land and water management decisions in the study area. These users are likely to include both specialists and non-specialists (See Section 2). The program has already published a variety of materials ranging from technical reports to historical maps of general interest (see Appendix C). However, because most of the program data have not yet been analyzed, these products are only a small portion of the eventual final output. This section therefore discusses the major products which the program will publish and distribute, and shows how these products relate to user information needs.

5.2 Information Dissemination

Distribution of the final products will be carried out by the program management staff, and will be the responsibility of the Information Specialist. Pamphlets will be circulated to federal, state and local agencies, libraries, universities, and interested citizens to advertise the availability of CREDDP products. Policy will be developed during the program concerning the parties who will receive copies of the final reports. These will include, at a minimum, selected local, state and federal agencies, local high schools and libraries, and university and college libraries in the region. The dissemination of the final products will be one of the last program activities. It is scheduled to take place in 1984, following completion of products by the Integration Team, the Cartographic contractor, and the program staff.

5.3 Final Products

Final Reports. Each scientific work unit in CREDDP will produce a final report. These reports will contain descriptions of the work carried out by each contractor, and will include the following kinds of information as appropriate:

- Background information. Summaries of relevant studies which develop a context for the CREDDP work.

- An outline of the study approach and sampling program, with maps; key species lists and descriptions of key species selection; description of the data sets collected and their adequacy.

- Descriptions of the data processing methods.

- A clear presentation of the results, using narrative, figures and tables, if applicable.

- A description of mathematical models, their verification and examples of computer output products.

- Discussion of the results with conclusions on and any relevant information related to resource management.

- Appendices with relevant data sets or other information.

These highly technical documents are intended for specialist users, mostly scientists in the same or related fields, or resource managers with a scientific background. These reports will be widely reviewed (Section 6.3), then edited, copied, and distributed by program staff. Under the present funding assumption, the level of detail in these reports will have to be reduced from an optimal level.

Data Management. The establishment of a program data archive under a Data Management work unit is described in detail in section 4.17. This archive is one of the final products of the program, and will probably be established at the U.S. Army Corps of Engineers Computer Services Facility in Portland. Archived information is a product aimed at specialist users such as research or resource management scientists who wish to examine, reinterpret or build further research projects on CREDDP data. An index to the data sets in the archive files will be included in the "Guide to the Use of CREDDP Information".

The Comprehensive Synthesis of Scientific Information. This comprehensive view of CREDDP is, generally speaking, the most important product because it is designed to reach a wide specialist and non-specialist audience. The results of the individual contractors together with the syntheses developed by the Integration Team will be presented in a lucid manner. The Data Integration Team, whose composition and functions are described in Section 4.15, will be instrumental in producing this document.

The Integration Team, along with the program management, will be responsible for developing the conceptual structure of the comprehensive synthesis and for preparing and editing the narrative. They will play a major role in graphics selection for this product.

Also vital to this product is the Cartographic contractor, described in section 4.16. The Cartographic work unit will concentrate on the graphics, formatting, and production of the synthesis document. Since the objective is to present the CREDDP information in a concise and easily interpreted way, the Cartographic work unit will be responsible for preparing color and black/white graphics and for the text layout in coordination with the Integration Team and program management.

The comprehensive synthesis of scientific information will focus on the following important areas:

- the historical and geographical setting,
- a conceptual model of estuarine processes and its theoretical basis,
- physical attributes of the estuary: narratives, maps and diagrams explaining the structural features and physical processes,
- biological attributes of the estuary: the spatial and temporal distribution of key taxa and their bioenergetics; their relationships to physical variables and to each other for primary producers, deposit feeders, suspension feeders, fish, avifauna and mammals,
- synthesis of the bioenergetics into annual or seasonal carbon budgets and into energy flow estimates.

This product will be the optimal way of presenting the results of the entire program to both specialists and non-specialists. The major findings of all work units will be presented together with the ecosystem view developed by the Integration Team. As a result, the functioning of the ecosystem and the significance of its individual features can be appreciated either superficially through the high quality graphics or in considerable detail through the narrative and graphics combined.

The Comprehensive Guide to the Use of CREDDP Information. This product will have two aims. First, it will describe the program for unfamiliar users through illustrated summaries of the major scientific contributions, with a glossary and a detailed index of the CREDDP data files. Second, it will discuss how the information relates to current management issues in the estuary and how it might be used in land and water use decisions. In the first section, the summaries will be drafted by the Integration Team and the data index will be a product of the Data Management contractor. The second section, addressing management issues, will be written by CREST staff with experience in both estuarine management and CREDDP.

Other products. Several products have been (Appendix C) or will be produced by CREDDP, including:

- Literature Survey of the Columbia River Estuary, Vols I & II. This product was compiled at the beginning of the program. It contains an extensive bibliography of literature on CREDDP work units and is of interest to specialists in these fields.

- The two-dimensional vertical model. Although this product will generate information for a number of purposes, it can only be used by those experienced in such models, preferably the designer. For this reason, the two-dimensional vertical model is a highly specialized product and distribution will be limited to users with a specific interest in modelling Columbia River Estuary circulation.

5.4 Quality Assurance.

Validation of the data sets will be the responsibility of individual work unit contractors and the Integration Team. Work units supplying data to the Data Manager and to the Integration work unit will be required to describe quality assurance activities in their final reports. These descriptions will cover the following areas as appropriate:

- relevant equipment specifications,
- method and frequency of instrument calibration,
- data collection procedures,
- verification of key-punched data,
- verification of transferred data,
- verification of computer program runs.

Final reports from work units will be subject to peer review by the Integration Team and by specialists outside the program. Review comments on data quality will also be solicited by program management. The Data Manager will review work unit quality assurance activities for data handling. The Integration work unit will use much of the program's data for computations of various estuarine processes. The Integration Team will check the accuracy of the data used for Integration as far as possible.

All program final products will be extensively reviewed by program staff, the Integration Team, other technical experts and by potential users of the program's products.

6. PROGRAM ORGANIZATION AND MANAGEMENT

6.1 Introduction

The organization for the completion of the Columbia River Estuary Data Development Program will be based on a cooperative agreement signed by CREST and the U.S. Water Resources Council (WRC) on September 7, 1982. The National Oceanic and Atmospheric Administration (NOAA) will assume the role of the U.S. Water Resources Council as the federal representative in this cooperative agreement. A Program Control board will establish policy and monitor all aspects of the program. The Program Manager and staff will conduct the day-to-day management of the program. All funding for the program will come from the federal government and the program will be completed by June 30, 1984.

