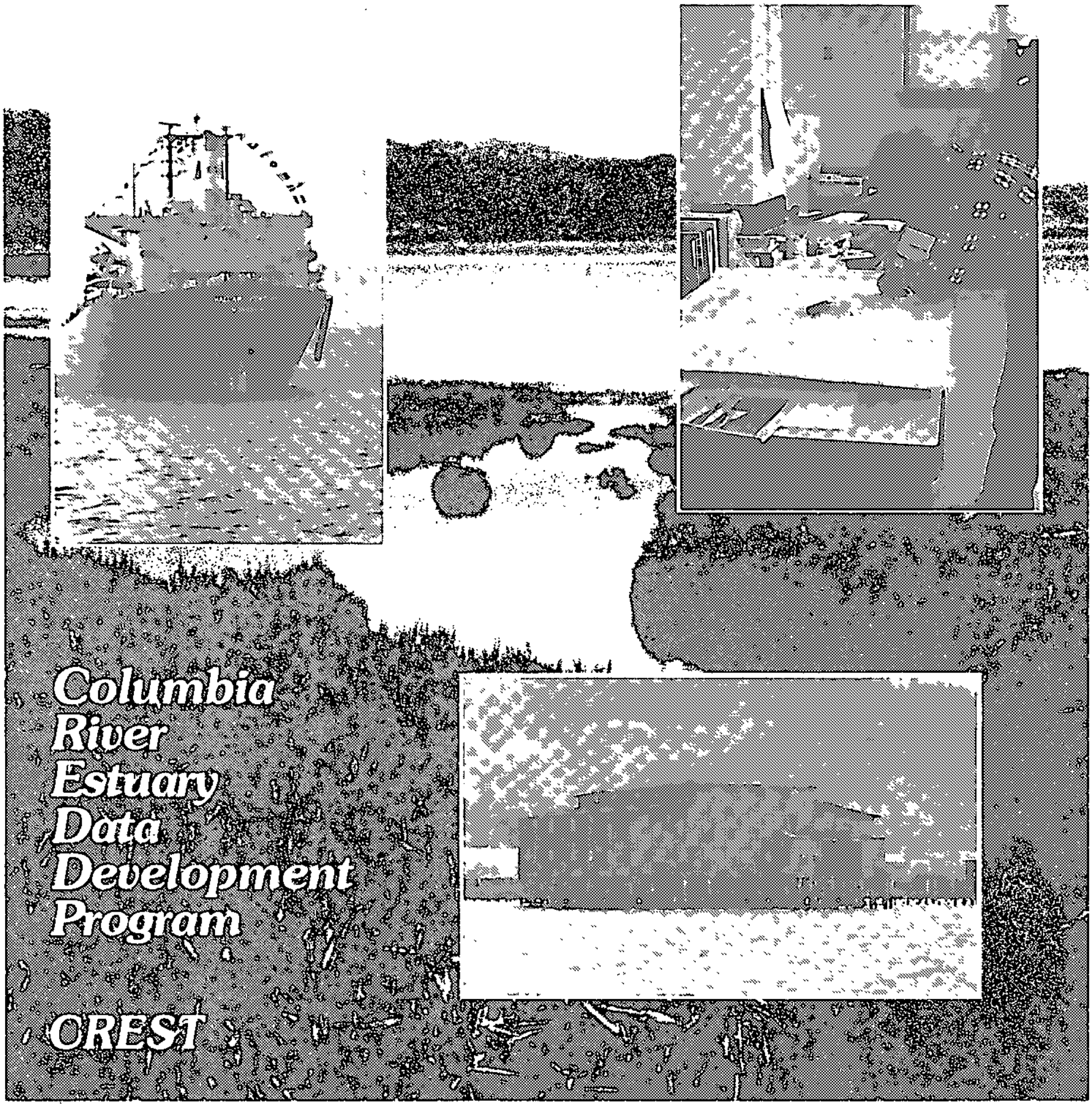
GUIDE TO THE USE OF C.R.E.D.D.P. INFORMATION FOR ENVIRONMENTAL ASSESSMENTS



Columbia
River
Estuary
Data
Development
Program

CREST

Columbia River Estuary

Data Development Program

(CREDDP)

GUIDE TO THE USE OF CREDDP INFORMATION FOR ENVIRONMENTAL ASSESSMENTS

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AUTHORS
Willa Nehlsen
Georgiana Blomberg
Stewart Bell

WORD PROCESSING
Isabel Turner
Julie Guerrero
Elizabeth Rummell

GRAPHICS
Elizabeth Krebill

TECHNICAL ASSISTANCE
William Barnett

TECHNICAL CONSULTANTS
David Jay
C. David McIntire
Charles Simenstad
Lawrence Small
Christopher Sherwood
George Blomberg

Copies of this document are available from:
Columbia River Estuary Study Taskforce (CREST)
P.O. Box 175
Astoria, Oregon 97103
(503) 325-0435

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The following individuals contributed their time and insights toward the conceptual development of this document:

Paul Benoit
George Blomberg
Al Burns
Steven Chesser
Nancy Ellifrit
David Flemer
Howard Harris
Malcolm Karr
Edward Long
Ann Saari
Jacqueline Wyland

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1. INTRODUCTION

The Columbia River Estuary Data Development Program (CREDDP), a federally-funded research program, began in 1978 and was completed in 1984. The purpose of the program was to provide a foundation of scientific knowledge about the estuary and to provide information useful in managing land and water resources through the public planning and permitting processes. This Guide was prepared for people who need to understand the effects on the estuary of proposed development projects, but who do not necessarily have special training in estuarine science. The Guide explains the principles on which environmental assessments are based and presents some necessary scientific background.

1.1 PURPOSE AND ORGANIZATION OF THIS GUIDE

In this Guide, the term "environmental assessment" is used to refer to any estimate of how a development project might affect the estuarine environment. Only physical, chemical, and biological effects on the estuary are considered; economic and social factors are not discussed. CREDDP has provided a basic description of the estuary's characteristics. This Guide suggests some ways that the effects of development projects on these characteristics can be estimated.

The effects of development projects (including construction, diking, filling, dredging, riverflow management, etc.) range from those of small-scale projects, primarily direct effects on the development site itself, to the direct and indirect effects of large-scale projects, which extend from the development site to larger areas of the estuary. To understand the potential direct and indirect effects of development projects, it is necessary to appreciate the ways in which the estuary's circulation, sediments, plants, and animals interact. Chapter 2 describes these complex relationships, and also presents a system for dividing the estuary into regions and habitat types.

Chapter 3 presents a general approach for using CREDDP information in environmental assessments. This approach may be applied to small-scale projects such as small dredging projects, diking or filling small areas, and construction of docks, bulkheads, and pilings. The approach in Chapter 3 may also be applied to large-scale projects such as major fills or dredging projects and alteration of the flow volume of the Columbia River.

Chapter 4 describes how CREDDP information and the approach in Chapter 3 may be used in the local permit process for small-scale projects. A small development project on the Columbia River Estuary can usually be permitted through an impact assessment, which is an assessment of the impact of the proposed development on the area's resources, presented in a particular format. Chapter 4 is intended to help permit applicants make use of CREDDP publications in completing this assessment.

Chapter 5 presents three example environmental assessments, showing some approaches used by scientists to evaluate the effects of large-scale development projects.

1.2 CREDDP AND ITS PUBLICATIONS

To fulfill its purposes, CREDDP sponsored a broad research effort in the Columbia River Estuary and published the results in a series of technical reports, a scientific synthesis, and an atlas designed for a general readership, plus several related publications.

CREDDP research was divided into thirteen "work units". Each work unit was performed by a separate research team, and each research team produced a technical report, called a work unit report, detailing its methods, results, and conclusions.

Three work units dealt exclusively with physical processes. The purpose of the Currents work unit was to provide an understanding of the forces governing the movement of water in the estuary. Tidal height, current direction and speed, water temperature and salinity (salt content), riverflow, and wind data were collected and analyzed. Another work unit, Simulation, involved the development of computer models of the estuary's circulation patterns, so that these patterns could be better understood and predicted. The third physical process work unit, Sedimentation and Shoaling, was designed to describe bottom sediment types, to map their distributions, to characterize the process whereby sediments are transported by currents, and to analyze the causes of shoaling and erosion.

Plant life was the subject of three work units. Plants are called primary producers because, through photosynthesis and the uptake of chemical nutrients, they form the base of the estuarine food web. A large portion of primary producers are microscopic. One group of researchers studied the microscopic plants that live in the water (Water Column Primary Production) while another dealt with those that live on or in the sediments (Benthic Primary Production). Marsh plants were the subject of the Emergent Plant Primary Production work unit. The goals of these research teams were to determine the amounts (standing crop) and distribution of the various primary producers, to measure the plants' rates of growth (productivity), and to learn how the plants' standing crop and productivity are influenced by their physical and chemical environment.

The seven other work units were devoted to the animal life of the estuary. Invertebrates (animals without backbones) were the primary focus of three work units. Invertebrates tend to be small. In the Columbia River Estuary they range in size from single-celled animals up to Dungeness crabs, which can weigh more than three pounds. Work units were assigned according to habitat and were called Zooplankton and Larval Fish, Benthic Infauna, and Epibenthic Organisms. The zooplankton consists of the invertebrates that live in the water column. The benthic infauna consists of invertebrates that live in the bottom sediments, while epibenthic organisms live on or just above the bottom. The purpose of the sampling program was to determine what species were present, where and when and in what numbers they were present, and how their abundance can be related to physical factors such as depth, temperature, salinity, and type of sediment.

The other four work units devoted to animal life dealt with vertebrates, the generally larger and more familiar animals in and around the estuary. The four classifications were Fish, Avifauna (birds), Marine Mammals, and Wildlife (aquatic and terrestrial mammals). Researchers used a variety of techniques to identify populations and to determine distributions, important habitats, feeding habits, growth rates, and life cycles.

Information and data produced by the work unit researchers provided the scientific basis for an ecological synthesis, one of the principal objectives of CREDDP. A team of scientists analyzed the work unit results and produced a comprehensive report entitled The Dynamics of the Columbia River Estuarine Ecosystem. In this document, the physical setting and processes of the estuary are described first. Next, a conceptual model of biological processes is presented, with particular attention to the connections among the components represented by the work units. This model provides the basis for a discussion of relationships between physical and biological processes and among the feeding types of organisms in the estuary. Historical changes in physical processes are also discussed, as are the ecological consequences of such changes. Finally, the estuary is divided into eight geographic regions according to physical criteria, and selected biological characteristics of the "habitat types" within each region are described.

Much of the raw data collected by each work unit research team was stored on magnetic tape and archived by CREDDP at the U.S. Army Corps of Engineers North Pacific Division Data Processing Center in Portland, Oregon. These data files, structured for convenient user access and available to anyone upon request, are described in an Index to CREDDP Data. The index also describes and locates several data sets which were not adaptable to computer storage.

The work unit reports, the ecological synthesis, and the data archive constitute the formal presentation and repository of the program's results and were produced primarily for scientists and for resource managers with a scientific background.

A portrait of the estuary intended for a general readership is presented in The Columbia River Estuary: Atlas of Physical and Biological Characteristics. This publication provides an introduction to the estuary which can serve as background for this Guide and for work unit reports. The Atlas contains color maps illustrating much of the information developed by the research teams, supported by text and graphic illustrations. The Atlas portrays physical properties and processes (for instance, salinity, circulation, and shoaling patterns). The Atlas also shows the geographical distribution of plant and animal species or categories of species, their standing crop, density, and productivity. The regions and habitat types are also mapped, a particularly useful feature of the Atlas for readers of this Guide.

The Bathymetric Atlas of the Columbia River Estuary contains color bathymetric contour maps for 1935, 1958, and 1982, and includes "differencing" maps illustrating depth changes between selected survey years dating back to 1868. Bathymetry is the measurement of water depths; a bathymetric contour map is a topographic map of the estuary bottom.

Two historical analyses are also available. Changes in Columbia River Estuary Habitat Types over the Past Century compares information on the extent and distribution of tidal swamps, tidal marshes, tidal flats, and various water depth regimes a hundred years ago with corresponding recent information and discusses the causes and significance of the changes measured. Columbia's Gateway is a cultural history of the estuary to 1920 prepared by the Oregon Historical Society. It includes 39 reproductions of historical maps.

All of these publications are described more completely in Abstracts of Major CREDDP Publications, which, in addition to abstracts, contains a listing of many useful materials that were developed as byproducts of the program, including base maps, literature surveys, and an herbarium collection. Also included is an annotated bibliography of all interim CREDDP reports and several other related documents.

CREDDP publications - and further information about the program, the estuary, and estuarine impact assessments - are available from the Columbia River Estuary Study Taskforce (CREST), which maintains a staff and library.

2. THE COLUMBIA RIVER ESTUARY

2.1 ESTUARIES

An estuary is defined by scientists as "a semi-enclosed body of water that has a free connection with the open sea and within which sea water is measurably diluted with fresh water derived from land drainage."* It is the dilution of seawater by freshwater drainage that sets estuaries apart from coastal bays and inlets. Near the ocean the salinity of estuarine water is nearly as high as in the ocean itself. From the mouth salinity gradually decreases upstream toward the freshwater source (usually one principal river, but sometimes more than one) until eventually the water becomes completely fresh.

There is a tendency in estuaries for the denser and heavier seawater to move into the estuary below the river water. The more saline water tends to remain at the bottom of the estuary. Thus, salinity varies not only from one end of the estuary to the other but also from surface to bottom. There is a lengthwise gradient (gradual change) in salinity and a vertical salinity gradient.

The locations in the estuary of seawater, river water, and the brackish water resulting from their mixing are determined primarily by the interaction of riverflow and tides. Riverflow transports water through an estuary at a rate which may vary dramatically with the change of seasons while the rise and fall of the tides move water both into (flood tide) and out of (ebb tide) the estuary. The interaction of riverflow and tides creates a constantly and often radically changing environment where physical properties (salinity, currents, sediments, etc.) are in a constant state of flux.

Such dynamic conditions constitute a stressful and rigorous, if not actually inhospitable, environment for plant and animal life. Those plants and animals that are adapted to live amid the ever-fluctuating estuarine environment therefore tend to be hardy, tolerating a relatively wide range of conditions.

Yet, estuaries are among the most biologically productive ecosystems in the world. To a great extent this is because estuaries tend to have large and concentrated supplies of the nutrients needed to support aquatic life. These important nutrients are derived from two major sources: river water, supplying nutrients leached from surrounding land areas, and from ocean waters. The nutrients transported into the estuary tend to be retained and concentrated within the estuarine system. The richness of the nutrient supply allows those plants and animals that are adapted to the estuarine environment to sustain high rates of productivity.

2.2 THE COLUMBIA RIVER ESTUARY

The area of study for CREDDP was the portion of the Columbia River

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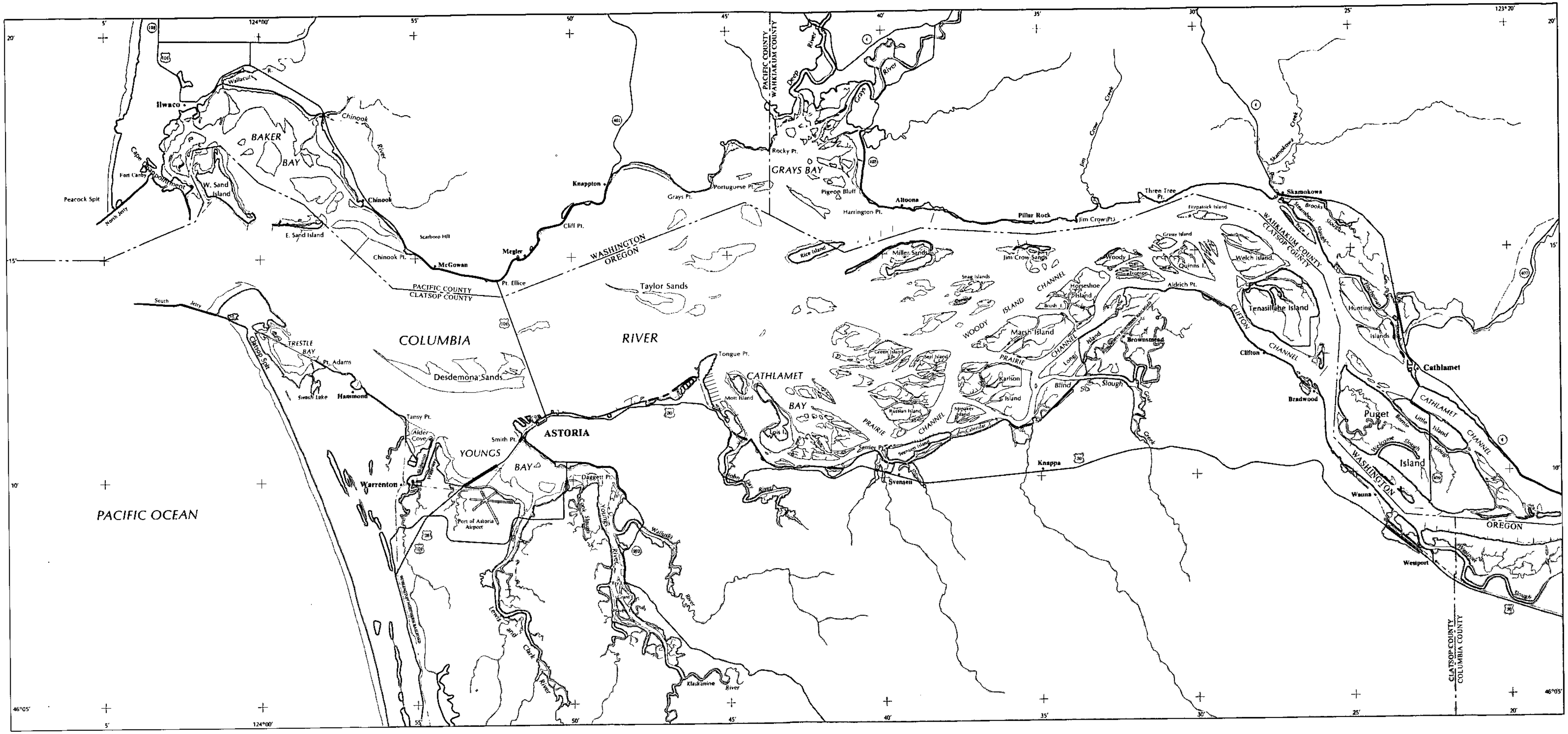
*From an article by D.W. Prichard in Lauff, G.H. (ed.), Estuaries (1967).

Figure 1 (opposite). The Columbia River Estuary, showing location names and intertidal features. The CREDDP study area boundaries are the shoreline, the heads of tide of tributaries, the eastern edge of the map, and a line joining the tips of the North and South Jetties.



Columbia River Estuary

Scale 1:160,000

0 1 2 3 4 5 6 7 8 9 10 Kilometers

0 1 2 3 4 5 6 Miles

Map produced in 1983 by Northwest Cartography, Inc.
for the Columbia River Estuary Data Development Program

- Shoreline (limit of non-aquatic vegetation)
- Intertidal vegetation
- Shoals and flats
- Lakes, rivers, other non-tidal water features
- Major highways
- Cities, towns
- Railroads
- Other cultural features

extending from the mouth at River Mile 0 (RM-0) to just upriver from the eastern tip of Puget Island at RM-46 (Figure 1). Along the shores and islands of the estuary, the study area extends into tidal marshes and swamps to the landward limit of aquatic vegetation. In the Columbia River Estuary, the elevation at which the transition from aquatic to non-aquatic vegetation occurs varies from about 2.4 to 3.7 meters above mean lower low water (MLLW). (MLLW is defined as the average elevation, over several years, of the lower of the two daily low tides. Its elevation is by definition zero.) Where tributaries enter the estuary, the study area was defined as extending upriver to the farthest extent of tidal influence (the head of tide). By this definition, the estuary has a surface area of about 41,200 hectares (1 hectare = 2.47 acres). This includes 25,300 hectares of subtidal area (where the bottom is deeper than one meter below MLLW and is never exposed at low tide), 9,950 hectares of unvegetated tidal flats, and 5,950 hectares of tidal marsh and swamp.

Oceanic processes and the regional climate influence the physical attributes of the estuary. Oceanic processes, particularly tides, result in the twice-daily rising and falling of the water level at the mouth of the river. The average tidal range, or difference between high and low tide, at the mouth is two meters. Tides vary. The principal pattern of variation follows a two-week cycle and is closely related to the phases of the moon. At a given time, there may be little difference between the two daily high tides or between the two daily low tides, and the tidal range is less than average; these are called neap tides. One week later, the difference between the two daily high tides is large, as is the difference between the two daily low tides, and the tidal range is greater than average; these are called spring tides. After another week, neap tide conditions prevail again. Spring tides can produce circulation and salinity patterns in the estuary that are very different from those produced by neap tides.

The regional climate influences the estuary primarily through its effects on riverflow, the volume of water coursing down the river at any given time. "Regional" here refers to the entire Columbia River drainage basin, which includes portions of seven states and one Canadian province. As a result of climatic differences within the drainage basin, the annual riverflow cycle can be divided into three seasons. July through October is the low riverflow season, with an average flow at the mouth of about 100,000 cubic feet per second (cfs). From November through March, winter rains west of the Cascades cause the riverflow to fluctuate on short time-scales between about 100,000 cfs and 500,000 cfs; this is called the fluctuating riverflow season. As the mountain snowpack melts between April and June, riverflow stabilizes at about 450,000 cfs; this is called the high riverflow season.

Tides and riverflow meet in the shallow, narrow basin of the Columbia River Estuary to produce turbulent and very rapid currents. This highly energetic water circulation strongly affects other important physical characteristics of the estuary such as salinity and sediment distribution. Saline ocean water moves into the estuary primarily as a result of tidal action, and its upriver movement is opposed by the riverflow. The extent to which salinity intrudes into the estuary is greater during low riverflow periods than during high riverflow periods. When spring tides occur during the high riverflow season, the estuary becomes completely freshwater for a few hours at a time when a strong ebb tide flushes all of the saline water from the estuary.

Most of the sediments in the estuary are composed of sand rather than silt. Sandy sediments are indicative of strong, turbulent currents which tend to flush the silty sediments away. Silty bottom sediments are largely restricted to the protected embayments of the estuary. The sediments of the estuary are constantly shifting in response to the strong water flows. Sediment transport in the Columbia River Estuary involves the movement of sand waves along the bottom, a process known as bedload transport, and the movement of finer sediment (very fine sand, silt, and clay) in suspension (suspended transport). The highest concentrations of suspended sediments occur near the upriver limit of salinity intrusion. When such a concentration is well developed, it is called a turbidity maximum. Changes in the distribution of sediments that affect the bathymetry of the estuary can cause changes in circulation.

Generally, the physical characteristics of the Columbia River Estuary differ from those of most other estuaries. River discharge is much greater, salinities are much lower, and the sediment is less stable. Because of the large volume of riverflow into the Columbia River Estuary, its flushing time (the amount of time water takes to move through the estuary) is only about one to five days. This contrasts with many other estuaries, in which water may take weeks or months to reach the ocean. For example, the average flushing time of Chesapeake Bay is about one year.

The physical characteristics of an estuary determine the composition of its biological communities. The most biologically important physical factor of an estuary is salinity. Plants and animals are highly sensitive to the salinity of water because this has a large influence on many biochemical and physical processes. Species are adapted to certain salinity ranges, and these salinity ranges determine where they are able to live.

As is the case with all biological systems, the plants and animals of the Columbia River Estuary are members of a food web. Animals feed on plants, and are in turn fed upon by other animals. Any particular feeding sequence of plant and animal species is a food chain. The food chains are interlinked with each other and all of them together make up the estuarine food web. The components of the estuarine food web can be described in general terms as a series of feeding levels. The first level consists of plants, which convert inorganic chemicals and the sun's energy into living material. Because all living material originates with plants, they are called primary producers, and the process of plant growth is called primary production. This living material is passed on to higher levels, called consumers, first through consumption of plants by herbivores (organisms that consume plants), then through consumption of these herbivores by carnivores (organisms that consume flesh), and finally through successive consumption of these carnivores by other carnivores. Detritivores are animals that eat particles of decaying plant or animal matter (detritus). The consumers in the Columbia River Estuary seem to be supported mostly by detritus and secondarily by living plants. For this reason, the food web of the Columbia River Estuary is said to be detritus-based.

The primary producers studied by CREDDP investigators include phytoplankton, benthic primary producers, and marsh plants. Most of the phytoplankton (single-celled drifting plants) in the Columbia River Estuary are freshwater forms. These freshwater phytoplankton are rapidly brought downriver, die as they reach the brackishwater area, and either settle to the bottom, are flushed out of the estuary, or are eaten. The benthic (bottom-dwelling) primary producers in the Columbia River Estuary consist almost entirely of a group of single-celled plants known as diatoms, which live among the surface sediments of the tidal flats. Large, productive beds of submerged flowering plants (for example, eelgrass) and large many-celled algae are not common in Columbia River Estuary benthic habitats, although they are in many other estuaries. The tidal marsh and swamp communities of the Columbia River Estuary show dramatic differences from many well-studied estuaries. First of all, there are no saltmarshes in the estuary; instead, all of the tidal marshes are either brackishwater or freshwater. This is due to the relatively low salinity of the Columbia River Estuary. In addition, some of the tidal swamps in the estuary are spruce swamps, a type that has become particularly rare along the coast of Oregon and Washington. Tidal swamps in the Columbia as well as other estuaries have been greatly reduced by diking, but there are still about 430 hectares of tidal spruce swamp in the Columbia River Estuary.

The invertebrates studied by CREDDP investigators include the zooplankton, the benthic infauna, and epibenthic organisms. The zooplankton (the community of very small animals suspended and passively floating in the water) of the Columbia River Estuary, as in many estuaries, includes marine, freshwater, and estuarine (brackishwater) groups. The estuarine group has a complex relationship with the circulation patterns of the estuary, allowing it to be maintained in the estuary and not flushed out. The benthic infauna (the community of animals living within the bottom sediments) is dominated by organisms adapted to live in fresh water or low-salinity brackish water. The estuary's epibenthic organisms (animals living on the sediment surface and/or in the overlying water layer) are mostly mobile organisms such as crabs and small shrimp. Large beds of clams and oysters are common in many more saline estuaries but do not exist in the Columbia.

Most of the invertebrates in the Columbia River Estuary are detritivores. Very few vertebrates can consume detritus even though it is far more abundant in the estuary than living plants. Instead, many vertebrates consume invertebrate detritivores, which are therefore key links in the detritus-based food web of the Columbia River Estuary.

The vertebrate consumers studied by CREDDP investigators include fish, birds, and mammals (including terrestrial, aquatic, and marine mammals). As with most estuaries, the Columbia River Estuary is an important nursery area for several fish species. This is due mainly to its large food supply and protective habitat. Like other estuaries, the

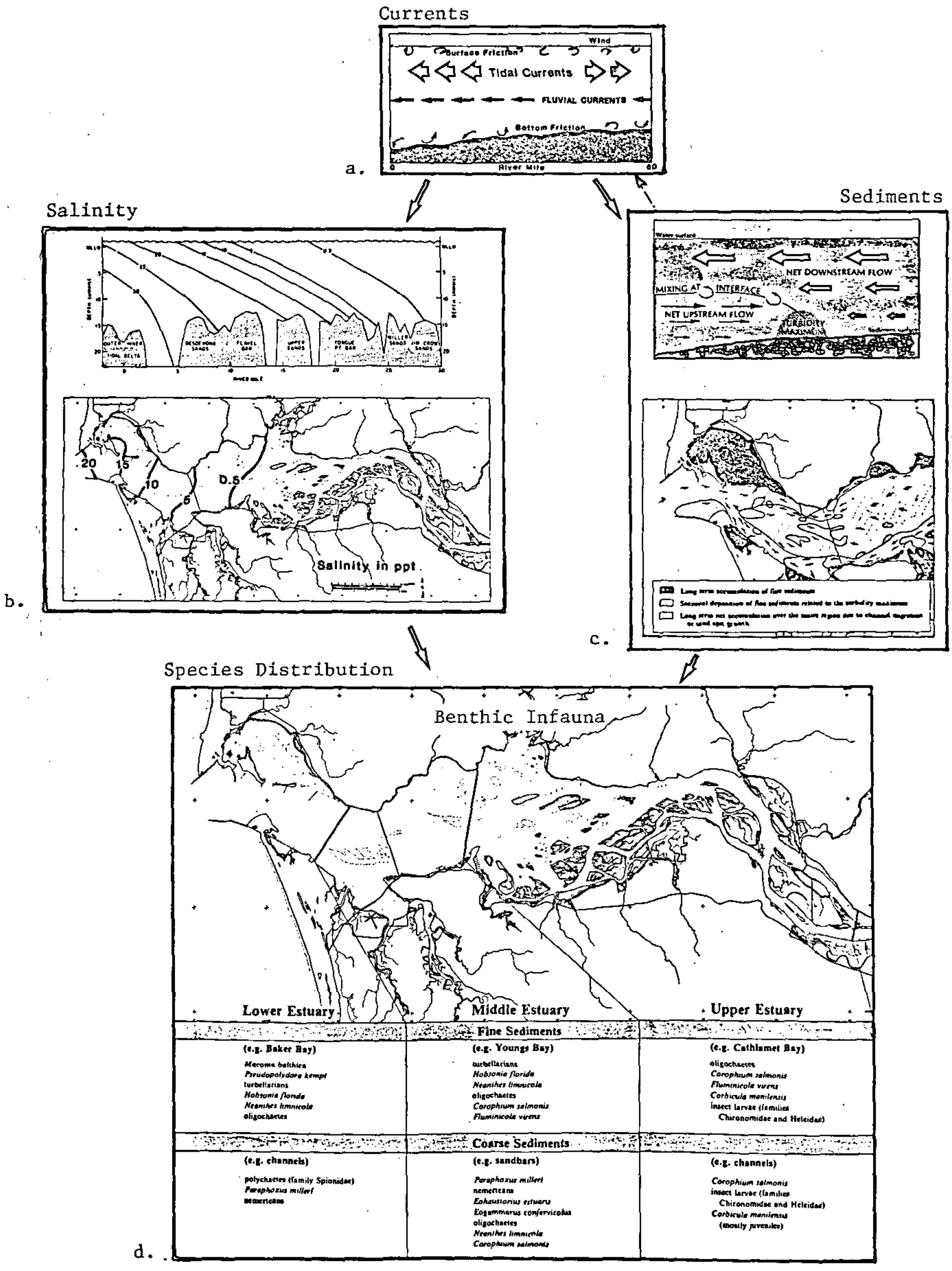


Figure 2. Major components of the estuarine ecosystem and their interactions (see text).

Columbia River Estuary is a feeding ground for many birds and provides a resting point for migratory species. Terrestrial and aquatic mammals find favorable feeding and denning sites in the marshes, swamps, and associated tidal channels of the estuary. Marine mammals feed in the Columbia River Estuary as in other estuaries but do not seem to breed here. Instead, adjacent estuaries or coastal regions are used for pupping.

Some major processes of the estuary are summarized in Figure 2. The primary factors influencing the estuary's circulation are tidal currents and fluvial (river-derived) currents (Figure 2a). Circulation influences the distribution of salinity and sediments (Figure 2b and 2c). For example, salinities tend to decrease gradually from the mouth to the head of the estuary (Figure 2b). The distribution of sediments is also affected by circulation (Figure 2c). For example, high concentrations of suspended sediments occur in the turbidity maximum zone. The bathymetry of a site is the result of sediment accumulation and erosion, which may be caused by circulation. The distribution of sediments may in turn affect circulation patterns (indicated by dotted arrow from 2c to 2a). The distribution of biological species is affected by distributions of salinity and sediments. Some groups, such as the benthic infauna (Figure 2d), are directly affected by these factors. The distribution of other groups, such as birds, results primarily from the distribution of species on which they depend for food or habitat, but this is an indirect result of salinity or sediment distributions because these cause the distribution of the prey or habitat species.

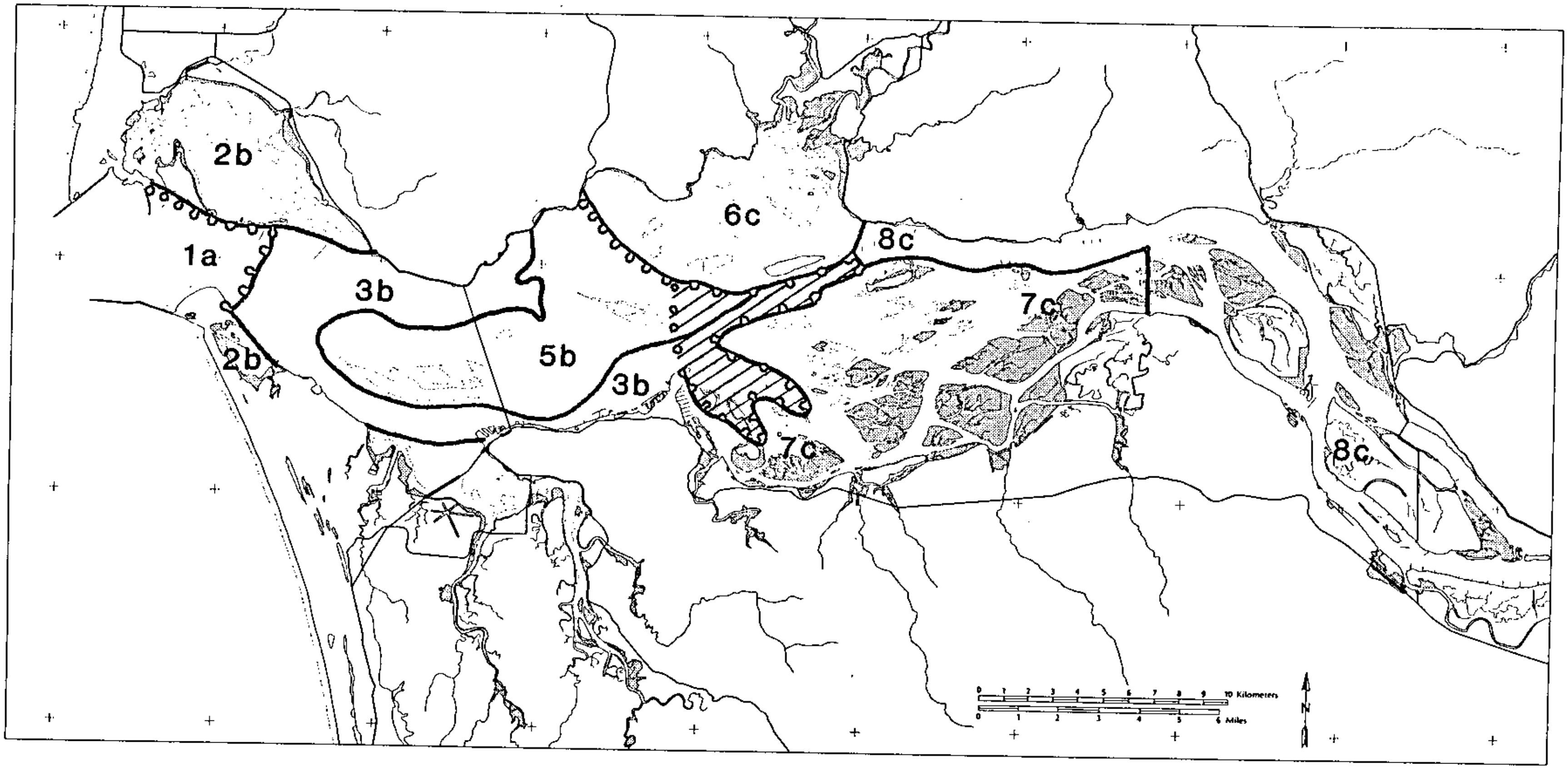
2.3 REGIONS AND HABITAT TYPES

Five CREDDP research team leaders and CREDDP staff collaborated to integrate the results of the program in The Dynamics of the Columbia River Estuarine Ecosystem (see Section 1.2). The purpose of this synthesis was to evaluate the relationships among the physical and biological characteristics of the estuary. To carry out this task, it was necessary to divide the estuary into smaller units having fairly uniform physical and biological characteristics. Data from sampling stations within each unit could then be combined, making it possible to describe each area, compare the attributes of different areas, and infer relationships between their physical and biological characteristics.

The first criterion used to divide the estuary was salinity, the most biologically important factor. The estuary was divided into three zones based on salinity and related circulatory processes. Second, the estuary was divided into eight regions based on general physical characteristics such as distribution of sediments. The amount of exposure to energy of currents resulting from tides and riverflow was also considered. The zones and regions are shown in Figure 3. Finally, each region was subdivided into six habitat types based on elevation or vegetation. The Atlas (Plate 28) shows these divisions.

Salinity Zones

The three salinity zones were labeled plume and ocean, estuarine



Regions

1 - Entrance
2 - Baker Bay and Trestle Bay
3 - Estuarine Channels
4 - Youngs Bay
5 - Mid-estuary Shoals
6 - Grays Bay
7 - Cathlamet Bay
8 - Fluvial Region

Salinity Zones

a - Plume and Ocean
b - Estuarine Mixing
c - Tidal Fluvial

Shaded area is in the tidal fluvial zone, except during the low riverflow season, when it is part of the estuarine mixing zone.

Figure 3. Regions and salinity zones of the Columbia River Estuary.

mixing, and tidal-fluvial.

Plume and Ocean

This zone has the highest proportion of ocean water and the highest salinities in the estuary. It is characterized by strong tidal currents and wave action. Suspended sediment concentrations are usually low; water in this zone is clearer than in areas of the estuary where turbid river water is more influential.

Estuarine Mixing

This zone is the major area in which salt water and fresh water meet and, to varying degrees, mix. The eastern boundary of this zone is the upriver limit of saltwater intrusion, whose position during the low riverflow season is farther upriver than its position during the other seasons. The estuarine mixing zone has high concentrations of suspended sediments; these are trapped in the turbidity maximum, which moves with the tides up- and downriver in this zone within a range that depends on riverflow season.

Tidal-Fluvial

This is a freshwater zone, but it has tidal currents and variations in water height. Its downriver extent, the boundary shared with the estuarine mixing zone, depends on season. Turbidity varies depending on the concentration of suspended sediments in the river water entering the zone.

Regions

Entrance (Region 1)

This region corresponds to the plume and ocean salinity zone. It consists mostly of deep water areas, and its sediments are predominantly medium-fine sand.

Baker Bay and Trestle Bay (Region 2)

These bays generally have lower energy levels than the main body of the estuary. Their sediments are finer and more varied in size than those of other parts of the estuary and include significant amounts of silt and clay. The construction of the entrance jetties has resulted in heavy sediment deposition.