6.2 Program Organization

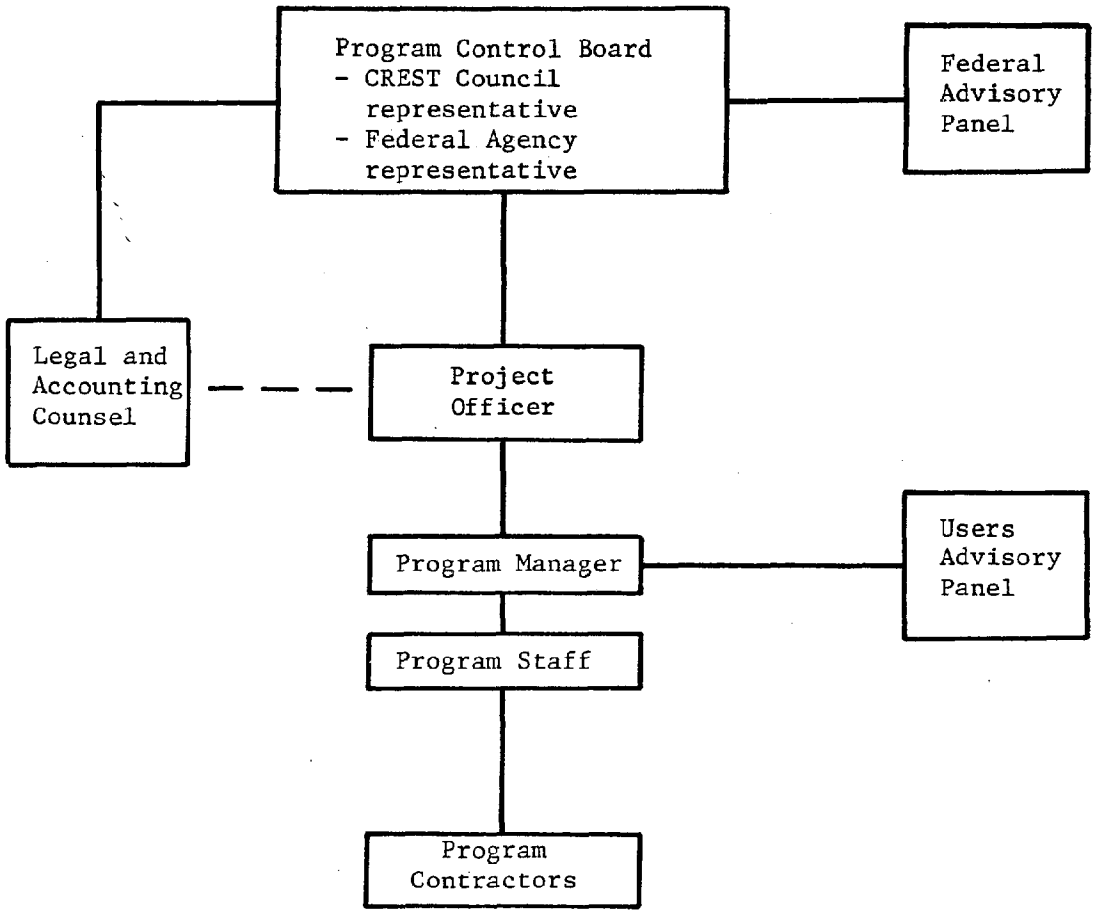
Program Control Board. A Program Control Board, composed of a representative from the CREST Council and a representative of NOAA will direct the completion of CREDDP (Figure 6.1). The Board will establish program policy and direction, provide oversight and make decisions by consensus to provide executive direction for the conduct of the program. It will be responsible for approving contracting procedures, setting staff salaries within CREST's structure, the approval of fiscal and technical reports, and the selection of the Program Manager. The Board will be responsible for approving changes to the Plan of Study during the program. All agreements with technical advisors, consultants, and private organizations or public agencies will require approval from the Board. The Program Control Board shall be responsible for all federal funds provided to the program. It will meet as required, and CREST will prepare written records of all Board decisions. The Federal member of the Program Control Board may require financial assistance to perform appropriate program related duties, and such funds will be provided from the program budget.

As a member of the Program Control Board, CREST

- will serve as fiscal agent for the program, and will be responsible for the receipt, disbursement and fiscal audit of program funds, and for the submission of Reports of Federal Cash Transaction (SF 272) and Requests for Advance or Reimbursement (SF 270).

- will return to the government all unused program funds within 30 days of completion of the program's final fiscal audit.

Figure 6.1. Program Organization.



- will maintain a financial records system and certify contractor fees.

Program Staff. The Project Officer, Program Manager and staff, will have the following responsibilities:

Project Officer. The Project Officer will be the Director of CREST and will serve a dual role for the Estuary Study.

As the Project Officer, the CREST Director will represent the CREST Council chairman on the Program Control Board, supervise the Program Manager, assign CREST staff and/or select staff for the program and recommend salary levels, secure CREST Council approval for the employment of contractors and the disbursement of program funds, keep the CREST Council informed of all Board decisions and program status, coordinate the services of the legal and financial records system advisors, and provide technical oversight and guidance to all contractors and for technical reports prepared by the project staff.

As the CREST member of the Program Control Board, the CREST Director will work closely with the Program Manager to ensure that the Study is conducted in accordance with the Plan of Study and Board directives, and perform the duties and responsibilities as a Board member which are described for the Board in this Plan of Study.

From March 1984 until completion of the Study, the Project Officer will also perform the duties of the Program Manager.

The Program Manager, selected by the Program Control Board and employed by CREST, will report to the Project Officer. The Program Manager will be responsible for the day-to-day management of the program and for ensuring that the program is conducted in a manner consistent with the Plan of Study and Board policy decisions. To accomplish this, he/she will:

- direct program staff, consultants and technical advisors;
- ensure adherence to schedules;
- secure Program Control Board approval for the disbursement of program funds;
- provide financial and bimonthly status reports to the Program Control Board members. These reports will include the Financial Status Report (SF-269), and any others requested by the Board;
- prepare and negotiate agreements consistent with Plan of Study objectives for Program Control Board approved technical advisors, consultants and public and private organizations.

The Program Manager, assisted by staff, will manage all program contracts. He/she will also chair, provide staff support and coordinate the activities of the

Users Advisory Panel, and will provide committee reviews, comments and recommendations on program activities and policies to the Program Control Board.

Should the position of the Program Manager become vacant during the Program, the Board will designate an Acting Program Manager, having the same powers, authorities, and duties as the Program Manager until a replacement is appointed.

Program Coordinators. The Technical Coordinator and the Science/Management Coordinator will work closely with contractors and ensure that they are adhering to schedules and to program objectives. They will evaluate the progress of contracts in producing the information needed by the Integration Team and in producing user-oriented products. They will work closely with the Integration Team in preparing the integrated products and will produce portions of the Users Guide (see section 5.3, Final Products). The Technical Coordinators will also produce reports and recommendations on the program for the Program Manager.