Estuarine Channels (Region 3)

This region contains both the main navigation channel and the north channel. Its eastern reach is alternately in the estuarine mixing salinity zone or in the tidal-fluvial zone, depending on riverflow season. The remainder of this region is always part of the estuarine mixing zone. Sediments are mostly medium-fine sand.

Youngs Bay (Region 4)

This region is usually subject to low energy levels except in channel areas. Like other embayments, its sediments are relatively fine and varied.

Mid-Estuary Shoals (Region 5)

This region consists of tidal flats and submerged sandbars separated by shallow channels. Most areas have moderate to high energy levels due to strong currents. Sediments are generally fine sand and, historically, sediment deposition has been heavy. The eastern reach of this region is part of the tidal-fluvial salinity zone except during the low riverflow season when the estuarine mixing zone expands eastward; the remainder is always part of the estuarine mixing zone.

Grays Bay (Region 6)

Sediments in this region range from medium sand to sandy silt, and deposition of sediments has been extensive. Grays Bay is subject to moderately energetic wave and current action because of its exposure to winds.

Cathlamet Bay (Region 7)

This is a large and diverse region with many islands composed of tidal flats, marshes, and swamps and with a complex network of channels. Sediment types vary accordingly. Fine sands and silts are found in tidal marshes and mudflats while medium-fine sand is found on the more exposed sandflats. The water in Cathlamet Bay is fresh except during low riverflow periods, when some salt water may enter along the bottom in the north channel and MARAD Basin. During low riverflow neap tide periods salinity may intrude along the bottom into the other channels south of Miller Sands. Salinity is probably always low or absent in shallow areas and only very rarely intrudes into the upriver half of the region.

Fluvial Region (Region 8)

This region includes the channels upriver of significant salinity intrusion and continues to the upriver limit of the CREDDP study area. Its sediments are among the coarsest in the estuary.

Habitat Types

Each region contains some or all of six habitat types, shown in profile in Figure 4. The habitat types are defined in the following paragraphs. Depths and elevations are given here in feet rather than metric units because the habitat-type classification system was developed using bathymetry maps showing depth contours in feet.

Water Column

The water column habitat type extends from the surface of the water

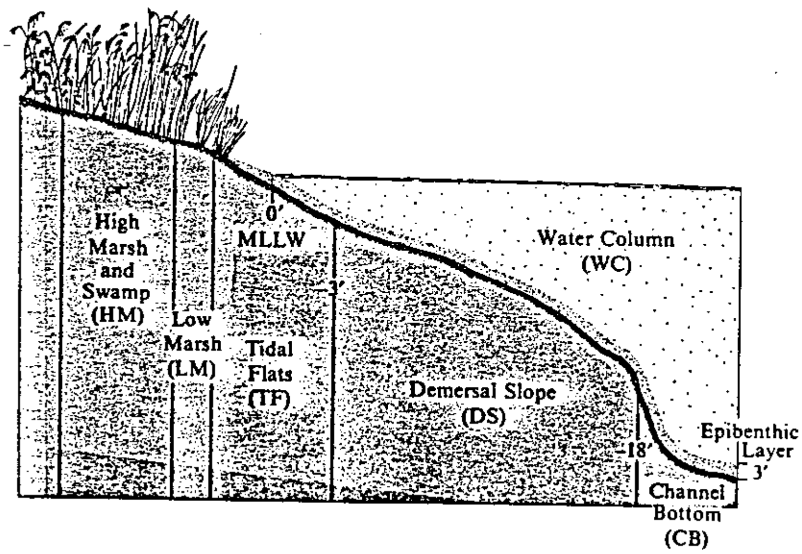


Figure 4. Columbia River Estuary habitat types.

down to three feet above the sediment surface. The three feet of water immediately overlying the bottom, called the epibenthic zone, is excluded from the water column habitat type; it is considered to be part of the habitat type that it overlies. For the purpose of measuring its surface area, the water column is defined as being bounded by the MLLW (zero elevation) contour, covering the channel bottom and demersal slope habitat types and the part of the tidal flats habitat type below MLLW. Because of tidal fluctuation the water column is not actually restricted to the boundary described here.

High Marsh and Swamp

This habitat type is defined as those tidal wetlands having high marsh or swamp vegetation. High marsh vegetation and swamp vegetation are defined in terms of the plant species present. The lower limit of these vegetation types is usually between 6.5 and 8.5 feet above MLLW and the upper limit is usually between 8.0 and 12.0 feet above MLLW. These areas receive only irregular tidal inundation.

Low Marsh

This habitat type is defined as those tidal wetlands having low marsh vegetation. Low marsh vegetation is defined in terms of the plant species present. Elevations of the lower limits of low marshes have seldom been measured in the Columbia River Estuary. Three feet above MLLW is probably a typical elevation of the lower limit, and the range of this limit may be from 2.5 to 5.0 feet above MLLW. The upper limit of low marsh vegetation is usually between 6.5 and 8.5 feet above MLLW. These areas receive regular tidal inundation.

Table 1. Areas of habitat types within each region of the Columbia River Estuary (in hectares). Region 2 includes Baker Bay and Trestle Bay. Regions 3 and 5 include areas that are always in the estuarine mixing zone and areas that are in the estuarine mixing zone only during the low riverflow season. Habitat types are abbreviated as follows: WC = water column, HM = high marsh and swamp, LM = low marsh, TF = tidal flats, DS = demersal slope, CB = channel bottom.

REGION/HABITAT TYPE	WC	HM			LM	TF			DS	CB	
	below MLLW	SWAMP	HIGH MARSH	TOTAL	LOW MARSH	above MLLW	MLLW to -3'	TOTAL	-3' to -18'	below -18'	TOTAL
1. Entrance	(3105)					(98)	(117)	215	567	2420	3203
2. Trestle Bay	((163))	((2))	((58))	(60)	(66)	((110))	((145))	(255)	(19)		(400)
Baker Bay	((1491))	((19))	((21))	(40)	(219)	((1226))	((784))	(2010)	(693)	(14)	(2975)
Total	(1654)	(21)	(79)	100	285	(1336)	(929)	2265	712	14	3375
3. Estuarine Channels											
estu. mixing zone	((5797))	((1))	((1))	(2)	(2)	((28))	((55))	(84)	(1007)	(4735)	(5829)
alternating zones	((1640))	((4))		(4)	(8)	((39))	((27))	(66)	(494)	(1119)	(1691)
Total	(7437)	(5)	(1)	6	10	(67)	(82)	150	1501	5854	7521
4. Youngs Bay	(1277)	(50)	(135)	185	285	(474)	(547)	1020	680	51	2220
5. Mid-Estuary Shoals											
estu. mixing zone	((4537))				(2)	((520))	((567))	(1087)	(3319)	(651)	(5058)
alternating zones	((557))					((24))	((182))	(206)	(326)	(49)	(581)
Total	(5094)				2	(544)	(749)	1293	3645	700	5639
6. Grays Bay	(3512)	(268)	(31)	299	274	(592)	(1386)	1978	1820	305	4678
7. Cathlamet Bay	(6036)	(1757)	(279)	2036	1823	(758)	(1944)	2703	3197	895	10653
8. Fluvial Region	(3203)	(334)	(115)	449	174	(66)	(269)	334	958	1976	3893
TOTAL ESTUARY	(31318)	(2435)	(640)	3075	2853	(3935)	(6023)	9958	13080	12215	41182

Tidal Flats

This habitat type covers the area from three feet below MLLW up to the lower limit of tidal marsh or swamp vegetation. In the few areas where there is no tidal vegetation, the upper limit of this habitat type is mean higher high water (MHHW - about eight feet above MLLW).

Demersal Slope

This habitat type covers the area from 18 feet below MLLW to three feet below MLLW and includes the bottom sediments and the epibenthic zone. It is always submerged, the upper limit coinciding with the lowest possible water level (Extreme Low Tide).

Channel Bottom

The channel bottom habitat type includes the estuary bottom deeper than 18 feet below MLLW plus the associated epibenthic zone.

The surface areas (in hectares) of these regions and habitat types are shown in Table 1. Some of the regions have been divided. For example, the areas of both Trestle Bay and Baker Bay (region 2) are shown, as well as the total area for the region. For the Estuarine Channels and Mid-Estuary Shoals regions (regions 3 and 5), the areas that are included in the estuarine mixing zone only when it expands during the low riverflow season are distinguished from the parts of these regions that are included in the estuarine mixing zone all year.

Some of the habitat types have also been divided. For the high marsh and swamp habitat type, the areas of swamp and high marsh are each shown, as well as the total. For the tidal flats habitat type, the areas with elevations above MLLW are distinguished from those with elevations below MLLW. The area of the water column habitat type is the sum of the areas of channel bottom, demersal slope, and the portion of tidal flats below MLLW.

3. ASSESSING THE EFFECTS OF DEVELOPMENT PROJECTS ON THE COLUMBIA RIVER ESTUARY

3.1 INTRODUCTION

This chapter describes how CREDDP information can provide a background for assessing the effects of development projects on the Columbia River estuarine environment. Some of the purposes for making such assessments are:

1) For planning. Permit applications are required of those desiring to carry out projects that involve modifying the estuary, ranging from building a small pier to dredging large areas. These permit applications involve a specific type of environmental assessment, the impact assessment, which will be discussed in more detail in Chapter 4.

2) As a basis for environmental legislation. Environmental laws and policies may be based on assessment of how development affects the estuary.

3) To form citizen opinion. A citizen who is informed about how environmental assessments are made has many opportunities to judge whether or not an assessment has been done adequately or to make an independent assessment. For example, a citizen may wish to present an opinion to a planning agency regarding a development proposal.

An assessment of the effects of a development project on the estuary may be very general and qualitative, or it may be fairly specific and precise. The level of precision depends primarily on the scientific data available. With extensive data (many sampling stations representing several geographic areas; frequent samples representing all seasons and many years), specific statements can be made regarding the species that would be affected by the activity and the extent of the effects. With sketchy data, only very general effects can be suggested. Characteristics of CREDDP data are described in Section 3.2.

The effects of small-scale projects, which are assumed to be primarily direct, can be described with greater precision than the effects of large-scale activities, which are direct and indirect. The indirect effects of large-scale projects include effects on species that depend on the directly-affected plants and animals for food or habitat. These indirect effects are very difficult to determine, and usually must be described in much more general terms than direct effects. To describe adequately the effects of small-scale projects, however, requires that data be available for the sites under consideration. Large-scale sampling programs (few sampling sites over a large area) would not provide adequate data to evaluate the effects of a small-scale activity.

3.2 CHARACTERISTICS OF CREDDP DATA

CREDDP sampling occurred between September 1979 and September 1981. This is a short sampling period for an estuary because it only reflects

A. Are circulation patterns changed?

B. Is the distribution of salinity changed?
Is the distribution of sediments changed?

C. Are salinity zones or habitat types changed?

D. What are the direct effects on species?

E. What are the indirect effects on species?

Figure 5. General pathway for evaluating the effects of development projects on the Columbia River Estuary. The questions shown here are based on the ecosystem components shown in Figure 2; each component affects the succeeding one. In addition, the distribution of sediments may affect circulation patterns.

limited climatological conditions. (Some estuarine scientists suggest that an estuary should be studied for at least ten years to have a good understanding of its climatological and seasonal cycles). Thus, CREDDP data provide a fair picture of the estuary during a two-year period, but cannot represent its full range of conditions. During the two-year sampling period an unusual event, the eruption of Mt. St. Helens, occurred; conditions in the estuary were not typical for a period after the May 18, 1980, eruption.

Each CREDDP work unit research team chose its own sampling locations and schedules. Each project thus has its own strengths and weaknesses in the quality of data.

The Currents project was designed to provide an understanding of major processes in the main body of the estuary. A continuous monitoring program used moored instruments at the Astoria-Megler Bridge from March to November 1980. In addition, there were two intensive sampling cruises: the first, in June 1980, represented a high riverflow period, while the second, in October 1980, represented a low riverflow period. The National Ocean Service also carried out a study from May to December 1981. Information from these field sampling programs was used in the Simulation project, to model the circulation in the estuary under a range of climatological conditions. The Currents and Simulation projects do not address the peripheral bays (Youngs, Grays, and Baker Bays) and are of too large a scale to address small areas of the estuary or the effects of small-scale activities.

The Sedimentation and Shoaling project sampled bottom sediments in all areas of the estuary during October 1979 and February, June, and October 1980. Bedform configurations were examined in the main channels during five cruises between September 1979 and October 1980. Suspended sediments were sampled in October 1980 at four stations in the main navigation channel: adjacent to the entrance, near Hammond, near Tongue Point, and upriver of the estuary. These stations were sampled every ½ to 1 hour for 16 to 38 hours, to provide an understanding of the tidal movements of suspended sediments.

Biological sampling information is shown in Appendix F. Investigators generally chose sampling sites to represent a range of the habitats of the species involved, with the exception of Zooplankton and Larval Fish, which employed samples in the main navigation channel only.

3.3 FRAMEWORK FOR ASSESSING EFFECTS OF HUMAN ACTIVITIES ON THE ESTUARY, AND USE OF CREDDP MATERIALS

CREDDP researchers have suggested that the pathway shown in Figure 5 be used when evaluating the effects of alterations to the estuary. This figure is derived from the same components and relationships as those in Figure 2, but poses questions about those components and states the order in which the questions should be addressed.

Table 2 shows the CREDDP publications that can provide background information when carrying out the steps in an environmental assessment shown in Figure 5, and Table 3 provides the bibliographic references for

Table 2. CREDDP publications related to environmental assessment framework. For each step, the most applicable materials are listed first.

Step (see Figure 5)	Reference (see Table 3)	Sections (Atlas), Chapters (Dynamics; Index) or work unit reports
A	Atlas	"Circulation and Salinity"*
	Dynamics	"Circulatory Processes"*
		"Historical Changes in Columbia River Estuarine Physical Processes"*
	Work Unit/Index	Currents*, Simulation*
B	Atlas	"Circulation and Salinity"*
		"Sediments"
	Dynamics	"Circulatory Processes"*
		"Sedimentary Geology"
		"Historical Changes in Columbia River Estuarine Physical Processes"*
	Work Unit/Index	Currents,* Simulation*, Sedimentation and Shoaling
C	Atlas	"Regions and Habitat Types: A Synthesis" (only discussion of habitat types is applicable to small-scale activities)
D	Appendix C**	
	Atlas	"Phytoplankton"
		"Benthic Primary Producers"
		"Tidal Marshes and Swamps"
		"Zooplankton"
		"Benthic Infauna"
		"Epibenthic Organisms"
	Dynamics	"Ecosystem Analyses by Regions and Habitat Types"
	Work Unit/Index	Water Column Primary Production
		Benthic Primary Production
		Emergent Plant Primary Production
		Zooplankton and Larval Fish
		Benthic Infauna
		Epibenthic Organisms
E	Appendix C**	
	Atlas	"Zooplankton"*
		"Fish"*
		"Birds"*
		"Marine Mammals"*
		"Aquatic and Terrestrial Mammals"*
	Dynamics	"Ecosystem Analyses By Regions and Habitat Types"*
	Work Unit/Index	Zooplankton and Larval Fish*
		Fish*
		Avifauna*
		Marine Mammals*
		Wildlife*

*These materials are not appropriate for assessing the effects of small-scale activities, because the data are insufficient. No information on circulation or salinity is at a sufficiently small scale for such problems (Steps A and B). Information is insufficient to address the effects of small-scale activities on organisms that are primarily indirectly affected by the activity (Step E).

**In this document

Table 3. Bibliographic references for the CREDDP publications referred to in Table 2.

Atlas:
Fox, D.S.; Bell, S.; Nehlsen, W.; Damron, J. 1984. The Columbia River Estuary: Atlas of physical and biological characteristics. Astoria, OR: Columbia River Estuary Data Development Program.

Dynamics:
Simenstad, C.A.; Jay, D.; McIntire, C.D.; Nehlsen, W.; Sherwood, C.R.; Small, L.F. 1984. The dynamics of the Columbia River estuarine ecosystem, volumes I and II. Astoria, OR: Columbia River Estuary Data Development Program.

Index:
Mercier, H. 1984. Index to CREDDP data. Astoria, OR: Columbia River Esutary Data Development Program.

Work unit reports:

Currents:
Jay, D. 1984. Circulatory processes in the Columbia River Estuary. Astoria, OR: Columbia River Estuary Data Development Program.

Simulation:
Hamilton, P. 1984. Hydrodynamic modeling of the Columbia River Estuary. Astoria, OR: Columbia River Estuary Data Development Program.

Sedimentation and Shoaling:
Sherwood, C.R.; Creager, J.S.; Roy, E.H.; Gelfenbaum, G.; Dempsey, T. 1984. Sedimentary processes and environments in the Columbia River Estuary. Astoria, OR: Columbia River Estuary Data Development Program.

Water Column Primary Production:
Frey, B.E.; Small, L.F.; Lara-Lara, R. 1984. Water column primary production in the Columbia River Estuary. Astoria, OR: Columbia River Estuary Data Development Program.

Benthic Primary Production:
McIntire, C.D.; Amspoker, M.C. 1984. Benthic primary production in the Columbia River Estuary. Astoria, OR: Columbia River Estuary Data Development Program.

Emergent Plant Primary Production:
Macdonald, K.B.; Winfield, T.P. 1984. Tidal marsh plant production in the Columbia River Estuary. Astoria, OR: Columbia River Estuary Data Development Program.

Zooplankton and Larval Fish:
Jones, K.K.; Bottom, D. 1984. Zooplankton and larval fishes of the Columbia River Estuary. Astoria, OR: Columbia River Estuary Data Development Program.

Benthic Infauna:
Holton, R.L.; Higley, D.L.; Brzezinski, M.A.; Jones, K.K.; Wilson, S.L. 1984. Benthic infauna of the Columbia River Estuary. Astoria, OR: Columbia River Estuary Data Development Program.

Epibenthic Organisms:
Simenstad, C.A. 1984. Epibenthic organisms of the Columbia River Estuary. Astoria, OR: Columbia River Estuary Data Development Program.

Fish:
Bottom, D.; Jones, K.K.; Herring, M.L. 1984. Fishes of the Columbia River Estuary. Astoria, OR: Columbia River Estuary Data Development Program.

Avifauna:
Hazel, C.R.; Ives, J.H.; Miller, K.J.; Edwards, D.K.; Tinling, J.S.; Dorsey, G.L.; Green, M.; Crawford, J.A. 1984. Avifauna of the Columbia River Estuary. Astoria, OR: Columbia River Estuary Data Development Program.

Marine Mammals:
Jeffries, S.J.; Treacy, S.D.; Geiger, A.C. 1984. Marine mammals of the Columbia River Estuary. Astoria, OR: Columbia River Estuary Data Development Program.

Wildlife (Aquatic and Terrestrial Mammals):
Dunn, J.; Hockman, G.; Howerton, J.; Tabor, J.; Merker, C.; Fenton, J.C. 1984. Key mammals of the Columbia River Estuary. Astoria, OR: Columbia River Estuary Data Development Program.

the publications referred to in Table 2. The following paragraphs describe the questions in Figure 5 in more detail and how the CREDDP materials listed in Table 2 can be applied to answering them.

A. Are circulation patterns changed?

Circulation in the estuary is dominated by two major factors: flow of fresh water into the estuary at its head, and entry of salt water at the mouth of the estuary. The amount of fresh water entering the estuary can be altered by increasing or decreasing the amount of water passing through the dams or by changes in the seasonal characteristics of riverflow. Salt water enters the estuary with the tides. The volume of salt water that enters is affected by the bathymetry of the entrance to the estuary. Large-scale changes, such as altering riverflow or bathymetry of the entrance, affect the distribution of salinity and sediments in the estuary. CREDDP materials related to these problems are listed in Table 2 (Step A); examples of their use are given in Chapter 5.

Structures that extend into the estuary, such as jetties and groins, may have large effects on circulation. The effects of these structures are not discussed in this Guide, but are addressed in the Simulation work unit report. Small-scale changes in the bathymetry of the estuary, such as those created by diking, filling, dredging, dredge spoil disposal, and bulkhead construction, affect the circulation of local areas. CREDDP information on circulation is at too large a scale to be applied to such small-scale activities.

B. Is the distribution of salinity or sediments changed?

Large-scale changes in circulation change the distribution of salinity in the estuary. For example, increases in riverflow increase the volume of fresh water in the estuary and increase the area of the estuary that has fluvial characteristics. On the other hand, increasing the amount of seawater entering the estuary causes salt water to intrude farther into the estuary. Examples of evaluating these large-scale changes using materials listed in Table 2 (Step B) are given in Chapter 5. CREDDP materials are not applicable to the effects of small-scale changes.

Changes in circulation affect the distribution of sediments, because altered current speeds cause sediments to be deposited in different patterns. These changes can result in creation of shoals in areas having slowed currents, changes in the type and texture of bottom sediments, and deposition of sediments adjacent to groins or breakwaters. Increases in the extent of saltwater intrusion or in the volume of freshwater flow cause the location of the turbidity maximum to shift up or downriver. These large-scale changes are discussed in Chapter 5.

The distribution of sediments may also be changed as a direct result of development projects, without being caused by changes in circulation. For example, filling, diking, dredging, and disposal of dredge spoils cause changes in sediment distribution. The present distribution of sediments is described in materials listed in Table 2 (Step B); from these materials the characteristics of an area to be altered can be described.

C. Are salinity zones or habitat types changed?

Large-scale changes in the salinity distribution in the estuary would cause the salinity zones to change. In general, increased freshwater flow would increase the area of the tidal-fluvial zone while an increase in the extent of saltwater intrusion would increase the area of the plume and ocean zone. Examples of such changes are described in Chapter 5.

Changes in sediment distribution would result in changes in habitat types. For example, through shoaling or spoil disposal an area may be made more shallow, becoming part of a shallower habitat type. Filling an area would remove it from the estuary entirely. Dredging an area may cause it to become part of a deeper habitat type; if continued maintenance dredging were required the area would be effectively destroyed.

To evaluate how a development project would change the habitat types at the proposed site, it is first necessary to define the present habitat types of the site. The map of estuarine habitat types included in the CREDDP atlas (Plate 28; scale 1:50,000) and the 1:12,000 maps produced by CREDDP should help in determining the habitat types that will be affected by the project.

It will then be necessary to determine how the existing habitat types would be affected by the proposed project. If a site were diked, then it would be removed from the estuary completely. A site may change from one habitat type to another by increases or decreases in elevation. An area of tidal shoals and flats to which enough dredge spoil were added to increase the elevation by six feet would then potentially become part of the low marsh habitat type. Decreases in elevation caused by dredging would have the opposite effect.

Worksheets referred to in this chapter are contained in Appendix D. Worksheet 1 may be used as a guide for determining how the areas of habitat types at the site would be affected by the project. Worksheet 1 is designed to apply to a single region; losses and gains in areas of the habitat types within that region are tabulated. By comparing the area lost or gained with the area in the region, it is possible to determine what percentage of the habitat type in the region is lost or gained by the proposed activity. Examples of this approach are shown in Chapter 5, Section 5.1.

D. What are the direct effects on species?

When the habitat type or salinity zone of a site changes, the organisms that are associated with the site also change. If an area of the estuary were completely filled, it would no longer support estuarine species. If its elevation were changed, it would support a new community of estuarine species characteristic of its new habitat type.

An increase in the area of saltwater intrusion would increase the area that supports marine species, while increasing the fluvial area would increase the area that is occupied by freshwater species.

Some species are more likely to be directly affected by projects, because they have a strong dependence on a specific site. Other species are more likely to be indirectly affected by a project through loss of food supply or habitat. The distinction between directly-affected species and indirectly-affected ones is not rigorous (many species may receive both kinds of effects), but it is convenient for the purposes of this Guide to make this assumption.

Directly-affected biological groups include benthic primary producers, marsh plants, and benthic infauna, all of which are attached to the site itself. Epibenthic organisms (including the epibenthic zooplankton) are also considered to be directly affected, because they are dependent on the estuary bottom. Water column primary producers are considered to be directly affected because they depend on the amount of water surface area; a decrease in the area of water column habitat type would decrease the physical habitat available to them. Zooplankton species (of the water column) are considered to be directly affected by projects that involve changes in salinity zones. Projects that cause habitat type changes are considered to affect the zooplankton only indirectly, because these organisms are assumed to be more affected by food supply than by availability of space.

Although it is assumed that fish, birds and mammals would not be directly affected by alterations to the estuary, destruction of nests or den sites would affect these groups directly.

When the area of a habitat type decreases at a site, it is possible to determine the species that would be directly affected and the standing crop and productivity of biological groups. Worksheets 2-4 provide guidance in carrying out this approach. The characteristics of regions and habitat types are tabulated in Appendix C. These tables include the major species associated with the habitat type (Appendix C, Table 1). The standing crop (expressed as weight of carbon per square meter) and productivity (expressed as weight of carbon produced per square meter per year) of major groups are listed in Appendix C, Table 2. (Carbon is used as a standard measure of plant and animal matter because it is the basic chemical component of biological material.)

In Worksheet 2, the changes in biomass (total weight of a group of organisms in a specified location) and productivity are determined for the site to be affected. A separate copy of Worksheet 2 is needed for each habitat type losing or gaining area at the site. Standing crop and productivity values per square meter can be obtained from Appendix C, Table 2. These values multiplied by the area of the habitat type lost or gained provide the changes in biomass and productivity. In Worksheets 3a and 3b, the changes in biomass (Worksheet 3a) and productivity (Worksheet 3b) for all habitat types are summed to provide the increase or decrease for the site. These values are then compared with the totals for the region (obtained from Appendix C, Table 2), to determine the percent gain or loss. If only one habitat type in the region is involved, Worksheets 2, 3a, and 3b are not necessary; the change in biomass and productivity will be the same percentage determined in Worksheet 1, Column E, for all biological groups found in the habitat type.

In Worksheet 4, the major species depending directly on the habitat type, obtained from Appendix C, Table 1, are listed. Like Worksheet 2, a separate copy of Worksheet 4 is needed for each habitat type losing or gaining area at the site. Section 5.1 shows examples of using Worksheet 4. The other CREDDP materials listed in Table 2 (Step D) provide more detailed information on the characteristics of locations in the estuary. The Atlas displays information on the distribution, standing crop, and productivity of individual species for generalized areas. Work unit reports supply such data for specific sampling locations.

E. What are the indirect effects on species?

Worksheets 2 through 4 include only biological groups that would be directly affected by changes in habitat types. (Zooplankton species are included because they would be directly affected by salinity changes.) Other groups are more likely to be affected by loss of species on which they depend for food or habitat. That is, direct effects on species described above may result in indirect effects on other species. Loss of plants or animals may affect other species because the eliminated organisms provide dwelling places, protection, or attraction of prey (habitat loss). Also, loss of species directly affected may indirectly affect the species that prey on them (food loss).

The major groups receiving indirect effects are the zooplankton (indirectly affected by loss of the water column habitat type), fish, birds, marine mammals, and aquatic and terrestrial mammals. Species that may be indirectly affected can be determined by listing in Worksheet 5 the species in the habitat type from Appendix C, Table 1 (one worksheet for each habitat type involved).

To confirm the information listed in Worksheet 5, the Atlas can be consulted to determine whether a species is normally found in the specific area of concern. Work unit reports provide more detailed information on the habitat requirements and distributions of the species. Section 5.1 shows examples of using Worksheet 5.

The pathway to be followed in an environmental assessment depends on the type of project being considered. For example, in considering the effects of freshwater flow alteration on the estuary, the scientists who carried out the assessment described in Chapter 5 followed the pathway A-B-C-D-E. In considering the effects of deepening the entrance channel, it was necessary to follow the pathway B-A-B-C-D-E. For most small scale projects it would be adequate to follow the pathway B-C-D.

3.4 INTERPRETATION

In interpreting an environmental assessment, the following questions should be addressed:

1a) Does the proposed project cause a decrease in area of a habitat type that is significant when compared to the total area of that habitat type in the region?

1b) Would the decrease in area of habitat type result in a significant decrease in the biomass or productivity of any biological group, considered as a percentage of regional values?

1c) Does the decreased area of habitat type represent a significant portion of the area of the habitat type occupied by a species in the region?

Question 1a relates to Worksheet 1. Question 1b may be answered from Worksheet 1 if only one habitat type is involved in the region; otherwise, Worksheets 2 (two or more), 3a and 3b are needed. Question 1c relates to Worksheets 1, 4 and 5. Worksheet 1 provides the percentage of area of habitat type lost, and Worksheets 4 and 5 provide the species affected.

Worksheets 1 through 3 yield the percentage loss or change in habitat types, biomass, and productivity for the region being considered. It is difficult to interpret such percentages using scientific criteria alone. Scientists are not able to define what percentage change in these variables can be sustained by the estuary without causing a major change in its nature or function. It is thus the province of planning agencies to determine how much change is acceptable based on their own criteria.

Choosing the appropriate unit against which to develop percentage changes in very important; the appropriate unit depends on the location and the kind of project. In developing percentages, this Guide assumes that the region is the basic functional unit of the estuary. In some instances smaller units than regions might be appropriate; larger units would rarely be appropriate. However, care should be taken in comparing percentage habitat type losses for different regions, because a loss in a small region will appear to be much more significant than the same size loss in a large region, although the effects may be similar.

A major issue in evaluating the significance of the percentage of change is that small changes eventually add up to large cumulative effects. It is necessary to evaluate each small change in the context of the many previous small changes and the anticipated future ones.

If a decision is to be made that a given percentage decrease in the area of the estuary or any of its habitat types is the maximum that will be accepted, an appropriate baseline should be chosen. A 25% decrease in present area of tidal marsh is very different from a 25% decrease from the estuary's original marshland, since the area of marshland has already been reduced by about 50% since 1870.

Worksheets 4 and 5 yield the species affected by the project and, in conjunction with Worksheet 1, can suggest the percentage loss of habitat type area for these species. This approach is most reliably applied to Worksheet 4, because species listed there are most likely to be directly affected by the project. Worksheet 5 should be considered also, but since the species listed there would be affected by the project indirectly, the percentage loss of habitat type area may be less reliable than for species listed in Worksheet 4.

2) Can it be shown that loss of an area would cause loss of prey or habitat to a species whose abundance would be decreased as a result?

This question relates to the species listed in Worksheet 5. These species are found in the habitat type to be affected by the project, and are presumed to depend on the area for food or habitat.

If the area of a habitat type is decreased, a decline in the abundance of species that prey upon organisms associated with the habitat type might be expected. However, such a relationship is difficult to show because there is no information indicating that the Columbia River Estuary cannot produce enough food for all of the animals that depend on it. As discussed in the Atlas ("Introduction to Primary Production"), the majority of organic material in the estuary is provided as detritus from upriver. The amount of phytoplankton production within the estuary does not affect the estuary's food supply very much. There may be some species in the estuary that would be more abundant if more food were available to them, but there are no data to show this. Most species are probably limited in their abundance by other factors, including physical conditions in the estuary, and conditions upriver or in the ocean. As a result, it is not possible to state that any species in the estuary would decline in abundance because of loss of prey.

Loss of habitat could have major effects on the species listed in Worksheet 5, but this is difficult to substantiate, as discussed with regard to question 1c. The approach suggested to answer question 1c, in which Worksheets 1 and 5 are used to suggest the percentage loss of a habitat type for those species occupying that habitat type, provides a starting point. However, to estimate whether the abundance of any given species would be affected by a given percentage decrease in a habitat type requires further evaluation. The approach suggested for question 1c implies that the species under consideration is widely distributed throughout the habitat type in the region. In reality, the species may occupy a limited area in the habitat type, such as a single nest or denning site. If a project were to destroy the nest or denning site, this would have a substantial effect on the species population, which would be seriously underestimated by assuming that the entire habitat type is occupied by the species. For this reason, the species' actual habitat should be defined as carefully as possible, using information from the Atlas and work unit reports. Once the species' distribution is known in as much detail as possible, the potential effects of a project on its habitat, and whether the loss of habitat might affect its abundance, can be considered.

3) Is there loss of an area that is associated with an endangered or threatened species?

For such species, the same considerations regarding loss of habitat must be made as were discussed for question 2. Although this Guide has generally assumed that small-scale projects would not significantly affect fish, birds, or mammals, effects of small-scale projects on threatened or endangered species could be more pronounced and must be considered. Specific guidance on this is given in Chapter 4.

4. IMPACT ASSESSMENTS FOR SMALL-SCALE PROJECTS

4.1 INTRODUCTION

Individuals wishing to carry out development projects involving modification of the estuary, surrounding wetlands, or estuarine shoreline must submit permit applications to their local governments. These applications may include presentation, in a specific format, of the considerations which come into play in environmental assessments discussed in earlier chapters.* In local Oregon jurisdictions (Clatsop County and the Cities of Astoria, Warrenton, and Hammond), the format is called an "impact assessment"; in local Washington jurisdictions (Pacific and Wahkiakum Counties and the cities of Chinook, Cathlamet, and Ilwaco) the assessment is submitted in the form of an "environmental checklist."

This chapter is intended to help applicants make use of CREDDP data and products in their permit applications. Since completion of the necessary forms relies on some understanding and knowledge of the resources to be affected, CREDDP information will be of considerable help. Specific references to available CREDDP products will be made throughout this chapter as they become relevant in discussion of the particular parts of the impact assessment forms, but a general understanding of the processes and functions of the estuary as a whole is an important first step in the application process. The general discussions presented in Chapters 2 and 3 of this Guide will help the applicant make sense of the information requested in the impact assessment forms. Chapters 1 and 3 provide a helpful overview of CREDDP products, and Table 2 in Chapter 3 lists sections and chapters of these publications which apply to particular questions about the estuary and how it is affected by development projects.

Though the general considerations involved are quite similar, the format for impact assessments differs between Oregon and Washington. These will, therefore, be discussed separately.

4.2 OREGON

The state of Oregon's Department of Land Conservation and Development (DLCD) has published 19 statewide planning goals and guidelines which all Oregon counties and cities are required to enforce.

*Other state and federal permits may also be required depending on the type, location, and site of the development uses and activities proposed. Information and guidance concerning these permit requirements may be obtained from local government planning staff. Application for permits other than the local development permit does not require the submission of an environmental assessment, though the Corps of Engineers itself prepares an environmental assessment in response to all permits issued by the Corps. Unfortunately, these Corps assessments are generally completed as a final step in the Corps permit process and are not available for use by applicants seeking local permits. Previous environmental assessments prepared by the Corps for similar projects in adjacent or similar locations, however, may be useful to applicants.

Goal 16, the estuarine resources goal, requires that each local government formulate a plan to protect its estuarine resources by balancing activities and uses in various areas of the estuary with what is termed the "resource capability" of those areas. Local jurisdictions on the Columbia River Estuary have divided the land within their boundaries bordering the estuary into aquatic management zones, each of which is managed for a different purpose. Thus different development activities and uses are allowed within each zone, with varying degrees of environmental assessment required in the permit application.

The first step in any permit application is a visit to the appropriate local planning office (applicants within city limits go to the city planning department, those outside of city limits go to the county planning department) to determine the zone in which the proposed project is located and the procedures which will be required in application for a permit. If the county or city comprehensive plan and zoning ordinance require that a resource capability determination be made before the proposed activity can take place, the applicant must submit an impact assessment.

The exact format for this assessment differs marginally between local jurisdictions, but the eleven areas of information requested in each are the same (see Appendix A). Of these, three are applicable to estuarine resources. These three will be discussed here, as they are the parts of the procedure to which CREDDP products apply. Other areas of information requested concern the proposal itself and some of its social effects. These can be filled in by the applicant, for the most part, without the help of outside information, though some assistance from the local planning department may be necessary. One item (2) is not applicable in this discussion of estuarine development permits, as it concerns shoreline resources. The final two items may be left by the permit applicant to be addressed by local planning staffs, though it may be worthwhile for the applicant to attempt to address these issues if possible.

Aquatic life forms and habitat (Item 1 in Appendix A, attached sample form). This is one of the most important areas of information requested and probably the one in which CREDDP data will be of most use. It requires, first, a listing and description of the animal and plant species found in the development and adjacent areas, and their use of these areas (as for breeding, feeding, migration, etc.), including information on seasonal variation in abundance, numbers, and use. Also requested are a description of the type and extent of alteration proposed, impacted species (including information on life cycles and stages affected), and percent of total habitat type to be altered.

The habitat type map (Plate 28) and text in Chapter 7 of the Atlas would be the best place to start for a general characterization of the area of proposed development. More detailed maps and text (Chapters 3 through 6) in the Atlas regarding particular life forms in the estuary will be useful. (See Table 2 for a complete list of Atlas sections.) For more complete information about vegetation, invertebrates, fish, birds, and mammals, the applicant may want to read some of the individual work unit reports, which are listed in Table 3.

After existing life forms and conditions are described, the applicant is asked to describe the proposal, including detailed information about the extent of alteration. This should be thorough and detailed, to show reviewers that the project has been carefully planned and designed.

The final part of this item concerns the effects of the proposed project on the life forms and habitat previously described. It asks for a list of impacted species, including information on threatened and endangered species, and for percent of total available habitat to be altered. Some species will be directly impacted, such as the bottom dwelling community of an area to be dredged or filled. These will be easy to list, as the applicant will already have done so in the first part of the section. Other life forms may be indirectly affected, such as those whose feeding habits change in response to availability of prey. Chapter 3 includes a brief discussion of some of these indirect effects. It is not expected that all the indirect impacts of the proposed development can be predicted, but an awareness of some of the less obvious impacts on the estuary and its life forms will aid in planning the project to minimize them. A consideration of the life cycles of the area's inhabitants, for example, is important in the timing of development activity. Information about particular life forms' life cycles can be found in the CREDDP work unit reports (listed in Table 3).

There are three endangered and one threatened species which spend at least a portion of their lives near the estuary: endangered are the Columbian white-tailed deer, the brown pelican, and the peregrine falcon; the northern bald eagle is threatened. Though it is unlikely that a small-scale aquatic development would directly affect any of these species, destruction of riparian habitat, particularly in the eastern part of the estuary, might adversely affect resources important to the white-tailed deer and the bald eagle.

Surface areas of habitat types in the estuary can be found in Table 1; Section 3.3(c) describes how to determine the percentage of habitat type to be altered by the proposed development.

Water quality (Item 3 in attached sample form). This item concerns expected changes in several aspects of water quality, including sedimentation, turbidity, dissolved oxygen concentration, biological and chemical oxygen demand, contaminated sediments, salinity, and water temperature. Of these, CREDDP information includes data only on salinity and sedimentation (Chapter 2 and Plates 3 through 9, Atlas). What is important here, however, is information on expected changes in water quality conditions. The applicant is not expected to quantify these expected changes, but to cite those changes that are expected and to present evidence of careful planning of the project for their minimization.