Editor/Administrative Officer. This staff member will oversee the fiscal aspects of the program and will be responsible for editing program reports and final products. He/she will coordinate the activities of the Word Processor Operator and the Bookkeeper/Secretary. The Editor/Administrative Officer will assist in providing management oversight for the period of March to June 1984.

Information Specialist. The Information Specialist will supply information as needed to all persons associated with the program. This staff member will also manage the program library which is a specialized collection of scientific and management literature on the Columbia River Estuary. The Information Specialist will be responsible for disseminating CREDDP final products to appropriate locations.

Cartographer. This staff member will be responsible for preparing the in-house graphics for the program. This work will include assisting contractors in drafting work unit maps and graphics for program reports.

These staff positions will either be filled by reassigning existing CREST staff, or by hiring additional staff. CREDDP staff positions are listed in Table 6.1.

Federal Advisory Panel. Representatives from federal agencies involved in estuarine management will be invited to advise the Program Control Board on how program content and direction affects the implementation of federal policies.

Table 6.1. CREDDP Staff.

POSITION	TIME ALLOTTED
Program Manager	Full time/18 mos.
Technical Coordinator	Full time/18 mos.
Science/Mgmt. Coordinator	Full time/18 mos.
Project Officer	33% time/22 mos.
Editor/Admin. Officer	33% time/22 mos.
Information Specialist	33% time/22 mos.
Cartographer	33% time/18 mos.
Word Processor Operator	Full time/18 mos.
Bookkeeper/Secretary	45% time/22 mos.

The Panel will be invited to three workshops (or more if needed). The federal representative on the Program Control Board will act as Chairman and will be responsible for scheduling meetings, coordinating the Panel's activities and representing their interests in the program. All proposed technical contracts will be forwarded to this Panel for their comment prior to approval by the Board.

Users Advisory Panel. A Users Advisory Panel will be established to assist program management in providing continuity and direction to the program. The Users Advisory Panel will be composed of representatives from federal, state, and local government agencies with management responsibility in the Columbia River Estuary. Agencies include but are not limited to: The National Marine Fisheries Service, U.S. Army Corps of Engineers, U.S. Fish and Wildlife Service, Washington Department of Ecology, Oregon Department of Land Conservation & Development, Washington Department of Game, Washington Department of Fisheries and Oregon Department of Fish and Wildlife. Other representative users and citizens will also be invited to participate.

The Advisory Panel will review all program products in draft form and advise the Program Manager on policy related to the information needs of users. The Advisory Panel will be convened for three workshops (or more if needed) during the completion of the program to monitor the program's progress. The workshops will be chaired by the Program Manager.

Legal and Financial Counsel. The Board will request CREST to contract with an attorney to provide legal advice to the program. The attorney will assist in developing and issuing contracts and will provide other legal services as necessary. The federal agency on the Program Control Board may also rely on its legal counsel.

CREST will also contract with a Certified Public Accountant to provide counsel and guidance on the preparation and maintenance of financial records to comply with OMB Circular 102 (revised).

6.3 Program Management

Procedures for Amending the Plan of Study. This Plan of Study may be amended as required by the Program Control Board either by its own initiative or in response to staff or other participant requests. All proposed amendments will be

prepared and/or evaluated relative to program objectives, schedules and budgets by the Program Manager. Copies of approved amendments will be distributed to interested parties.

The Cooperative Agreement. CREST and the WRC enter into a cooperative agreement to administer CREDDP to an orderly completion by June 1984. NOAA will succeed WRC in that federal role. The Cooperative Agreement will describe the responsibilities of CREST and the federal agency, financial controls, the duration of the Agreement and other management activities as discussed in this Plan of Study. The Agreement will include a budget listing management costs, including staff salaries.

Fiscal Management. After approval of the Plan of Study and execution of the Cooperative Agreement, CREST requested an advance of federal funds for the first period as shown in Table 6.2. Cash Flow Needs. When received, these funds will be deposited in a separate account with a federally insured bank. All interest paid on funds advanced to CREST will be returned to the federal government. The program will then request funds on a quarterly basis. The program will terminate on June 30, 1984. Limitations on the expenditure of Federal funds will be specified in the Cooperative Agreement.

CREST will have a close-out fiscal audit conducted by a Certified Public Accountant other than the CPA providing fiscal records guidance selected by CREST. This audit is to be paid with program funds and submitted to NOAA by July 31, 1984.

Technical Review of CREDDP Products. The Integration Team and other contractors will assist in assuring the technical adequacy of program products by providing scientific peer review. This will include the establishment of guidelines for the quality assurance review of data sets, the review of data analysis procedures and the development of guidelines for filtering aberrant data values. In addition, peer review for all CREDDP products by federal, state and local government agencies, and by university and other users will be provided through the Users Advisory Panel. These products will include final reports from each technical work unit, the data archive index, the management volume, and the comprehensive synthesis volume. In addition, final reports from each work unit will be sent for review to scientists independent from the program. These review activities are listed on the program schedule, Figure 6.2.

Table 6.2. Program Cash Flow Needs

Start - October 30, 1982	$ 75,000
November 1, 1982 - January 31, 1983	125,000
February 1 - April 30, 1983	207,000
May 1 - July 31, 1983	227,000
November 1, 1983 - January 31, 1984	217,000
February 1 - April 30, 1984	92,000
May 1 - June 30, 1984	50,000
TOTAL	$1,220,000

Contract Management. Contracting procedures will conform to Program Control Board requirements. The Program Manager will be responsible for the day-to-day management of the program contracts. Following Board approval, CREST will contract will technical advisors, consultants, and private organizations or public agencies to meet the Goals and Objectives described in this Plan of Study. CREST will prepare contracts for all work units described in Section 4 in order to finish the scientific and support work on the program in the most efficient manner.

Selection of Contractors. Most of the scientific contracts in prior CREDDP activities have produced a substantial amount of data that have not been analyzed or interpreted. As a result, it will be necessary to contract with many investigators who were previously active in the program and to consider these contracts as noncompetitive negotiations (sole source) for the following reasons:

1) time savings - all program activities are scheduled to be completed by June 30, 1984. This exigency requires immediate performance of the investigation services and delivery of the data products;

2) sole source - only one source of supply for these data and services is available for the scientific contracts because a large quantity of data have been collected by each contractor and these data cannot be easily transferred to another researcher;

3) professional services performed personally by a designated individual - the services that are required are of a professional nature and are required of the contractor in person because the services are an extension of prior work;

4) competitive selection - a competitive selection procedure was used when these contracts were initially awarded. Requests for proposals were sent to prospective contractors and the proposals submitted to CREDDP were reviewed and screened by a Technical Advisory Committee. A blind initial review procedure was used and technical adequacy was the primary consideration.