The construction and operation of particular types of development may adversely affect water quality. During contruction, sediments leached from disturbed slopes and shorelines or released during in-water construction or dredging activities may enter the water column, resulting in physical changes (discussed under the section on hydraulic characteristics, below) and increasing the turbidity of estuarine waters. Increased amounts of suspended sediments, if contaminated or high in organic materials, may result in rapid and prolonged decreases in dissolved oxygen, with associated adverse effects on estuarine life forms. (See also Chapter 2 of this Guide for a general discussion of physical characteristics of the estuary and Chapter 3 for effects of development on these characteristics.)

Important factors to evaluate regarding the operation of development uses located in or adjacent to estuarine areas include intake of water and discharge of waste streams. Use of large amounts of water, for manufacturing or other uses, and discharge of heated water could alter important estuarine resource functions. Waste effluents from development uses have the potential of depleting dissolved oxygen levels.

Hydraulic characteristics (Item 4 in attached sample form). These fall under the heading of physical characteristics of the estuary, and as such are discussed, along with some water quality considerations, in Chapters 2 and 3 of this Guide and Chapter 2 of the Atlas.

Circulation in the estuary is affected by anything that interferes with existing currents and water movement, such as rubble break-waters, groins, pile dikes, piers and wharves, and any other in-water structure. It is also affected by any change in the bathymetry of the estuary through dredging, filling, and dredged material disposal. Effects on circulation of small changes in bathymetry, however, will probably be minor and difficult to predict.

Shoaling patterns are directly affected by circulation patterns; shoaling occurs when moving water carrying suspended sediments is slowed down or stopped, can no longer carry the same quantity of sediment, and deposits some or all of it on the estuary floor. Chapter 2 of the Atlas includes useful text and graphics on currents and sedimentation, as well as high resolution maps of the estuary's shoals and bathymetry (Plate 2).

Potential erosion or accretion is also dependent on circulation patterns. Accretion occurs for the same reasons as shoaling, but sediment is deposited on a shoreline rather than on the bottom of the estuary. Erosion is the opposite: an increase in the force of water movement along a portion of the shoreline will cause sediments to be scoured away, picked up by the moving water, and ultimately deposited elsewhere.

Flushing capacity is the rate at which the water in an inlet replaces itself. Circulation is an important factor governing flushing capacity. Anything that alters circulation may reduce water exchange, with the potential result that decreases in dissolved oxygen supply or accumulation of contaminants from upland sources may decrease the area's ability to support biological resources.

Federal floodplain maps are available at any local planning office.

The floodplain will change as the estuary's bathymetry is altered (by either natural means or human intervention), but these changes will probably be negligible in the case of small-scale changes caused by individual dredging and filling projects.

In providing information for this item, the applicant should present a detailed account of the changes in bathymetry and/or obstruction to estuarine circulation that the proposal will entail. It is important to determine whether proposed structures and the activities necessary to place them will result in persistent disruption of existing water circulation and exchange.

4.3 WASHINGTON

In Washington, the governing environmental legislation for aquatic and shoreland areas is the State Environmental Policy Act (SEPA), which is administered by the State Department of Ecology (DOE), and the Shoreline Management Act (SMA). Under these acts, local Washington governments require that all development proposals must be accompanied by submission of an "Environmental Checklist," in addition to the required local development permit(s) and Substantial Development Permit (SDP) required for any activity proposed in the state's aquatic or shoreland areas.

The first step in the permit application process is a visit to the appropriate local planning office to determine what steps must be taken. In most cases, an environmental checklist will be required. It is a standard form used by all state and local agencies in the state of Washington, and some of the questions do not apply to estuarine development proposals.

This checklist, once submitted, is evaluated by the "lead agency" to determine whether further information in the form of an Environmental Impact Statement (EIS) will be required. In almost all instances of small-scale development, the lead agency is the city or county planning department, and the EIS will not be required, particularly when the environmental checklist is well prepared. If, however, the local jurisdiction decides that additional expertise is necessary for judging a particular project, it may request that a state resource agency, such as the Department of Fisheries or Department of Ecology, assume the position of lead agency.

The decision as to whether an EIS is required is called the "threshold determination" and it is based largely on the information presented in the checklist, from which reviewers make an assessment of the significance of expected environmental impacts of the project. This determination is officially expressed in a "declaration of significance/nonsignificance."

The environmental checklist has recently been greatly simplified. It is divided into two parts. The first, "Background," is for information regarding the proposal itself. The second, "Environmental Elements," is the portion dealing with potential environmental and social impacts of the proposed development; a sample of this portion of the checklist is attached (Appendix B). It is composed of a list of seventeen elements to be considered in relation to the proposal. Of these, only portions of four of them - those termed Earth, Water, Plants, and Animals - require information about the physical and biological resources of the site. The remaining elements seek details about the proposal itself and some information relating to current land and shoreline uses and plan designations, which may be obtained at the local planning office.

The type of information requested in those elements concerning the physical and biological resources of the site is very simple. The applicant is not asked to assess or predict, even qualitatively, any changes that will result from the proposal, with the exception of a listing of species to be directly removed or destroyed. Generally, the applicant provides information about all aspects of the proposal which may affect the environment, but is not asked to interpret it; this is left to reviewers of the proposal.

The elements in the checklist requiring information about the site's resources, which are the elements in which CREDDP data will be of use, are discussed below.

Earth (Element B.1. in the Checklist). The first three parts of this element request a physical description of the site, its slope, and types of soil found there. Chapter 2, "Physical Characteristics," of the Atlas will probably be of most help; Plates 6 through 9 are sediment maps, and Plate 2 is a bathymetry map which will help in determing the slope of the site. Local planning departments have maps of soil types. Chapter 3 of this guide discusses sedimentation patterns.

Water (Element B.3. in the Checklist). The only part of this element requiring information about the estuary is that which asks whether the proposal lies within a 100-year floodplain. This information can be found on federal floodplain maps available at the local planning office.

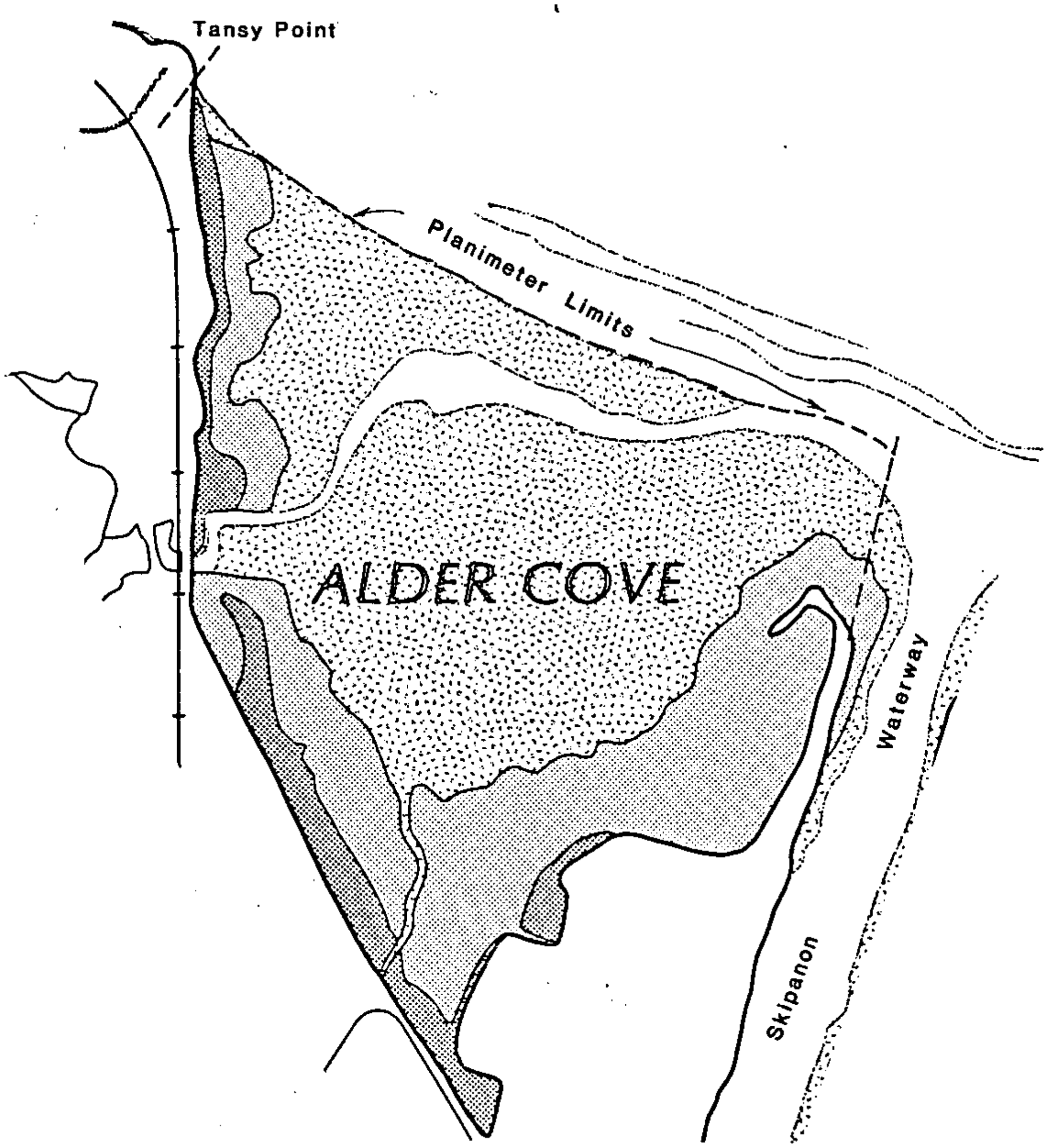
Plants and Animals (Elements B.4. and B.5. in the Checklist). In each of these elements, the applicant is given a list of kinds of plants or animals and asked to circle those present at the proposal site. Each list also has a space for species other than those listed which the applicant is to fill in. Section 3.3 (D and E) and Appendix C (Table 1) of this Guide describe how to obtain this information.

Both the plant and animal elements request information about threatened and endangered species at or near the site. A list of threatened and endangered species which spend at least a portion of their lives at or near the estuary is included in Section 4.2.

4.4 CONCLUSION

With increasing levels of development activity on and in the estuary, each new development proposal - no matter how seemingly insignificant - must be examined closely for its additional potential burden on the estuary's resources. The impact assessment procedure for smaller-scale development projects is relatively straightforward because impacts are usually assumed to be only on those species and properties of the estuary which are directly affected. This is an overly simplified assumption, because all alterations of the estuary, however small, have some secondary effects, though these are difficult to deal with on a small scale. There is also, ultimately, the question of the cumulative impact of many small alterations, but this issue can not be dealt with by the individual permit applicant. It is, however, an issue that local planners and state resource agencies must face, and one of the reasons for the permit process.

Therefore, considerable work must be done to submit a permit application and receive a permit for development on the estuary. However, careful consideration of the effects of a proposed project on the estuary and evidence of this consideration in the submitted impact assessment can do much to speed and facilitate, insofar as possible, acquisition of the necessary permits. CREDDP products are valuable resources to permit applicants, enabling them to plan proposed developments carefully for minimization of impacts on estuarine life and processes, and to present evidence of this planning in the submitted impact assessment.



ELEVATION RANGE		HECTARES
-3 to 0	Tidal Flats	5.50
0 to 3'	Tidal Flats	57.34
Low Marsh		30.05
High Marsh		8.95
Total Area		101.84

Figure 6. Areas of habitat types in Alder Cove.

5. ASSESSING SOME EFFECTS OF THREE EXAMPLE LARGE-SCALE PROJECTS

The purpose of this chapter is to provide examples of how a scientist might use CREDDP information to evaluate effects of three hypothetical large-scale projects: a major fill, an increase in the depth of the main entrance channel, and a decrease in freshwater flow from the Columbia River into the estuary. These projects were chosen because they represent a range of ecological effects of interest to the Columbia River Estuary community. The assessments in this chapter were performed by the CREDDP researchers who served as technical consultants for this document.

5.1 A MAJOR FILL

In this hypothetical project, Alder Cove, adjacent to Youngs Bay, would be filled. Alder Cove is in the estuarine mixing salinity zone, and in the Youngs Bay region (Figure 3). The habitat types that comprise Alder Cove and their areas are shown in Figure 6.

The major effect of such a fill would be a decrease in area of estuarine habitat types. Some effects on circulation would also result, but evaluating these would require more detailed modeling than was carried out by CREDDP. (CREDDP investigators suggest that such a fill would probably cause a slight weakening of currents in the main channel adjacent to the fill and downriver from it.) In evaluating this hypothetical project, the pathway (Figure 5) B-C-D-E will be followed.

B. Is the distribution of salinity or sediments changed?

The distribution of sediments is changed, and area is removed from the estuary because it is no longer subject to tidal influence.

C. Are salinity zones or habitat types changed?

Because the filled site would no longer be part of the estuary, areas of estuarine habitat types would be decreased. It is possible to estimate the extent of decrease using the procedure outlined in Section 3.3 which results in Appendix E, Table 1.

D. What are the direct effects on species?

Species directly associated with the area would be eliminated from it. Appendix C can be used to provide the information shown in Appendix E, Tables 2 through 4, as described in Section 3.3.

E. What are the indirect effects on species?

The species found in the affected habitat types of the Youngs Bay region, obtained from Appendix C, Table 1, are listed in Appendix E, Tables 5a through 5d. For more detailed information on species distributions related to Alder Cove, the Atlas was consulted. The following information was obtained.

The CREDDP Avifauna investigators did not sample in Alder Cove, but mallards, western grebes, hybrid gulls, peeps, and great blue herons were found in Youngs Bay adjacent to Alder Cove, and might be expected to inhabit Alder Cove.

The nearest marine mammal haulout sites are harbor seal sites at Desdemona Sands. There were no incidental sitings of marine mammals in the area of Alder Cove. These animals probably would not be affected by loss of habitat for themselves, but could be affected by loss of habitat for fish species upon which they prey. The fish species occurring most abundantly in Alder Cove are starry flounder and shiner perch; other species found there are American shad, Pacific herring, coho salmon, Chinook salmon, and Pacific staghorn sculpin. The terrestrial mammals most likely to be affected by loss of Alder Cove habitat are muskrat and nutria, which are abundant in Youngs Bay and inhabit high and low marsh areas.

5.2 DEEPENING THE ENTRANCE CHANNEL

The main navigation channel is presently maintained at a depth of 48 feet at the entrance, and at 40 feet from the entrance to Portland. In the project described here, the channel would be deepened to 67 feet to River Mile 5 (RM-5) (adjacent to Clatsop Spit), and to 52 feet to RM-18 (Tongue Point) (north half of channel only).

Such a project would involve four major categories of effects: effects resulting from changes in channel morphology, construction and maintenance dredging, local habitat destruction, and dredge spoil disposal. Only effects resulting from changes in channel morphology will be discussed here. This category was chosen because it provides an opportunity to address changes in circulation and physical structure, which were not addressed in Section 5.1. Effects of local habitat destruction and dredge spoil disposal (if the latter involved filling an estuarine area) could be addressed in the same way as in Section 5.1.

To assess the effects of changing channel morphology, the pathway (Figure 5) B-A-B-C-D-E will be followed. In this way, effects of altering the physical structure (channel morphology) on circulation (salinity intrusion) and resultant effects on physical structure (distribution of salinity and sediments) are described, followed by direct and indirect effects on species.

B. Is the distribution of salinity or sediments changed?

The distribution of sediments is changed by deepening the channel to 67 feet at the entrance and to 52 feet to Tongue Point.

A. Are circulation patterns changed?

Circulation patterns change because a larger volume of saline water is allowed to enter the estuary, resulting in intrusion of salt water farther into the estuary. In addition, the greater depth reduces the speed of tidal currents and riverflow, resulting in less mixing and greater stratification. Increased salinity would be most critical during the low riverflow season (July through October), and these effects will be the focus of the following discussion.

B. Is the distribution of salinity or sediments changed?

Salinity. The changes in salinity distribution that would result from deepening the entrance to 67 feet and the channel to 52 feet to Tongue Point were modeled by the CREDDP Simulation investigator in a separate study for the U.S. Army Corps of Engineers*. Table 4, showing simulated salinity changes and their effect on 1981 salinity distributions for RM-5 to RM-19 and RM-19 to RM-23, is based on information and interpretation provided by the CREDDP Currents investigator. For comparison, 1981 salinities are mapped for surface and 30-foot depths (low riverflow season) on Plate 5 of the Atlas.

Of all the areas considered, mean salinity would increase most in the area between RM-5 and RM-19, especially in deep water. A greater salinity increase would occur under neap tide conditions (not shown in Table 4) when greatest mean salinity intrusion would be expected; an increase of 4-10 parts per thousand (ppt) was projected at RM-5 to RM-19 in deep water.

For the area below RM-5, none of the simulated conditions resulted in a salinity increase greater than 2 ppt. The simulation showed no salinity increase in Baker Bay or Grays Bay. The projected salinity increase in Youngs Bay ranged from 1 to 2 ppt under all the conditions considered. For the area between RM-19 and RM-23, salinity was projected to increase from 0 to 3 ppt.

Sediments. At present, upstream transport of bedload sediments in the main channel under low flow conditions moves bedload sediments up to about RM-18. The increased upstream flow resulting from the deepened channel could be expected to increase the upstream limit of bedload transport.

Suspended sediments would also be transported farther upstream. The turbidity maximum moves up and down the estuary with the twice-daily tides. At present, during the low riverflow season the turbidity maximum moves up and downriver between approximately RM-5 and RM-20. If the channel were deepened, the range of movement would be shifted some distance upriver.

Decreased current velocities resulting from the deepened channel would increase the tendency for sediments to be deposited rather than remaining suspended. Shoaling would occur more rapidly in the deeper channel than it does in the present one. As a result, more frequent maintenance dredging would be required.

*Hamilton, P., 1983. Numerical modeling of the depth dependent salinity instrusion for the coal port deepening project in the Columbia River Estuary. Tech. Report (Contract No. DACW47-83-M-1703). Portland, OR: U.S. Army Corps of Engineers Portland District.

Table 4. Comparison of present salinity distribution with simulated effect of channel deepening, for area of channel from River Mile 5 to River Mile 23 (mean salinity, low flow season).

		RM-5	RM-19	RM-23
Approximate Present Salinity in ppt.	Surface	15	0.5	0
	12'	20	0.5	0
	30'	25	5	0.5

		RM-5 to RM-19	RM-19 to RM-23
Simulated Increase (Range of Possible Values) in ppt.	Surface	2-4	0-2
	18'	4-6	0-3
	40'	6-8	0-3

		RM-5	RM-19	RM-23
Resultant Salinity (Range of Possible Mean Values) in ppt.	Surface	17-19	0.5-2*	0-2
	12'/18'	24-26	0.5-3*	0-3
	30'/40'	31-33	5-8*	0.5-3.5

*Assume increase in RM-19 to RM-23 range

C. Are salinity zones or habitat types changed?

CREDDP investigators estimate that the net effect of the changes described in the previous section would be to move the low riverflow boundary between the Estuarine Channels Region (and associated section of the estuarine mixing salinity zone) and the Fluvial Region (and associated section of the tidal-fluvial zone) 5 miles upriver of its presently defined location. The effects of this change on areas of habitat types are shown in Appendix E, Tables 6a and b. About 161 hectares of channel bottom and water column habitat types would change from the tidal-fluvial to the estuarine mixing salinity zone. Shallower areas would also be affected, but this is more difficult to evaluate.