Contracting procedures used by the program will be consistent with OMB Circular A-102 (Attachment O). In each case, the program will select the investigator who can best perform the services needed in the least time and at the lowest cost. In some cases a prior subcontractor or associate investigator may be selected.

Contract Monitoring. The program staff will monitor the progress of program contracts. Bimonthly reports will be submitted by all contractors and will

describe problems or delays, the implications of these problems, and accomplishments in relation to the contract schedule and the Plan of Study. The reports will also include financial assessments. The Program Manager will present the reports to the Program Control Board and any significant problems will be brought to their immediate attention. Program staff will monitor the quality assurance procedures discussed in Section 5.4. This includes ensuring that each contractor performs quality assurance procedures prior to submitting that work unit's data to program management and to the Integration Team and also overseeing the quality assurance procedures of the Integration Team.

Contract Payment. Contractors will be paid quarterly upon receipt of evidence of work accomplished and acceptance of a documented billing and receipt and acceptance of bimonthly reports and the final report. Final billings from Contractors will not be paid until all bimonthly reports and final products are received and validated. The Program Manager will provide written comments to a contractor if interim or final products or a billing justification is not acceptable. Contracts in this program may provide for a retainage to be withheld from quarterly payments until all contractural obligations have been met.

6.4 Program Schedule

The following schedule (Figure 6.2) for completing CREDDP on July 30, 1984 assumes a September 1, 1982 start-up date. The research analysis and report writing activities of the research contractors, other than the Integration Team, will occur between November 1, 1982 and mid-December 1983. Draft reports from the program work units will be submitted to program management between July 1, 1983 and October 15, 1983. The period from the time each work unit draft report is due until December 15, 1983 will be used for technical peer review and user review and for final contractor corrections. The final technical contract reports will be submitted to program management between September 1, 1983 and December 15, 1983.

The Integration Team will function between November 1, 1982 and January 31, 1984 with the principal portion of the Team's activities occurring in Spring and Summer 1983. The final Integration Report will be required in draft form by December 1, 1983 and final form by January 31, 1984.

Program staff will be assigned to the program as indicated in Table 6.1. After March 1, 1984, the information dissemination activities of the program will

Figure 6.2 Program Schedule

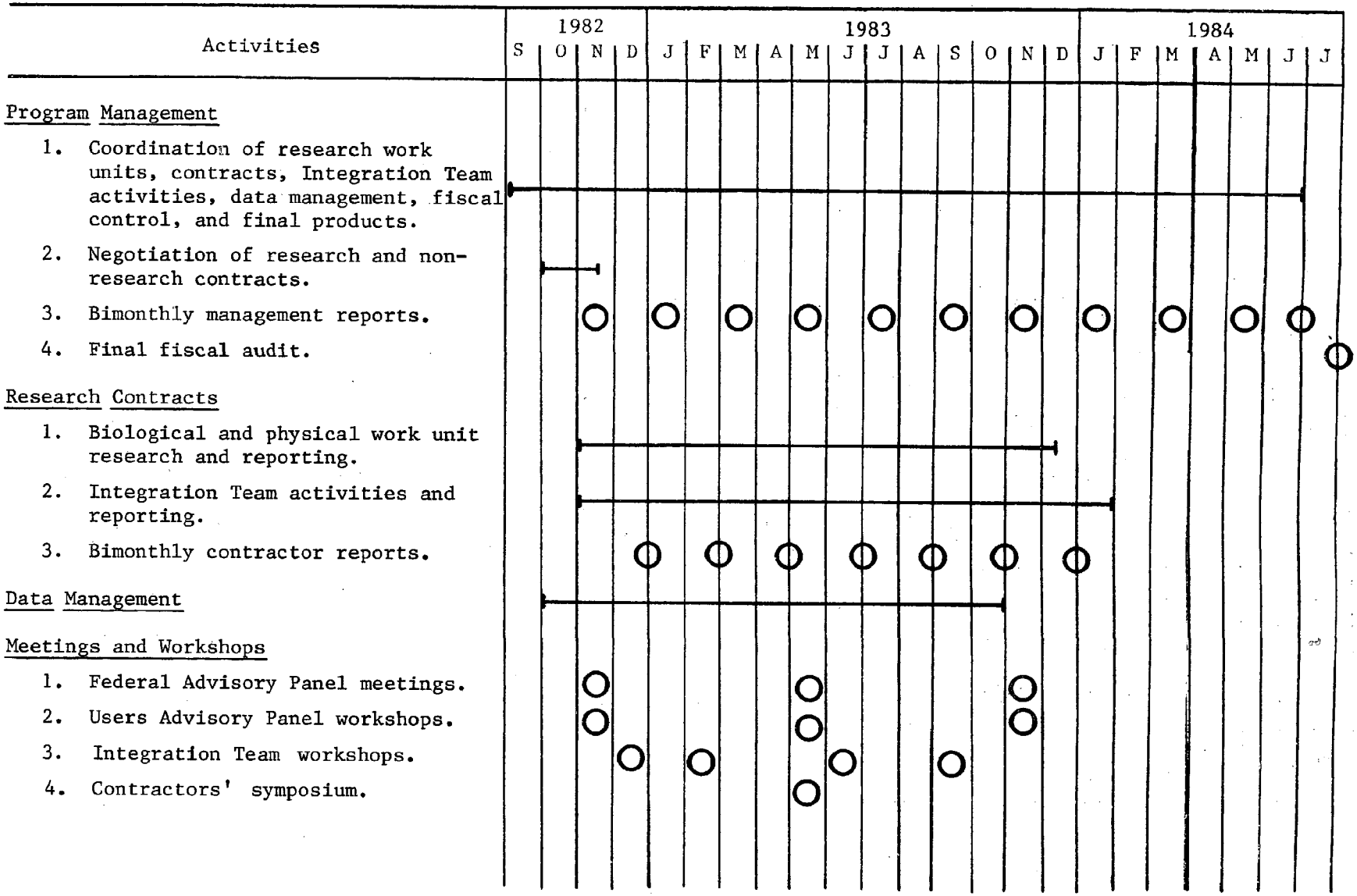
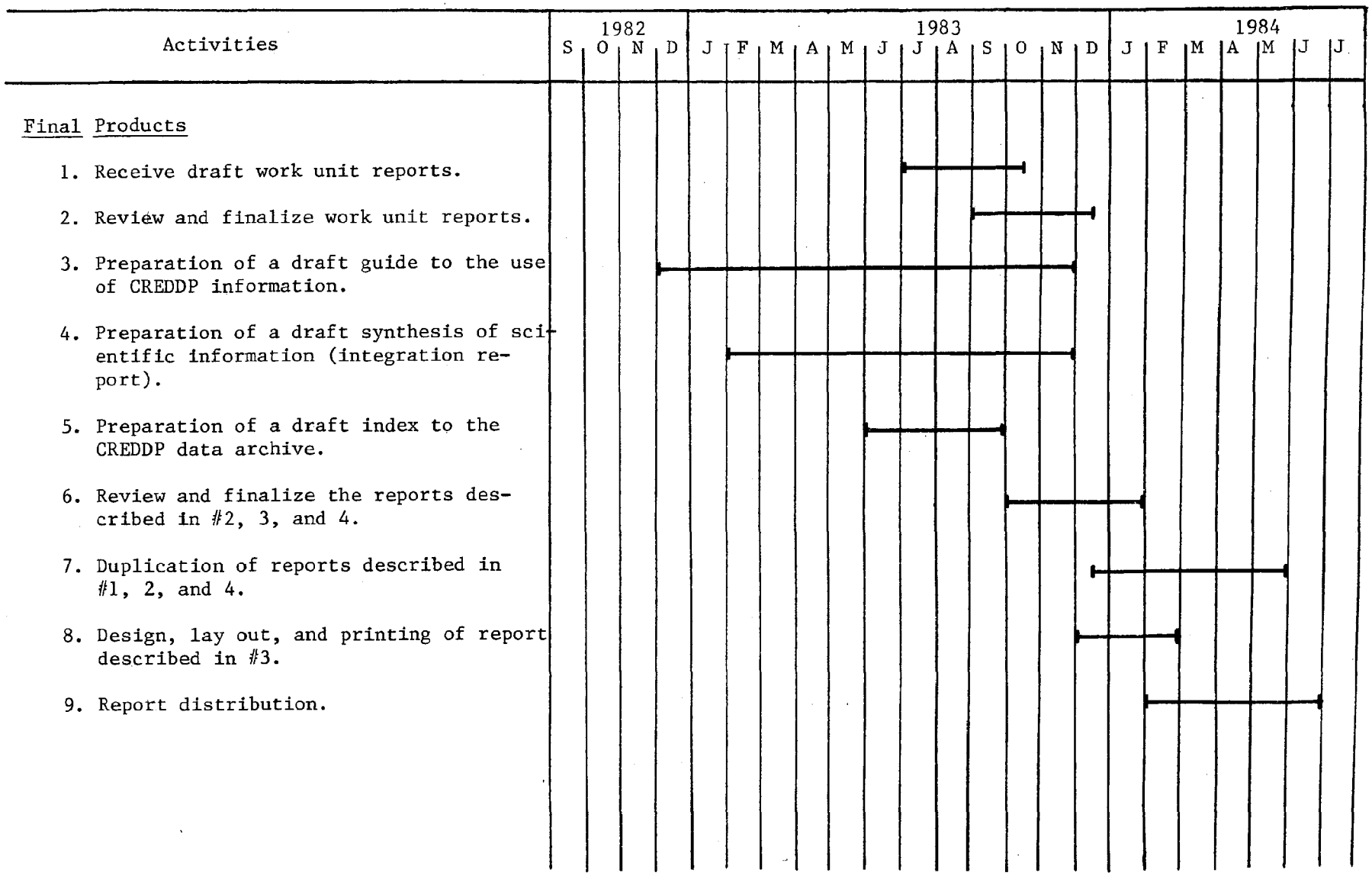


Figure 6.2. Program Schedule (continued)



be carried out by the Project Officer, the Editor/Administrative Officer, the Information Specialist and the Bookkeeper/Secretary.

6.5 Program Budget

WRC has advised CREST during the preparation of the budget for this Plan of Study that $1,220,000 will be available for the Study, and that figure has been used. They further suggested that the Plan of Study include information reflecting high priority work which would be done should additional funds become available (Section 6.6, Additional Work Tasks). Tables 6.3 and 6.4. summarize program management and program contractor budgets.

6.6 Additional Work Tasks

Table 6.5. lists work tasks that may be completed if funding beyond the $1.22 million base becomes available for the completion of the program. The additional benefits for each work unit are discussed in Section 4, Work Programs. Possible new tasks may become known as the program proceeds; therefore, this list is not be considered complete. Moreover, the costs are only approximations intended to give an idea of how increased funding could be apportioned among tasks. The order of tasks on the list in no way reflects their level of priority. The decision on which additional tasks will be funded, if any, will be the responsibility of program management.

Table 6.3. Program Management Budget by Object Classification.

A.	Total Personnel	$ 200,465.
B.	Overhead (15%)*	30,070.
C.	Personnel Benefits (12% of Line A)	24,055.
D.	Travel and Conferences	10,000.
E.	Rent, Utilities, Communications	17,600.
F.	Printing and Reproduction (other than final products)	6,000.
G.	Other Professional Services	5,000.
H.	Supplies	3,410.
I.	Equipment Rental**	23,400.
		$ 320,000.

* Estimated, subject to experience

** Word Processor, Photocopier, Typewriters

Table 6.4. Program Budget $1,220,000

Emergent Plant Primary Production	$25,000
Benthic Primary Production	40,000
Water Column Primary Production	40,000
Zooplankton and Larval Fish	50,000
Benthic Infauna	50,000
Epibenthic Organisms	40,000
Fish	79,000
Avifauna	10,000
Wildlife	10,000
Marine Mammals	20,000
Sedimentation and Shoaling	83,000
Currents	73,000
Simulation	65,000
Integration	110,000
Data Management	35,000
Program Management	340,000
Final Products (including Cartographic work unit)	150,000
TOTAL BUDGET	$1,220,000

Table 6.5. Additional work tasks and approximate costs.

Task	Cost
Emergent Plant Primary Production	
1) Increased data analysis and interpretation and a more detailed final report (all objectives).	up to $10,000
Benthic Primary Production	
1) Increased data analysis and interpretation and a more detailed final report (all objectives).	$3,000
2) Survey and subsequent data analysis to gather information for more accurate mapping (objective 1) and to assess the distribution and productivity of eelgrass (new objective).	$5,000
Water Column Primary Production	
1) Increased data analysis and interpretation and a more detailed final report (all objectives).	up to $10,000
2) Process phytoplankton samples for species identification and enumeration to better define the relationships between phytoplankton and the null zone (objective 2).	$10,000
3) Perform additional analyses in order to refine the estimates of particle sinking rates and zooplankton grazing rates (objective 3).	$8,000
Zooplankton and Larval Fish	
1) Process selected samples from the October 1980 to April 1981 sampling set and analyze data (objective 1).	$7,500
2) Process selected tidal/diel/depth samples and analyze data (new objective).	$7,500
Benthic Infauna	
1) Process 100 of the distributional survey biological samples and analyze data (objectives 1 and 2).	$19,000
2) Process 200 of the distributional survey sediment samples and analyze data (objectives 1 and 2).	$12,000
3) Process quarterly survey samples and analyze data (objectives 1 and 2).	$4,000
4) Process vertical distribution samples and analyze data (objectives 2 and 3).	$1,800