D. What are the direct effects on species?

Increases and decreases in biomass and productivity for the two regions involved are shown in Appendix E, Tables 7a through 7d. Comparison of Tables 7a and 7c shows that primary productivity for the estuary would decrease by (115,276 minus 80,822) 34,454 kilograms of carbon per year. This is because the freshwater phytoplankton in the fluvial zone are more productive than in the estuarine mixing zone, where they are inhibited or destroyed by salinity.

Productivity and biomass of benthic infauna (Tables 7b and 7d) would decrease for the estuary. The tidal-fluvial salinity zone normally supports a higher infaunal standing crop than the estuarine mixing zone, mostly because of the presence of the freshwater clam Corbicula manilensis and the abundant and productive amphipod Corophium salmonis (see Atlas). Decreasing the area of the tidal-fluvial zone thus results in decreased infaunal biomass and productivity. Corophium salmonis is an important food source to juvenile migrating salmonids and to wading birds. Its habitat extends from Baker Bay upriver at least to Portland. Seasonal increases in salinity result in population declines in some areas of the estuarine mixing zone due to emigration, suggesting the possibility that increased salinities in this zone could cause declines in Corophium salmonis abundance.

Production by epibenthic organisms would increase (Tables 7b and 7d). This is probably related to the fact that productive species like the epibenthic zooplankter Eurytemora affinis and the mobile macroinvertebrate Crangon franciscorum are associated with the estuarine mixing zone. These species tend to be associated with the turbidity maximum, which would range farther upriver as a result of the channel deepening. Phytoplankton and detritus are concentrated in the turbidity maximum, providing a rich food supply for epibenthic organisms and contributing to their high productivity (see Atlas).

The effects of these changes on the two regions involved are shown in Appendix E, Tables 8a, 8b, 9a, and 9b. Worksheet 4 (Appendix D) would provide a list of the directly-affected species.

E. What are the indirect effects on species?

Worksheet 5 (Appendix D) would provide a list of indirectly-

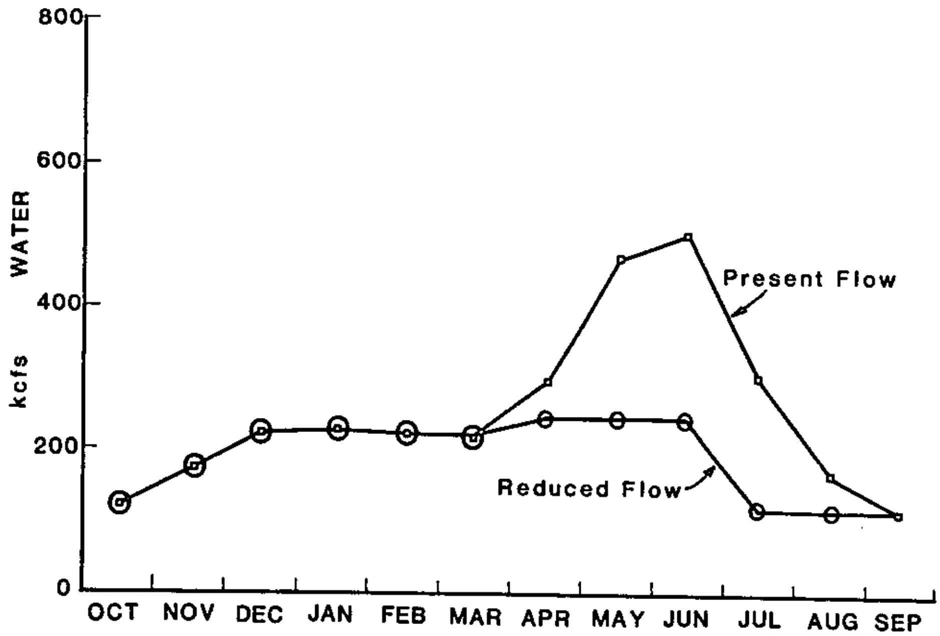


Figure 7. Present flow and reduced flow - monthly means.

affected species. Because of the availability of phytoplankton from upriver, it is unlikely that the decrease in phytoplankton productivity would affect food availability in the estuary. The distribution of Crangon franciscorum would extend upriver, partly because of the direct effect of salinity (discussed in the previous section) and partly because of the upriver expansion of its principal prey, the epibenthic zooplankton. The changed distribution of Crangon franciscorum would affect the distribution of its predators. For example, starry flounder and other estuarine fish might be expected to occur farther upriver than they presently do. Harbor seals, which feed on starry flounder and Crangon franciscorum, might expand their feeding range upriver.

5.3 ALTERATION OF FRESHWATER FLOW

This section examines some of the effects that could be expected if riverflow from April through August were reduced (Figure 7). This reduction would result from a large diversion of water on the east side of the Cascades, upriver of the Cowlitz and Willamette Rivers. The yearly average flow would be reduced from about 257 kcfs (257,000 cubic feet per second) to about 196 kcfs.

A. Are circulation patterns changed?

The basic circulation patterns would not change, and riverflow seasons would remain the same.

B. Is the distribution of salinity or sediments changed?

Salinity. Whether salinity intrusion would be increased can be estimated by looking at years whose flows were similar to those of the projected conditions.

For the high riverflow season, May 1981 (riverflow 276 kcfs) provides a good example. During that period, salinity intrusion at the bottom rarely reached much beyond Tongue Point in the navigation channel. The present mean high riverflow salinity distribution (see Atlas) shows a bottom salinity of 0.5 ppt just downstream of Tongue Point. Thus, extensive changes in salinity intrusion would not be expected during the high riverflow season.

For the low riverflow season, CREDDP October 1980 data (see Currents work unit report) give a good idea of how salinity distribution would be affected by reduced flow. Salinity intrusion would reach RM-25 to RM-30 at the bottom of the navigation channel, compared with the present low flow mean of RM-23 (see Atlas). Much less change would be expected in the bays, where deep saline water cannot intrude.

Sediments. The increased intrusion of saline water would enhance the upstream movement of sediments into the estuary, causing an upriver shift in the location of the turbidity maximum and causing increased trapping of sediments in the estuary. The extreme high flow events that would flush sediments out of the estuary would occur less frequently, if at all. These factors would increase sedimentation in the estuary.

Table 5. Comparison of present and reduced carbon transport to estuary.

		APRIL	MAY	JUNE	JULY	AUG	TOTAL	% DECREASE
PRESENT	POC concentration milligrams/cubic meter	883	910[1]	1,045	818	1,189		
PRESENT	POC transport, metric tons/month	21,300	31,109[1]	38,327[2]	18,600	14,415	125,751	
PRESENT	PPOC concentration milligrams/cubic meter	279	279[1]	330[2]	382	364		
PRESENT	PPOC transport metric tons/month	6,720	10,140[1]	12,111[2]	8,680	4,420	42,071	
REDUCED	POC transport metric tons/month	14,898	15,864	17,630	7,451	10,827	66,679	
REDUCED	PPOC transport metric tons/month	4,700	4,853	5,575	3,473	3,321	21,922	
DIFFERENCE	Flow, millions of cubic meters	7,240	18,950	19,806	13,630	3,018		
DIFFERENCE	POC transport, metric tons/month	6,393	17,245	20,697	11,149	3,588	59,072	47%
DIFFERENCE	PPOC transport metric tons/month	2,020	5,287	6,536	5,207	1,099	20,149	48%

1. May and June carbon data were not available because of the eruption of Mt. St. Helens. May transport values were obtained by multiplying April concentrations by June flows. May concentrations were assumed to be the same as April.
2. June transport values were obtained by averaging April and July concentrations and multiplying by June flows. June concentrations were assumed to be the average of April and July.

On the other hand, the reduced discharge would reduce the input of sediments into the estuary, with the effect of reducing sedimentation. It is impossible with the present information to suggest what the net effect would be.

C. Are salinity zones or habitat types changed?

The effect of this alteration on estuarine habitat types would be similar to the effects discussed in Section 5.2, in that the extent of salinity intrusion would be increased.

In evaluating the effects of flow reduction, CREDDP researchers chose to examine a factor not previously discussed, the potential decrease in detritus entering the estuary.

Loss of detritus

One effect of reduced freshwater discharge would be the loss of the detritus that the diverted water would have brought into the estuary. Detritus from the Columbia River is the major source of food for the detritus-based food web of the estuary. Carbon is the major chemical constituent of detritus, as it is of living plants and animals. Particulate organic carbon (POC) refers to all carbon associated with living or dead particulate biological matter, including detritus and living phytoplankton. PPOC (phytoplankton particulate organic carbon) refers to the fraction of POC associated with living phytoplankton. The present concentrations of POC and PPOC in water entering the estuary are shown in Table 5.

The present transport, or load, of these materials to the estuary was obtained by multiplying the flow of water (illustrated in Figure 7) by the concentration. These transport values are shown in Table 5. To determine the amount of reduction under reduced flow conditions, the difference in total riverflow volume for each month (the gap between present flow and reduced flow in Figure 7) was multiplied by the present concentrations of materials, resulting in the difference in transports. The reduced transports were obtained by subtracting the difference from the present condition.

The present and reduced flow transports are shown in Figure 8, indicating that the greatest effect occurs in June.

Total reduction in transport (Table 5) for the 5-month period examined is 47% for POC and 48% for PPOC. This represents a reduction of 22% for POC for the entire year (assume annual POC is 265,000 metric tons) and 29% for PPOC (assume annual total of 70,000 metric tons). The decrease during the 5-month period is probably more meaningful than the annual decrease, since that 5-month period is the estuary's most productive.

This represents a significant loss of detritus to the estuary, but it is difficult to evaluate its importance because the use of detritus in estuarine food webs is not understood. The most likely effect would be on the epibenthic organisms of the turbidity maximum, whose high

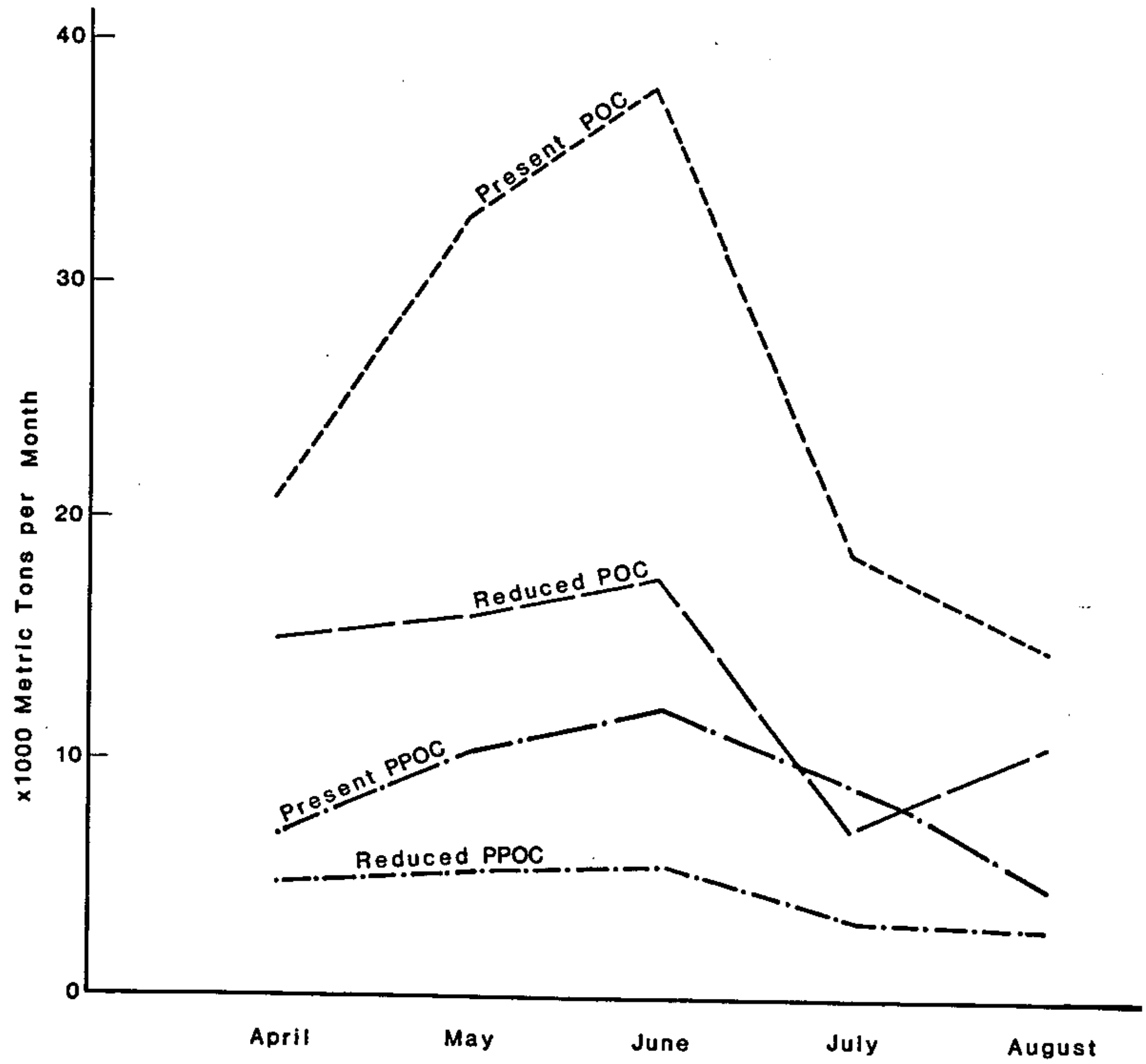


Figure 8. Comparison of present and reduced carbon transport to estuary. PPOC: Phytoplankton organic carbon; POC: Particulate organic carbon.

productivity is supported primarily by detritus and phytoplankton supplied from upriver.

APPENDIX A

Information to be provided in
the impact assessment (Oregon)

INFORMATION TO BE PROVIDED IN THE IMPACT ASSESSMENT

for projects proposed on the Oregon side of the Columbia River Estuary (from Section 5.800 of the Clatsop County Zoning Ordinance)

(1) Aquatic life forms and habitat, including information on: habitat type and use (e.g., rearing, spawning, feeding or resting area, migration route), species present, seasonal abundance, sediment type and characteristics, vegetation present. Type of alteration, including information detailing the extent of alteration (e.g., area measurement, depths to which alteration will extend, volumes of materials removed and/or placed as fill), impacted species, including threatened or endangered species, life stages and life cycles affected with regard to timing of the proposed alteration, percent of total available habitat type subjected to alteration.

(2) Shoreland life forms and habitat, including information on: habitat type and use (e.g., feeding, resting, or watering areas, flyways), species present, seasonal abundance, soil types and characteristics, vegetation present. Type of alteration, including information detailing the extent of alteration (e.g., area measurement, extent of grading and excavation, removal of riparian vegetation), impacted species, including threatened or endangered species, life stages and cycles affected with regard to timing of the proposed alteration, percent of total available habitat type subjected to alteration.

(3) Water quality, including information on: increases in sedimentation and turbidity, decreases in dissolved oxygen concentration, changes in biological and chemical oxygen demand, contaminated sediments, alteration of salinity regime, disruption of naturally occurring water temperatures, changes due to reduction, diversion or impoundment of water.

(4) Hydraulic characteristics, including information on: changes in water circulation patterns, shoaling patterns, potential of erosion or accretion in adjacent areas, changes in the flood plain, decreases in flushing capacity or decreases in rate of water flow from reduction or diversion or impoundment of water resources.

(5) Air quality, including information on: quantities of emission of particulates, expected inorganic and organic airborne pollutants.

(6) The impact of the proposed project on navigation and public access to shoreline and aquatic areas.

(7) Demonstration that any proposed structures or devices are properly engineered.

(8) Demonstration that the public good will benefit positively from the development alteration, and that the public's need and gain will offset any adverse impacts resulting from the proposed development.

(9) Demonstration that non-water dependent uses will not pre-empt existing or future water-dependent utilization of the area.

(10) Determination of the potential cumulative impact of the proposed development, including alteration of adjacent significant estuarine fish and wildlife habitat and perturbation of essential properties of the estuarine resource.

(11) Determination of methods for alteration and accommodation of the proposed development, based on items (1) through (10) above, in order to minimize preventable adverse impacts. Determination of the need for mitigation.

APPENDIX B

Environmental checklist (Washington)

ENVIRONMENTAL CHECKLIST (WASHINGTON)

(from WAC 197-11-99325)

B. ENVIRONMENTAL ELEMENTS

1. Earth

a. General description of the site (circle one):

Flat, rolling, hilly, steep slopes, mountainous, other __.

b. What is the steepest slope on the site (approximate percent slope?)

c. What general types of soils are found on the site (for example, clay, sand, gravel, peat, muck)? If you know the classification of agricultural soils, please specify them and note any prime farmland.

d. Are there surface indications or history of unstable soils in the immediate vicinity? If so, describe.

e. Describe the purpose, type, and approximate quantities of any filling or grading proposed.

f. Could erosion occur as a result of clearing, construction, or use? If so, generally describe.

g. Approximately what percent of the site will be covered with impervious surfaces after project construction?

h. Proposed measures to reduce or control erosion, or other impacts to the earth, if any:

2. Air

a. What types of emissions to the air would result from the proposal (i.e. dust, automobile, odors, industrial wood smoke) during construction and when the project is completed? If any, generally describe and give approximate quantities if known.

b. Are there any off-site sources of emissions or odor which may affect your proposal? If so, generally describe.

c. Proposed measures to reduce or control emissions or other impacts to air, if any:

3. Water

a. Surface:

1) Is there any surface water body on or in the immediate vicinity of the site (including year-round and seasonal streams, saltwater, lakes, ponds, wetlands)? If yes, describe type and

provide name. If appropriate, state what stream or river it flows into.

2) Will the project require any work over, in, or adjacent to (within 200 feet) the described waters? If yes, please described and attach available plans.

3) Estimate the amount of fill and dredge material that would be placed in or removed from surface water or wetlands. Indicate the source of fill material.

4) Will the proposal require surface water withdrawals or diversions? Give general description, purpose, and approximate quantities if known.

5) Does the proposal lie within a 100-year floodplain? If so, note location on the site plan.

6) Does the proposal involve any discharges of waste materials to surface waters? If so, describe the type of waste and anticipated volume of discharge.

b. Ground:

1) Will ground water be withdrawn, or will water be discharged to ground water? Give general description, purpose, and approximate quantities if known.

2) Describe waste material that will be discharged into the ground from septic tanks or other sources, if any. Describe the general size of the system, the number of such systems, the number of houses to be served (if applicable), or the number of animals or humans the system(s) are expected to serve.

c. Water Runoff (including stormwater):

1) Describe the source of runoff (including stormwater) and method of collection and disposal, if any (include quantities, if known). Where will this water flow? Will this water flow into other waters? If so, describe.