Task	Cost
Epibenthic Organisms	
1) Process selected stomach samples of Dungeness crab, crangonid shrimp, and mysids, and analyze data (objectives 3 and 4).	$5,000 - $10,000
Fish	
1) Process up to 250 additional stomach samples from the diel and distributional surveys, and analyze data (objectives 3, 4, and 6).	up to $10,000
Avifauna	
1) Identify possible factors that limit bird use of particular habitats (new objective).	$2,000
2) Determine the relative importance of the Columbia River Estuary within the Pacific Flyway as an overwintering ground and migration route (new objective).	$500
Wildlife	
1) Increased data interpretation, increased mapping accuracy, and a more detailed final report (all objectives).	$3,000
Marine Mammals	
1) Analyze tagging data to describe marine mammal activity patterns (new objective).	$5,000
2) Estimate the consumption rates of marine mammals (new objective).	$8,000
3) Analyze methods of avoiding marine mammal/fisheries interactions (new objective).	$5,000
Sedimentation and Shoaling	
1) Calculate suspended sediment fluxes (new objective).	$21,000
2) Process up to 60 additional sediment samples in order to increase mapping accuracy (objective 1).	up to $3,600
Currents	
1) Preliminary processing of vertical profile data (Dobrocky data) (objective 5).	$16,000
2) More statistical and descriptive analysis of the vertical profile data (objective 5).	$5,800

Task	Cost
3) More analysis of salinity and residual flow data with more detailed reporting (objectives 3 and 4).	$3,000 - $8,000
4) Process and analyze additional National Ocean Survey (NOS) data (objective 2).	$1,000
Simulation	
1) Increased effort on final report (all objectives).	$4,000 - $6,000
2) Additional refinement of two-dimensional horizontal model (objective 1).	$5,000 - $9,000
3) Additional numerical experiments on two-dimensional horizontal model (objective 1).	$2,000 - $11,000
4) Additional refinement and verification of two-dimensional vertical model (objective 2).	$5,000
Cartographic Work Unit	
1) Increase the number of maps and/or length of text in the final integration report.	up to $20,000

APPENDIX A

CREDDP Chronology of Events

A Chronology of the Development of CREDDP, and Meetings of the PNRBC Estuary Program Subcommittee, the CREDDP Technical Advisory Committee (TAC), and the Citizen Advisory Committee (CAC)

1975	
October	First draft of "Federal-state study program to assist CREST management program development"
Nov. 21	Draft Columbia River Estuary Special Study Proposal to Study submitted by PNRBC
1976	
June	PNRBC FY 79 budget request for Special Estuary Study submitted
Aug. 31	PNRBC TAC meeting -- discussion of Special Study proposal
1977	
June	PNRBC FY 79 budget request for Special Estuary Study submitted
1978	
February	Interim Project Director, Dr. Robert Holton, hired
April 4	CREST Director testifies before Senate and House Public Works Committee on appropriation for CREDDP funding
Sept. 27	1st CREDDP Technical Advisory Committee (TAC) meeting held (PNRBC office, Vancouver, WA)
October	PL 89-90 appropriates $828,900 in FY 79 to PNRBC for Special Study
November	Program Director, Mr. Robert Moulton, hired
Dec. 8	CREST submits draft CREDDP Plan of Study outline to Moulton
Dec. 18	CREST submits report "The Columbia River Estuary Research Program: Purpose, Objectives, Structure"
Dec. 22	Revised draft CREDDP Plan of Study sent for review
1979	
Jan. 3	Citizen Advisory Committee (CAC) designated
Feb. 7	Second CREDDP TAC meeting held to review preliminary draft Plan of Study (PNRBC office, Vancouver, WA)

1979 continued

Feb. 15	PNRBC Briefing on Study
March 15	Plan of Study approved by PNRBC
April 16	CAC meeting (Pier 11, Astoria)
May 11	TAC meeting (PNRBC office, Vancouver, WA)
? May 21	CAC meeting (Ilwaco, WA)
June 4	CAC meeting (Ilwaco, WA)
July 11-12	TAC meeting (PNRBC office, Vancouver, WA)
Aug. 1	CAC meeting (Pier 11, Astoria)
Sept. 19-20	Contractors' coordination meeting
Oct. 3	TAC meeting (PNRBC office, Vancouver, WA)
Oct. 16	CAC meeting (Ilwaco, WA)
Nov. 14	CAC meeting (CREST office)
Dec. 6	Contractors' coordination meeting
Dec. 14	Estuary Program Subcommittee meeting (PNRBC office, Vancouver, WA)
Dec. 19	CAC meeting (Port of Ilwaco, WA)

1980

Jan. 16-17	TAC meeting (PNRBC office, Vancouver, WA)
Feb. 2	CAC meeting (Port of Ilwaco, WA)
Feb. 27-28	Contractors' coordination meeting (NMFS Montlake Lab., Seattle)
? March 1	Field collection begun in earnest
May 6	CAC meeting in Skamokawa, WA with editorial contractor
June 18-19	Contractors quarterly meeting; Estuary Program Subcommittee meeting (Thunderbird, Astoria)
July 14	Interactions workshop -- Biophysical contractor (Ilwaco, WA)
August 11	Estuary Program Subcommittee meeting (PNRBC office, Vancouver, WA)
August 22	CAC meeting in Skamokawa, WA with Bob Moulton
? Sept. 25	TAC meeting

1980, continued

Oct. 7	Estuary program Subcommittee meeting (PNRBC office, Vancouver, WA)
Oct. 13	Estuary program Subcommittee meeting (PNRBC office, Vancouver, WA)
Oct. 17	CAC meeting (Port of Ilwaco, WA)
Oct. 27-28	Contractors' quarterly meeting (PNRBC office, Vancouver, WA)
Nov. 12	Estuary Program Subcommittee meeting

1981

? Jan. 15	TAC meeting
Jan. 22	Estuary Program Subcommittee meeting (PNRBC office, Vancouver, WA)
March 18-19	Contractors' quarterly meeting (PNRBC office, Vancouver, WA)
March 31	CAC meeting (Port of Ilwaco, WA)
April 16	Estuary Program Subcommittee meeting (PNRBC office, Vancouver, WA)
April 27	CAC meeting (Warrenton, OR)
May 14	TAC meeting
May 15	Estuary Congressional Tour
May 16	Estuary Program Subcommittee meeting (PNRBC office, Vancouver, WA)
May 22	CREST-CREDDP workshop preparation meeting (CREST office)
June 5	CREST workshop, "How Will Research Assist the Management of the Columbia River Estuary?"
July 29	CAC meeting (CREST office) -- joint CREST and CREDDP
Aug. 3	Dr. John Damron replaces Bob Moulton as CREDDP Program Manager
Aug. 4	Estuary Program Subcommittee meeting (PNRBC office, Vancouver, WA)
Aug. 14	CAC -- Management Contractor (Port of Ilwaco, WA)
Aug. 26	CAC meeting (Astoria)
Aug. 29	Notice of program termination sent to contractors
Sept. 30	Program terminated
Nov. 1-5	CREDDP session at Estuary Research Federation Conference (Salishan, OR)

1981 continued

Dec. 11	President signs Energy & Water Development Bill appropriating funds for completion of CREDDP
Dec. 16	CREST Contracts to prepare for U.S. Water Resources Council an evaluation of previous CREDDP contracts and billings.

1982

Feb. 15	CREST submits "Evaluation of Contracts and Billings" to WRC
Mar. 15	CREST submits "Status of Work: The Columbia River Estuary Data Development Program.
May 1	CREST begins Cooperative Agreement with WRC to prepare Plan of Study for completion of CREDDP
June 2	CREDDP Users Workshop to evaluate Revised Goals and Objectives for completion of CREDDP
July 2	Draft Plan of Study distributed for review
July 23	Final Plan of Study submitted to U.S. Water Resources Council

Appendix B

Past CREDDP Contracts (1979 - 1981)

Contract #	Contract Titles	Contractor
79-1	Guide to Aquatic Organisms	VTN Oregon, Inc.
79-2	Historical Maps, 1792-1900	Oregon Historical Society
79-3	Wetland Mapping	U.S. Fish and Wildlife Service
79-4	Bibliography	Oregon State University
79-5	Personal Services - Wildlife	Washington Department of Game
79-6	Computer Equipment	Northwest Economic Associates
79-7	Computer Services	Boeing Computer Services
79-8	Information Transfer Services	CREST
79-9	Management Contractor	Envirosphere, Inc.
79-10	Editorial Contractor	Oceanographic Institute of Wa.
79-11	Benthic Primary Production	Oregon State University
79-12	Water Column Primary Production	Oregon State University
79-13	Benthic Infauna	Oregon State University
79-14	Currents and Shoaling Patterns	Mathematical Sciences Northwest
79-15	No Contract Issued	
79-16	Historical Bathymetric Maps	Northwest Cartography, Inc.
79-17	Sedimentation	University of Washington
79-18	Epibenthic Organisms	Dames and Moore, Inc.
79-19	Salmonid and Non-Salmonid Fishes	National Marine Fisheries Service
79-20	Avifauna	Jones and Stokes, Inc.
80-1	Zooplankton and Larval Fish	University of Washington
80-2	Emergent Plant Production	Science Applications, Inc.
80-3	Vessel Lease	Oregon State University
80-4	Wildlife	Washington Department of Game
80-5	Current Studies	Dobrocky Seatech, Ltd.
80-6	Characterization of Water Quality	Envirosphere, Inc.
80-7	Log Storage	Envirosphere, Inc.
80-8	Biophysical Interactions	Science Applications, Inc.
80-9	Data Systems	Boeing Computer Services
80-10	Marine Mammals	Washington Department of Game
80-11	Simulation	Science Applications, Inc.
81-1	Bareboat Charter	Sea Lease, Inc.

APPENDIX C

Publications Available from the
COLUMBIA RIVER ESTUARY INFORMATION CENTER

CREST

Columbia River Estuary Inventory. (1977).	Library
Columbia River Estuary Regional Policies. (1977).	Library
Columbia River Estuary Regional Management Plan. (1979).	$25.00
An Economic Analysis of the Columbia River Estuary. (1981).	16.00
Historical Analysis of the Columbia River Estuary: An Ecological Approach. (1981).	8.00
A Review of Recent Scientific Literature on the Columbia River Estuary, Emphasizing Aspects Important to Resource Managers. (1981).	15.00
Mitigation Policy Paper for the Columbia River Estuary. (1982).	5.50

CREDDP

Annual Report. (1979). Pamphlet.	No charge
Plan of Study. (1979). 144pp.	Library
Style Guide. (1979). 40pp.	Library
A Review of Numerical Models of the Columbia River Estuary. Lewis, James K. and Peter Hamilton. (1980).	2.00
A Review of the U. S. Army Engineers Waterways Experiment Station Sediment Transport Model. Mathematical Sciences Northwest. (1980). 34pp.	Library
Annual Data Report. 2 Vol. (1980). Vol. I:	2.00
Vol. II:	15.00
Literature Review of Nitrogen Fixation in the Columbia River Estuary. Lawley and Zamber. (1980). 16pp.	Library
Literature Review of Reptiles and Amphibians in the Columbia River Estuary. Beyer et al. (1980). 15pp.	Library

* Publications with the number of pages indicated after the title are available for purchase at a copying charge of 10¢ a page (20¢ if over 100 pages).

PUBLICATIONS AVAILABLE FROM THE COLUMBIA RIVER ESTUARY INFORMATION CENTER
-- PAGE TWO --

Literature Review of Seed Production in the Columbia River Estuary. Beyer et al. (1980). 15pp.	Library
Literature Review of Terrestrial Insects of the Columbia River Estuary. Caldwell et al. (1980). 11pp.	Library
Literature Survey of the Columbia River Estuary. 2 Vol. (1980).	Vol. I: $ 3.00 Vol. II: 10.00
Procedures Manual. (1980). 415pp.	Library
Vegetation Survey and Herbarium. Thomas, Duncan. (1980). 19pp.	Library
Water Quality Summary. Envirosphere. (1980).	5.00
Water Quality Appendices. Envirosphere. (1980). 642pp.	Library
Avifauna Draft Report. Jones and Stokes Associates. (1981).	No charge
Columbia's Gateway. 1 book; 45 maps. Oregon Historical Society. (1981).	3.00 ($13.00 w/maps)
Columbia River Estuary Hydrodynamic Modeling. Hamilton, Peter. (1981). 40pp.	Library
Marine Mammals - Fisheries Interactions on the Columbia River and Adjacent Waters. Everitt et al. (1981). 24pp.	Library
Salmonid and Non-Salmonid Fish. NMFS. (1981). 146pp.	Library
Wildlife Final Report. Wash. Dept. of Game. (1981). 224pp.	Library
Status of Knowledge on the Effects of Log Storage on the Columbia River Estuary. Envirosphere. (1981).	5.50
Water Column Primary Production in the Columbia River Estuary. Frey, B. et al. (1981). 45pp. + appendices.	Library
Juvenile and Adult Steelhead and Sea-Run Cutthroat Trout Within the Columbia River Estuary. Wash. Dept. of Game.	Library
Plan of Study for the Completion of the Columbia River Estuary Data Development Program. (1982). 121pp. + appendices.	Library

MAPS: Bathymetric and Differencing Series. Northwest Cartography. 2.00
(1980). DATES: 45.00

Bathymetric: 1968-1977; 1926-1937;
1949-1958.