2) Could waste materials enter ground or surface waters? If so, generally describe.

d. Proposed measures to reduce or control surface, ground, and runoff water impacts, if any:

4. <u>Plants</u>

a. Check or circle types of vegetation found on the site:

_____deciduous tree: alder, maple, aspen, other
_____evergreen tree: fir, cedar, pine, other

_____shrubs
_____grass
_____pasture
_____crop or grain
_____wet soil plants: cattail, buttercup, bullrush, skunk cabbage, other
_____water plants: water lily, eelgrass, milfoil, other
_____other types of vegetation

b. What kind and amount of vegetation will be removed or altered?

c. List threatened or endangered species known to be on or near the site.

d. Proposed landscaping, use of native plants, or other measures to preserve or enhance vegetation on the site, if any:

5. <u>Animals</u>

a. Circle any birds and animals which have been observed on or near the site or are known to be on or near the site:

birds: hawk, heron, eagle, songbirds, other:____________
mammals: deer, bear, elk, beaver, other: ____________
fish: bass, salmon, trout, shellfish, other:____________

b. List any threatened or endangered species known to be on or near the site.

c. Is the site part of a migration route? If so, explain.

d. Proposed measures to preserve or enhance wildlife, if any:

6. <u>Energy and Natural Resources</u>

a. What kinds of energy (electric, natural gas, oil, wood stove, solar) will be used to meet the completed project's energy needs? Describe whether it will be used for heating, manufacturing, etc.

b. Would your project affect the potential use of solar energy by adjacent properties? If so, generally describe.

c. What kinds of energy conservation features are included in the plans of this proposal? List other proposed measures to reduce or control energy impacts, if any:

7. <u>Environmental Health</u>

a. Are there any environmental health hazards, including exposure to toxic chemicals, risk of fire and explosion, spill, or hazardous waste, that could occur as a result of this proposal? If so, describe.

b. Describe special emergency services that might be required.

c. Proposed measures to reduce or control environmental health hazards, if any:

8. Land and Shoreline Use

a. What is the current use of the site and adjacent properties?

b. Has the site been used for agriculture? If so, describe.

c. Describe any structures on the site.

d. Will any structures be demolished? If so, what?

e. What is the current zoning classification of the site?

f. What is the current comprehensive plan designation of the site?

g. If applicable, what is the current shoreline master program designation of the site?

h. Has any part of the site been classified as an "environmentally sensitive" area? If so, specify.

i. Approximately how many people would reside or work in the completed project?

j. Approximately how many people would the completed project displace?

k. Proposed measures to avoid or reduce displacement impacts, if any:

l. Proposed measures to ensure the proposal is compatible with existing and projected land uses and plans, if any:

9. Housing

a. Approximately how many units would be provided, if any? Indicate whether high, middle, or low-income housing.

b. Approximately how many units, if any, would be eliminated? Indicate whether high, middle, or low-income housing.

c. Proposed measures to reduce or control housing impacts, if any:

10. Noise

a. What types of noise exist in the area which may affect your project (for example: traffic, equipment operation, other)?

b. What types and levels of noise would be created by or associated with the project on a short-term or a long-term basis (for example: traffic, construction, operation, other)? Indicate what hours noise would come from the site.

c. Proposed measures to reduce or control noise impacts, if any:

11. Aesthetics

a. What is the tallest height of any proposed structure(s), not including antennas; what is the principal exterior building material proposed?

b. What views in the immediate vicinity would be altered or obstructed?

c. Proposed measures to reduce or control aesthetic impacts, if any:

12. Light and Glare

a. What type of light or glare will the proposal produce? What time of day would it be produced?

b. Could light or glare from the finished project be a safety hazard or interfere with views?

c. What existing off-site sources of light or glare may affect your proposal?

d. Proposed measures to reduce or control light and glare impacts, if any:

13. Recreation

a. What designated and informal recreational opportunities are in the immediate vicinity?

b. Would the proposed project displace any existing recreational uses? If so, describe.

c. Proposed measures to reduce or control impacts on recreation, including recreation opportunities to be provided by the project or applicant, if any:

14. Historic or Cultural Preservation

a. Are there any places or objects listed on, or proposed for, national, state, or local preservation registers known to be on or adjacent to the site? If so, generally describe.

b. Generally describe any landmarks or evidence of historic, archaeological, scientific, or cultural importance known to be on or adjacent to the site.

c. Proposed measures to reduce or control impacts, if any:

15. Transportation

a. Identify public streets and highways serving the site, and describe proposed access to the existing street system. Show on site plans, if any.

b. Is the site currently served by public transit? If not, what is the approximate distance to the nearest transit stop?

c. How many parking spaces would the completed project have? How many would the project eliminate?

d. Will the proposal require any new road or street or improvements to existing roads and streets, not including driveways? If so, generally describe (indicate whether public or private).

e. Will the project use or occur in the immediate vicinity of water, rail, or air transportation? If so, generally describe.

f. How many vehicular trips per day would be generated by the completed project? If known, indicate when peak volumes would occur.

g. Proposed measures to reduce or control transportation impact, if any:

16. Public Services

a. Would the project result in an increased need for public services (for example: fire protection, police protection, health care, schools, other)? If so, generally describe.

b. Proposed measures to reduce or control direct impacts on public services, if any:

17. Utilities

a. Circle utilities currently available at the site: electricity, natural gas, water, refuse service, telephone, sanitary sewer, other.

b. Describe the utilities which are proposed for the project, the utility providing the services, and the general construction activities on the site or in the immediate vicinity which might be needed.

APPENDIX C

Species, standing crop, total biomass,
productivity, and total productivity
of habitat types in regions

Appendix C - Table 1. Species occurring in Columbia River Estuary regions and habitat types.

+ = predominant (among the most conspicuous) blank = not present nd = no data

TAXON Region:	Entrance			Baker Bay & Trestle Bay					Estuarine Channels			Youngs Bay					Mid-Estuary Shoals			Grays Bay					Cathlamet Bay					Fluvial Region					
Habitat Types:	WC	TF	CB	WC	HM	LM	TF	DS	WC	DS	CB	WC	HM	LM	TF	DS	WC	TF	DS	WC	HM	LM	TF	DS	WC	HM	LM	TF	DS	WC	HM	LM	TF	DS	CB
PRODUCERS:																																			
PHYTOPLANKTON:																																			
Asterionella formosa	+			+					+			+					+			+					+					+					
Chaetoceros decipiens	+																																		
Coscinodiscus perforatus v. *cellulosa*	+								+																										
Fragilaria crotonensis	+			+					+			+					+			+					+					+					
Melosira granulata				+					+			+					+			+					+					+					
Melosira italica	+			+					+			+					+			+					+					+					
Skeletonema costatum	+																																		
BENTHIC ALGAE:																																			
Achnanthes hauckiana		nd				nd	+							nd	+							nd					nd	+				nd	+		
Achnanthes lanceolata		nd				nd								nd								nd	+				nd	+				nd	+		
Achnanthes lemmermanni		nd				nd	+							nd	+							nd					nd					nd			
Amphora ovalis		nd				nd								nd								nd					nd	+				nd			
Amphora ovalis v. *pediculus*		nd				nd								nd								nd	+				nd					nd			
Diatoma tenue v.*elongatum*		nd				nd								nd	+							nd					nd	+				nd	+		
Fragilaria brevistriata		nd				nd								nd								nd					nd					nd	+		
Fragilaria pinnata		nd				nd								nd	+			+				nd	+				nd	+				nd	+		
Gyrosigma fasciola		nd				nd								nd	+							nd					nd					nd			
Navicula capitata v. *hungarica*		nd				nd								nd								nd	+				nd	+				nd	+		
Navicula cryptocephala		nd				nd	+							nd	+							nd					nd					nd			
Navicula diserta		nd				nd	+							nd								nd					nd					nd			
Navicula gregaria		nd				nd								nd	+			+				nd	+				nd	+				nd	+		
Navicula minima		nd				nd								nd				+				nd					nd					nd			
Navicula placentula		nd				nd								nd								nd					nd	+				nd			
Navicula pygmaea		nd				nd	+							nd								nd					nd					nd			
Navicula salinicola		nd				nd	+							nd								nd					nd					nd			
Navicula submuralis		nd				nd								nd				+				nd	+				nd	+				nd	+		
Navicula tenuipunctata		nd				nd								nd								nd					nd	+				nd			
Nitzschia frustulum v. *perpusilla*		nd				nd	+							nd				+				nd					nd	+				nd	+		
Nitzschia hungarica		nd				nd								nd	+							nd					nd					nd			
Nitzschia palea		nd				nd								nd	+			+				nd	+				nd	+				nd	+		
Nitzschia sigma v. *sigmatella*		nd				nd								nd	+							nd					nd					nd			
Opephora martyi		nd				nd								nd								nd	+				nd					nd			

WC = Water Column HM = High Marsh and Swamp LM = Low Marsh
TF = Tidal Shoals and Flats DS = Demersal Slope CB = Channel Bottom

TAXON Region:	Entrance			Baker Bay & Trestle Bay					Estuarine Channels			Youngs Bay					Mid-Estuary Shoals			Grays Bay					Cathlamet Bay					Fluvial Region					
Habitat Types:	WC	TF	CB	WC	HM	LM	TF	DS	WC	DS	CB	WC	HM	LM	TF	DS	WC	TF	DS	WC	HM	LM	TF	DS	WC	HM	LM	TF	DS	WC	HM	LM	TF	DS	CB
MARSH PLANTS:																																			
Agrostis alba					+	+								+																					
Alisma plantago-aquatica														+													+								
Aster subspicatus					+																	+				+					+	+			
Athyrium felix-femina					+								+																						
Bidens cernua																											+								
Caltha asarifolia																					+														
Carex lyngbyei						+								+							+	+					+					+			
Carex obnupta					+								+																						
Cornus stolonifera																										+					+				
Deschampsia caespitosa						+															+	+				+	+				+	+			
Eleocharis palustris														+								+					+					+			
Elodea canadensis																						+	+												
Equisetum fluviatile																											+								
Festuca arundinacea																					+					+					+				
Impatiens capensis																										+					+				
Juncus balticus						+																+										+			
Juncus oxymeris																						+					+					+			
Lathyrus palustris					+								+																						
Lilaeopsis occidentalis						+																+										+			
Lonicera involucrata													+																						
Lotus corniculata																					+					+					+				
Lysichitum americanum																										+					+				
Mentha piperita																					+														
Oenanthe sarmentosa					+	+							+	+																					
Picea sitchensis													+																						
Potentilla pacifica					+								+								+														
Rubus spectabilis													+																						
Sagittaria latifolia																						+					+					+			
Salix hookeriana													+																						
Salix lasiandra																										+					+				
Salix sitchensis																										+					+				
Scirpus acutus						+																					+								
Scirpus americanus						+																													
Scirpus microcarpus																					+														
Scirpus validus						+								+								+					+					+			
Sium suave																					+						+					+			
Spiraea douglasii																										+					+				
Triglochin maritinum						+																													
Typha angustifolia						+								+													+					+			
Typha latifolia																																+			

TAXON Region:	Entrance			Baker Bay & Trestle Bay					Estuarine Channels			Youngs Bay					Mid-Estuary Shoals			Grays Bay					Cathlamet Bay					Fluvial Region					
Habitat Types:	WC	TF	CB	WC	HM	LM	TF	DS	WC	DS	CB	WC	HM	LM	TF	DS	WC	TF	DS	WC	HM	LM	TF	DS	WC	HM	LM	TF	DS	WC	HM	LM	TF	DS	CB
CONSUMERS:																																			
ZOOPLANKTON																																			
(Suspension Feeders):																																			
Acartia clausii	nd			nd					+			nd					nd			nd					nd										
Acartia longiremis	nd			nd					+			nd					nd			nd					nd										
Barnacle nauplii	nd			nd					+			nd					nd			nd					nd										
Bivalve larvae	nd			nd					+			nd					nd			nd					nd										
Bosmina longirostris	nd			nd					+			nd					nd			nd					nd					+					
Calanus pacificus	nd			nd					+			nd					nd			nd					nd										
Centropages abdominalis	nd			nd					+			nd					nd			nd					nd										
Ceriodaphnia pulchella	nd			nd								nd					nd			nd					nd					+					
Cyclops bicuspidatus v. thomasi	nd			nd					+			nd					nd			nd					nd					+					
Cyclops vernalis	nd			nd					+			nd					nd			nd					nd					+					
Daphnia gateata v. mendotae	nd			nd					+			nd					nd			nd					nd					+					
Daphnia pulex	nd			nd					+			nd					nd			nd					nd					+					
Diaptomus ashlandi	nd			nd					+			nd					nd			nd					nd					+					
Diaptomus brachyurum	nd			nd					+			nd					nd			nd					nd					+					
Diaptomus franciscanus	nd			nd					+			nd					nd			nd					nd					+					
Diaptomus novamexicanus	nd			nd					+			nd					nd			nd					nd					+					
Eogammarus confervicolus	nd			nd					+			nd					nd			nd					nd										
Euphausiacea nauplii	nd			nd					+			nd					nd			nd					nd										
Eurytemora affinis	nd			nd					+			nd					nd			nd					nd					+					
Evadne nordmanni	nd			nd					+			nd					nd			nd					nd										
Gastropod larvae	nd			nd					+			nd					nd			nd					nd										
Oikopleura dioica	nd			nd					+			nd					nd			nd					nd										
Oithona similis	nd			nd					+			nd					nd			nd					nd										
Paracalanus parvus	nd			nd					+			nd					nd			nd					nd										
Podon leucharti	nd			nd					+			nd					nd			nd					nd										
Pseudocalanus elongatus	nd			nd					+			nd					nd			nd					nd										
(Predators):																																			
Archaeomysis grebnitzkii	nd			nd					+			nd					nd			nd					nd										
Neomysis mercedis	nd			nd					+			nd					nd			nd					nd					+					
Sagitta elegans	nd			nd					+			nd					nd			nd					nd										

TAXON	Entrance			Baker Bay & Trestle Bay					Estuarine Channels			Youngs Bay					Mid-Estuary Shoals			Grays Bay					Cathlamet Bay					Fluvial Region					
Region: / Habitat Types:	WC	TF	CB	WC	HM	LM	TF	DS	WC	DS	CB	WC	HM	LM	TF	DS	WC	TF	DS	WC	HM	LM	TF	DS	WC	HM	LM	TF	DS	WC	HM	LM	TF	DS	CB
LARVAL FISHES:																																			
Cottus asper	nd			nd					+			nd					nd			nd					nd					+					
Engraulis mordax	nd			nd					+			nd					nd			nd					nd										
Osmeridae	nd			nd					+			nd					nd			nd					nd					+					
EPIBENTHIC ORGANISMS																																			
(Deposit Feeders):																																			
Alonella sp.																							+										+		
Attheyella sp.																							+										+	+	+
Bryocamptus spp.							+	+																											
Candona sp.																																	+		
Chironomidae																							+											+	
Corophium spp.			+															+					+	+									+	+	
Ectinosomatidae			+				+	+			+				+			+	+				+	+									+	+	
Eogammarus confervicolus								+																											
Huntemannia jadensis																		+																	
Laophontidae							+								+								+												
Leucon sp.								+																											
Limnocythere sp.											+							+					+	+									+	+	
Microarthridion littorale			+				+				+				+			+					+												
Nematomorphii																																			+
Paraleptastacus sp.																			+																
Podocopa																								+									+		
Scottolana canadensis			+				+	+			+				+			+	+				+	+										+	
Tachidius discipes																							+												
Tachidius triangularis							+	+							+			+	+															+	
(Predators):																																			
Cancer magister			+				+	+			+																								
Crangon franciscorum			+				+	+			+				+			+	+				+	+					+						
Neomysis mercedis			+				+				+							+	+				+	+									+	+	+
(Suspension Feeders):																																			
Acartia clausii			+																+																
Alona spp.																																	+	+	
Balanomorpha (Cypris)			+				+	+			+				+																				
Bosmina sp.			+								+							+	+					+					+				+	+	+
Cyclops bicuspidatus			+					+			+				+			+	+				+	+					+				+	+	+
Cyclops vernalis			+								+				+			+	+				+	+					+				+	+	+
Daphnia spp.											+																		+				+	+	+
Diaptomus sp.			+								+				+								+	+									+	+	+
Eurytemora affinis			+				+	+			+				+			+	+					+										+	+
Halicyclops sp.																																	+		
Oithona sp.			+																+																
Paracyclops fimbriatus																							+												
Rotifera			+					+			+								+				+	+					+				+		+

TAXON Region: Habitat Types:	Entrance			Baker Bay & Trestle Bay					Estuarine Channels			Youngs Bay					Mid-Estuary Shoals			Grays Bay					Cathlamet Bay					Fluvial Region					
	WC	TF	CB	WC	HM	LM	TF	DS	WC	DS	CB	WC	HM	LM	TF	DS	WC	TF	DS	WC	HM	LM	TF	DS	WC	HM	LM	TF	DS	WC	HM	LM	TF	DS	CB
BENTHIC INFAUNA																																			
(Deposit Feeders):																																			
Chironomidae																							+	+				+	+				+	+	+
Corophium salmonis										+					+	+		+	+				+	+				+	+				+	+	+
Eohaustorius estuarius										+								+	+																
Fluminicola virens																							+	+				+	+				+	+	
Goniobasis plicifera																							+					+					+		
Hobsonia florida							+	+							+																				
Macoma balthica							+	+			+				+																				
Neanthes limnicola		+					+	+			+				+	+		+											+					+	
Oligochaeta							+	+							+	+		+					+	+				+	+				+	+	+
Paraonella platybranchia			+																																
Paraphoxus milleri		+	+							+	+																								
Pseudopolydora kempi							+																												
Spio spp.			+																																
(Suspension Feeders):																																			
Corbicula manilensis																							+	+				+	+				+	+	+
Mya arenaria							+																												
(Predators):																																			
Eogammarus confervicolus										+	+					+		+	+																
Eteone spp.		+					+	+																											
Heleidae																								+				+	+				+	+	+
Nephtys californiensis			+																																
Rhynchocoela		+	+					+		+	+				+	+		+	+				+	+											+
Saduria entomon																		+																	
Turbellaria		+					+	+							+																				

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TAXON Region:	Entrance			Baker Bay & Trestle Bay					Estuarine Channels			Youngs Bay					Mid-Estuary Shoals			Grays Bay					Cathlamet Bay					Fluvial Region					
Habitat Types:	WC	TF	CB	WC	HM	LM	TF	DS	WC	DS	CB	WC	HM	LM	TF	DS	WC	TF	DS	WC	HM	LM	TF	DS	WC	HM	LM	TF	DS	WC	HM	LM	TF	DS	CB
FISH (Predators):																																			
Acipenser transmontanus		nd																										nd	+	+					
Allosmerus elongatus	+	nd																		+								nd							
Alosa sapidissima	+	nd		+					+			+								+					+			nd		+					
Ammodytes hexapterus		nd	+																									nd	+						
Catostomus macrocheilus		nd																						+				nd	+						
Citharichthys stigmaeus		nd						+							+													nd							
Clupea harengus pallasi	+	nd							+			+								+					+			nd							
Cottus asper		nd						+		+	+				+	+		+	+				+	+				nd	+					+	+
Cymatogaster aggregata		nd						+		+	+				+	+		+	+				+	+				nd	+				+	+	
Engraulis mordax	+	nd																										nd							
Gasterosteus aculeatus	+	nd		+					+			+					+			+					+			nd		+					
Hypomesus pretiosus	+	nd							+			+								+					+			nd							
Isopsetta isolepsis		nd	+																									nd	+						
Lampetia azresii		nd																		+								nd							
Leptocattus arinatus		nd						+		+	+				+	+		+	+				+	+				nd	+				+	+	+
Lumpenus sagitta		nd	+					+			+																	nd							
Microgadus proximus		nd	+					+			+																	nd							
Mylocheilus caurinus		nd	+							+	+				+	+			+				+	+				nd	+						+
Oncorhynchus kisutch	+	nd		+					+			+					+			+					+			nd		+					
Oncorhynchus nerka	+	nd							+																			nd							
Oncorhynchus tshawytscka	+	nd		+					+			+					+			+					+			nd		+					
Parophrys vetulus		nd	+					+			+				+	+		+	+				+	+				nd	+				+	+	
Platichthys stellatus		nd	+							+	+				+	+		+	+				+	+				nd	+				+	+	+
Psettichthys melanostictus	+	nd																										nd							
Salmo clarki	+	nd	+					+	+		+																	nd							
Salmo gairdneri	+	nd		+					+			+					+			+					+			nd		+					
Spirinchus thaleichthys	+	nd	+					+	+		+	+								+					+			nd		+					
Thaleichthys pacificus	+	nd		+					+			+								+					+			nd		+					