Differencing: 1868-1877 vs. 1926-1937;
1926-1937 vs. 1949-1958;
1852 vs. 1868-1877.

Special Differencing Edition on the River
Mouth: 1868-1877 vs. 1885;
1895 vs. 1902-1911;
1895 vs. 1926-1935.

Appendix D

DRAFT PLAN OF STUDY DISTRIBUTION LIST

Members of Congress and Congressional Staff

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- Tom Imeson, Portland
- Steve Crow, Appropriations Committee, Washington, D.C.

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- Bill McClusky, Washington, D.C.

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- Suzanne Bohn, Washington, D.C.
- Mark Gaede, Portland

Congressman Don Bonker

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Rocky Beach/Steve Treacy, WDG
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Joe Creager, Univ. of Wash.
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Tom English, Univ. of Wash.

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APPENDIX E

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APPENDIX F

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APPENDIX G

RELATIONSHIP BETWEEN GOALS AND OBJECTIVES

I. LOWER TROPHIC LEVELS

A. Describe and map productivity and biomass patterns of Columbia River Estuary primary producers.

Objectives:

1. Describe and map emergent plant biomass primary productivity patterns.

2. Describe and map benthic microalgal productivity, biomass, and related variable patterns.

3. Describe and map phytoplankton productivity and biomass patterns.

B. Determine to the extent possible the carbon budget of priarmy producers.

Objectives:

1. Estimate the export of detritus from marshes.

2. Determine the emergent plant carbon budget.

3. Determine the benthic microalgal carbon budget.

4. Measure or estimate phytoplankton and other organic particulate inputs and outputs.

C. Describe the relationships among primary producers and productivity levels and physical factors.

Objectives:

1. Relate marsh vegetation types and productivity to elevation, salinity, and other pertinent physical and chemical factors.

2. Relate benthic microalgal productivity to sediment parameters, salinity, and other pertinent physical and chemical factors.

3. Relate phytoplankton productivity and biomass to salinity, currents, nutrients, and other pertinent physical and chemical factors.

II. HIGHER TROPHIC LEVELS

A. Describe and map abundance patterns of the invertebrate and vertebrate groups.

Objectives:

1. Describe and map key and selected other zooplankton and larval fish species, by principal life history stages or assemblages in terms of occurrence, density and standing stock over time.

2. Describe population structure and dynamics and life history of Eurytemora.

3. Describe and map key and selected other benthic infauna species or assemblages in terms of density, standing stock, and production over time.

4. Determine the population structure, dynamics, life history and turnover rates of Corophium, Macoma, Hobsonia, and Pseudopolydora.

5. Describe and map key and selected other epibenthic species or assemblages in terms of density, standing stock, and production over time.

6. Describe the population structure, dynamics, life history, and trophic relationships of Dungeness crab, crangonid shrimp, and mysids.

7. Describe and map key and selected other fish species by life history stage, or assemblages in terms of density and standing stock over time.

8. Describe and map migration routes and timing (seasons, residence time) of juvenile and adult salmon and the feeding habits of juvenile salmon in different estuarine habitats.

9. Describe and map key avifauna species abundance and habitats.

10. Describe and map key wildlife species occurrence and density.

11. Describe and map key marine mammal species occurrence, density, and standing stock.

12. Generate estimates of growth over time of identifiable cohorts of key fish species residing within the estuary.

B. Determine function relationships among higher trophic groups.

Objectives:

1. Define functional relationships of benthic infauna in the ecosystem, including predator prey linkages, emigration and immigration, and role in the estuary carbon budget.

2. Define functional relationships of epibenthic organisms in the ecosystem, including predator prey linkages, emigration and immigration, and role in the estuary carbon budget.

3. Estimate mean consumption rates of key fish species/life history stages and proportional contribution of principal prey taxa in different regions/habitats of the estuary. Discuss the role of a key species in the estuary's carbon budget.

4. Tabulate composition, abundance, and biomass of prey of key fish species and life history stages with emphasis on diel samples.

5. Determine avifauna food requirements and prey composition.

6. Estimate the rate of consumption of food/prey by wildlife.

C. Describe the relationships among vertebrate and invertebrate species and physical factors.

Objectives:

1. Quantify functional relationships among zooplankton and larval fishes and physical (salinity, temperature, tide stage) and biological (planktivorous predators) factors.

2. Quantify relationships among benthic infauna and physical (salinity, sediments, depth) and biological (other species) factors.

3. Quantify relationships among epibenthic organisms and physical (salinity, sediments, depths) and biological factors.

4. Quantify relationships among key fish species and physical (salinity, temperature, tide stage) and biological factors.

III. SEDIMENTATION AND SHOALING

A. Characterize and map bottom sediment distribution.

Objectives:

1. Characterize and map bottom sediments.

2. Perform grain-size analysis of sediment samples collected by biologists.

3. Define modern sedimentary environments and processes (including important temporal and spatial scales) in the estuary.

B. Characterize sediment transport.

Objectives:

1. Characterize and map bedform types and migration directions.

2. Characterize estuarine suspended sediment field.

C. Determine (qualitatively) the causes of historic and modern shoaling.

Objective:

1. Investigate causes of modern and historical bathymetric change.

IV. CURRENTS AND SIMULATION

A. Evaluate and model circulation patterns.

1. Describe and analyze tidal circulation.

2. Incorporate NOS data into CREDDP data base and use in all analyses, as appropriate.

3. Describe and analyze low frequency flow, including "null zone" location and processes.

4. Model circulation patterns through the use of a two-dimensional, horizontal model. Use the model to study atmospheric, freshwater and tidal forcings. To analyze circulation in peripheral bays, and to assist the Sedimentation Unit in determing shoaling patterns.

B. Evaluate and model salinity and mixing patterns.

Objectives:

1. Describe and analyze salinity and temperature patterns.

2. Describe and analyze vertical mixing processes.

3. Formulate and use a two-dimensional multichannel vertical model to examine tidal forcings, salinity intrusion, freshwater inflow, atmospheric forcing, vertical mixing, and residual flow processes.

V. INTEGRATION

A. Integrate program data for a more complete understanding of biological and physical structure and processes.

Objectives:

1. Analyze effects of physical processes on key species and the taxonomic structure of communities.

2. Integrate program information to define functional linkages among organisms, to developa carbon budget, and relate these to the physical processes in the Columbia River Estuary.

3. Classify and map habitat types in relation to appropriate physical and biological parameters (depth/elevation, salinity, sediment, emergent vegetation type).

4. Using information developed by work unit contractors, "characterize" (i.e., describe) the biological communities in each habitat type.

5. Integrate current and salinity results and sediment results to develop an understanding of the estuarine sedimentological processes.

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