TAXON	Entrance			Baker Bay & Trestle Bay					Estuarine Channels			Youngs Bay					Mid-Estuary Shoals			Grays Bay					Cathlamet Bay					Fluvial Region					
Region: Habitat Types:	WC	TF	CB	WC	HM	LM	TF	DS	WC	DS	CB	WC	HM	LM	TF	DS	WC	TF	DS	WC	HM	LM	TF	DS	WC	HM	LM	TF	DS	WC	HM	LM	TF	DS	CB
BIRDS (Predators):																																			
Aechmophorus occidentalis				+								+								+					+					+					
Azelaius phoeniceus																					+	+				+	+				+	+			
Ardea herodias					+	+	+					+	+	+	+						+	+	+			+	+	+			+	+	+		
Aythya valisineria				+			+													+					+					+					
Calidris alba							+																												
Calidris alpina							+														+	+	+			+	+	+			+	+	+		
Calidris mauri					+	+	+								+						+	+	+			+	+	+			+	+	+		
Calidris minutilla					+	+	+								+						+	+	+												
Cistothorus palustris							+						+	+												+	+				+	+			
Corvus brachyrhynchus							+						+	+	+						+	+	+			+	+	+			+	+	+		
Geothlypis trichas													+	+																					
Hirunda rustica				+			+						+	+	+					+	+	+	+		+	+	+	+		+	+	+	+		
Iridoprocne bicolor													+	+						+	+	+			+	+	+	+		+	+	+	+		
Larus californicus				+								+			+						+	+	+			+	+	+			+	+	+		
Larus canus				+								+			+					+	+	+	+		+	+	+	+		+	+	+	+		
Larus delawarensis				+	+	+	+					+			+					+	+	+	+		+	+	+			+	+	+			
Larus glaucescens				+											+						+	+	+			+	+				+	+			
Larus occidentalis				+			+								+					+	+	+	+			+	+				+	+			
Larus philadephia				+			+													+															
Melanitta perspicillata				+																															
Petrochelidon pyrrhonota																				+	+	+	+			+	+				+	+			
Phalacrocorax auritus				+								+								+					+					+					
Porzana carolina													+	+																					
Sterna cuspia				+																					+					+					
Tachycineta thalassina													+	+						+	+	+	+			+	+				+	+			
(Wetland Herbivores):																																			
Anser acuta																										+	+				+	+			
Anser americana																										+	+				+	+			
Anser platyrhynchos				+	+	+	+					+	+	+	+					+	+	+	+		+	+	+	+		+	+	+	+		
MARINE MAMMALS (Predators):																																			
Eumetopias jubatus	+	+	+	+			+	+	+	+	+	+			+	+	+	+	+	+		+	+		+			+	+	+			+	+	+
Phoca vitulina	+	+	+	+			+	+	+	+	+	+			+	+	+	+	+	+		+	+		+			+	+	+			+	+	+
Zalophus californianus	+	+	+	+			+	+	+	+	+	+			+	+	+	+	+	+		+	+		+			+	+	+			+	+	+
TERRESTRIAL/AQUATIC MAMMALS																																			
(Wetland Herbivores):																																			
Castor canadensis					+	+							+	+							+	+				+	+				+	+			
Myocastor coypus					+	+	+						+	+	+						+	+	+			+	+	+			+	+	+		
Ondatra zibethicus					+	+	+						+	+	+						+	+	+			+	+	+			+	+	+		
(Predators):																																			
Lutra canadensis					+	+	+						+	+	+						+	+	+			+	+	+			+	+	+		
Procyon lotor					+	+	+						+	+	+						+	+	+			+	+	+			+	+	+		

Appendix C, Table 1, Addendum: Common names of some Columbia River Estuary species.

MARSH PLANTS

Agrostis alba	Creeping bentgrass
Alisma plantago-aquatica	Water plantain
Aster subspicatus	Douglas' aster
Athyrium felix-femina	Lady fern
Bidens cernua	Bur marigold
Caltha asarifolia	Western marsh marigold
Carex lyngbyei	Lyngby's sedge
Carex obnupta	Slough sedge
Cornus stolonifera	Red osier dogwood
Deschampsia caespitosa	Tufted hairgrass
Eleocharis palustris	Creeping spike rush
Elodea canadensis	Rocky mountain waterweed
Equisetum fluviatile	Swamp horsetail
Festuca arundinacea	Reed fescue
Impatiens capensis	Orange balsam
Juncus balticus	Baltic rush
Juncus oxymeris	Pointed rush
Lathyrus palustris	Marsh pea
Lilaeopsis occidentalis	Western lilaeopsis
Lonicera involucrata	Black twin-berry
Lotus corniculata	Birdsfoot trefoil
Lysichitum americanum	Yellow skunk cabbage
Oenanthe sarmentosa	Pacific water-parsley
Picea sitchensis	Sitka spruce
Potentilla pacifica	Pacific silverweed
Rubus spectabilis	Salmonberry
Sagittaria latifolia	Broad-leaved arrowhead
Salix hookeriana	Coast willow
Salix lasiandra	Red willow
Salix sitchensis	Sitka willow
Scirpus americanus	Tree-square bulrush
Scirpus microcarpus	Small-fruited bulrush
Scirpus validus	Softstem bulrush
Sium suave	Hemlock water parsnip
Spiraea douglasii	Western spiraea
Triglochin maritimum	Seaside arrow-grass
Typha angustifolia	Lesser cattail
Typha latifolia	Common cattail

FISH

Alosa sapidissima	American shad
Clupea harengus pallasi	Pacific herring
Cymatogaster aggregata	Shiner perch
Engraulis mordax	Northern anchovy
Leptocottus armatus	Pacific staghorn sculpin
Oncorhynchus kisutch	Coho salmon
Oncorhynchus tshawytscha	Chinook salmon
Parophrys vetulus	English sole

Platichthys stellatus	Starry flounder
Spirinchus thaleichthys	Longfin smelt

BIRDS

Aechmophorus occidentalis	Western grebe
Anser platyrhynchos	Mallard
Ardea herodias	Great blue heron
Aythya valisineria	Canvasback
Calidris alba	Sanderling
Calidris alpina	Dunlin
Calidris mauri	Western sandpiper
Haliaeetus leucocephalus	Bald eagle
Larus sp.	Gull
Melanitta perspicillata	Surf scoter
Mergus merganser	Common merganser
Phalacrocorax auritus	Double-crested cormorant
Phalacrocorax pelagicus	Pelagic cormorant

MARINE MAMMALS

Eumetopias jubatus	Northern sea lion
Phoca vitulina	Harbor seal
Zalophus californianus	California sea lion

AQUATIC AND TERRESTRIAL MAMMALS

Castor canadensis	Beaver
Lutra canadensis	River otter
Myocastor coypus	Nutria
Ondatra zibethicus	Muskrat
Procyon lotor	Raccoon

Appendix C - Table 2. Standing crop, total biomass, productivity, and total productivity of biological groups in the habitat types of Columbia River Estuary regions. (nd = no data. Where no value is indicated, the biological group does not occur in the habitat type.)

REGION: 1 (Entrance)
HABITAT TYPE: 1 (water column)
AREA (hectares): 3,105

BIOLOGICAL GROUPS	Standing Crop[a]	Total Biomass[b]	Productivity[c]	Total Productivity[d]
Phytoplankton	13.2	40,986	410	1,273,050
Benthic Primary Producers				
Marsh Plants				
Zooplankton	nd	nd	nd	nd
Epibenthic Organisms				
Benthic Infauna				
Fish	1.18	3,664	0.59	1,832
Birds	nd	nd	nd	nd
Marine Mammals	0.40	1,242	0.07	217
Aquatic and Terrestrial Mammals	nd	nd	nd	nd

a. kilograms of carbon per hectare: kgC/ha
b. kilograms of carbon: kgC
c. kilograms of carbon per hectare per year: kgC/ha/yr
d. kilograms of carbon per year: kgC/yr

Appendix C - Table 2. (continued)

REGION: 1 (Entrance)
HABITAT TYPE: 4 (tidal flats)
AREA (hectares): 215

BIOLOGICAL GROUPS	Standing Crop[a]	Total Biomass[b]	Productivity[c]	Total Productivity[d]
Phytoplankton				
Benthic Primary Producers	13.3	2,860	34.9	7,504
Marsh Plants				
Zooplankton				
Epibenthic Organisms	nd	nd	nd	nd
Benthic Infauna	0.77	165	3.13	672
Fish	nd	nd	nd	nd
Birds	Incidental			
Marine Mammals	Included in water column habitat type, Region 1			
Aquatic and Terrestrial Mammals	nd	nd	nd	nd

a. kilograms of carbon per hectare: kgC/ha
b. kilograms of carbon: kgC
c. kilograms of carbon per hectare per year: kgC/ha/yr
d. kilograms of carbon per year: kgC/yr

Appendix C - Table 2. (continued)

REGION: 1 (Entrance)
HABITAT TYPE: 6 (channel bottom)
AREA (hectares): 2,420

BIOLOGICAL GROUPS	Standing Crop[a]	Total Biomass[b]	Productivity[c]	Total Productivity[d]
Phytoplankton				
Benthic Primary Producers				
Marsh Plants				
Zooplankton				
Epibenthic Organisms	0.50	1,209	4.06	9,826
Benthic Infauna	1.05	2,540	4.30	10,406
Fish	nd	nd	nd	nd
Birds				
Marine Mammals				
Aquatic and Terrestrial Mammals				

a. kilograms of carbon per hectare: kgC/ha
b. kilograms of carbon: kgC
c. kilograms of carbon per hectare per year: kgC/ha/yr
d. kilograms of carbon per year: kgC/yr

Appendix C - Table 2. (continued)

REGION: 2 (Baker Bay/Trestle Bay)
HABITAT TYPE: 1 (water column)
AREA (hectares): 1,654

BIOLOGICAL GROUPS	Standing Crop[a]	Total Biomass[b]	Productivity[c]	Total Productivity[d]
Phytoplankton	nd	nd	415	686,410
Benthic Primary Producers				
Marsh Plants				
Zooplankton	nd	nd	nd	nd
Epibenthic Organisms				
Benthic Infauna				
Fish	nd	nd	nd	nd
Birds	Included in low marsh habitat type, Region 2			
Marine Mammals	Included in low marsh habitat type, Region 3			
Aquatic and Terrestrial Mammals				

a. kilograms of carbon per hectare: kgC/ha
b. kilograms of carbon: kgC
c. kilograms of carbon per hectare per year: kgC/ha/yr
d. kilograms of carbon per year: kgC/yr

Appendix C - Table 2. (continued)

REGION: 2 (Baker Bay/Trestle Bay)
HABITAT TYPE: 2 (high marsh/swamp)
AREA (hectares): 100

BIOLOGICAL GROUPS	Standing Crop[a]	Total Biomass[b]	Productivity[c]	Total Productivity[d]
Phytoplankton				
Benthic Primary Producers				
Marsh Plants	3,190	319,000	3,310	331,000
Zooplankton				
Epibenthic Organisms				
Benthic Infauna				
Fish				
Birds	Included in low marsh habitat type, Region 2			
Marine Mammals				
Aquatic and Terrestrial Mammals	2.03	203	1.42	142

a. kilograms of carbon per hectare: kgC/ha
b. kilograms of carbon: kgC
c. kilograms of carbon per hectare per year: kgC/ha/yr
d. kilograms of carbon per year: kgC/yr

Appendix C - Table 2. (continued)

REGION: 2 (Baker Bay/Trestle Bay)
HABITAT TYPE: 3 (low marsh)
AREA (hectares): 285

BIOLOGICAL GROUPS	Standing Crop[a]	Total Biomass[b]	Productivity[c]	Total Productivity[d]
Phytoplankton				
Benthic Primary Producers	261	74,385	418	119,130
Marsh Plants	3,700	1,054,500	3,720	1,060,200
Zooplankton				
Epibenthic Organisms				
Benthic Infauna				
Fish				
Birds (includes habitat types 1, 2, and 4 of Region 2)	0.32	493	0.24	388
Marine Mammals	Incidental			
Aquatic and Terrestrial Mammals	1.70	484	1.19	339

a. kilograms of carbon per hectare: kgC/ha
b. kilograms of carbon: kgC
c. kilograms of carbon per hectare per year: kgC/ha/yr
d. kilograms of carbon per year: kgC/yr

Appendix C - Table 2. (continued)

REGION: 2 (Baker Bay/Trestle Bay)
HABITAT TYPE: 4 (tidal flats)
AREA (hectares): 2,265

BIOLOGICAL GROUPS	Standing Crop[a]	Total Biomass[b]	Productivity[c]	Total Productivity[d]
Phytoplankton				
Benthic Primary Producers	183	414,495	341	772,365
Marsh Plants				
Zooplankton	nd	nd	nd	nd
Epibenthic Organisms	0.31	701	2.54	5,752
Benthic Infauna	35.7	80,905	49.8	112,888
Fish	1.02	2,310	0.51	1,155
Birds	Included in low marsh habitat type, Region 2.			
Marine Mammals	Included in low marsh habitat type, Region 3.			
Aquatic and Terrestrial Mammals	nd	nd	nd	nd

a. kilograms of carbon per hectare: kgC/ha
b. kilograms of carbon: kgC
c. kilograms of carbon per hectare per year: kgC/ha/yr
d. kilograms of carbon per year: kgC/yr

Appendix C - Table 2. (continued)

REGION: 2 (Baker Bay/Trestle Bay)
HABITAT TYPE: 5 (demersal slope)
AREA (hectares): 712

BIOLOGICAL GROUPS	Standing Crop[a]	Total Biomass[b]	Productivity[c]	Total Productivity[d]
Phytoplankton				
Benthic Primary Producers				
Marsh Plants				
Zooplankton				
Epibenthic Organisms	1.09	776	8.83	6,286
Benthic Infauna	23.26	16,561	28.55	20,328
Fish	0.48	342	0.24	171
Birds				
Marine Mammals	Included in water column habitat type, Region 3			
Aquatic and Terrestrial Mammals				

a. kilograms of carbon per hectare: kgC/ha
b. kilograms of carbon: kgC
c. kilograms of carbon per hectare per year: kgC/ha/yr
d. kilograms of carbon per year: kgC/yr

Appendix C - Table 2. (continued)

REGION: 3 (Estuarine Channels)
HABITAT TYPE: 1 (water column)
AREA (hectares): 7,437

BIOLOGICAL GROUPS	Standing Crop[a]	Total Biomass[b]	Productivity[c]	Total Productivity[d]
Phytoplankton	20	148,740	502	3,733,374
Benthic Primary Producers				
Marsh Plants				
Zooplankton	21.9	162,871	219	1,625,728
Epibenthic Organisms				
Benthic Infauna				
Fish/Larval Fishes	0.18/3.20	1,339/23,798	0.24/3.20	1,785/23,798
Birds	nd	nd	nd	nd
Marine Mammals	Incidental			
Aquatic and Terrestrial Mammals				

a. kilograms of carbon per hectare: kgC/ha
b. kilograms of carbon: kgC
c. kilograms of carbon per hectare per year: kgC/ha/yr
d. kilograms of carbon per year: kgC/yr

Appendix C - Table 2. (continued)

REGION: 3 (Estuarine Channels)
HABITAT TYPE: 5 (demersal slope)
AREA (hectares): 1,501

BIOLOGICAL GROUPS	Standing Crop[a]	Total Biomass[b]	Productivity[c]	Total Productivity[d]
Phytoplankton				
Benthic Primary Producers				
Marsh Plants				
Zooplankton				
Epibenthic Organisms	nd	nd	nd	nd
Benthic Infauna	4.04	6,064	13.5	20,203
Fish	1.13	1,696	0.57	856
Birds				
Marine Mammals	Included in water column habitat type, Region 3.			
Aquatic and Terrestrial Mammals				

a. kilograms of carbon per hectare: kgC/ha
b. kilograms of carbon: kgC
c. kilograms of carbon per hectare per year: kgC/ha/yr
d. kilograms of carbon per year: kgC/yr

Appendix C - Table 2. (continued)

REGION: 3 (Estuarine Channels)
HABITAT TYPE: 6 (channel bottom)
AREA (hectares): 5,854

BIOLOGICAL GROUPS	Standing Crop[a]	Total Biomass[b]	Productivity[c]	Total Productivity[d]
Phytoplankton				
Benthic Primary Producers				
Marsh Plants				
Zooplankton				
Epibenthic Organisms	0.26	1,522	2.27	13,288
Benthic Infauna	0.99	5,795	4.09	23,943
Fish	1.51	8,840	0.76	4,450
Birds				
Marine Mammals	Included in water column habitat type, Region 3.			
Aquatic and Terrestrial Mammals				

a. kilograms of carbon per hectare: kgC/ha
b. kilograms of carbon: kgC
c. kilograms of carbon per hectare per year: kgC/ha/yr
d. kilograms of carbon per year: kgC/yr

Appendix C - Table 2. (continued)

REGION: 4 (Youngs Bay)
HABITAT TYPE: 1 (water column)
AREA (hectares): 1,277

BIOLOGICAL GROUPS	Standing Crop[a]	Total Biomass[b]	Productivity[c]	Total Productivity[d]
Phytoplankton	3.78	4,827	318	406,086
Benthic Primary Producers				
Marsh Plants				
Zooplankton	nd	nd	nd	nd
Epibenthic Organisms				
Benthic Infauna				
Fish	nd	nd	nd	nd
Birds	Included in low marsh habitat type, Region 4.			
Marine Mammals	Included in water column habitat type, Region 3.			
Aquatic and Terrestrial Mammals				

a. kilograms of carbon per hectare: kgC/ha
b. kilograms of carbon: kgC
c. kilograms of carbon per hectare per year: kgC/ha/yr
d. kilograms of carbon per year: kgC/yr

Appendix C - Table 2. (continued)

REGION: 4 (Youngs Bay)
HABITAT TYPE: 2 (high marsh/swamp)
AREA (hectares): 185

BIOLOGICAL GROUPS	Standing Crop[a]	Total Biomass[b]	Productivity[c]	Total Productivity[d]
Phytoplankton				
Benthic Primary Producers				
Marsh Plants	3,190	590,150	3,310	612,350
Zooplankton				
Epibenthic Organisms				
Benthic Infauna				
Fish				
Birds	Included in low marsh habitat type, Region 4.			
Marine Mammals				
Aquatic and Terrestrial Mammals	2.03	376	1.42	263

a. kilograms of carbon per hectare: kgC/ha
b. kilograms of carbon: kgC
c. kilograms of carbon per hectare per year: kgC/ha/yr
d. kilograms of carbon per year: kgC/yr

Appendix C - Table 2. (continued)

REGION: 4 (Youngs Bay)
HABITAT TYPE: 3 (low marsh)
AREA (hectares): 285

BIOLOGICAL GROUPS		Standing Crop[a]	Total Biomass[b]	Productivity[c]	Total Productivity[d]
Phytoplankton					
Benthic Primary Producers		296	84,360	695	198,075
Marsh Plants		7,020	2,000,700	7,020	2,000,700
Zooplankton					
Epibenthic Organisms					
Benthic Infauna					
Fish					
Birds	(includes habitat types 1, 2, and 4 of Region 4)	0.48	82.2	0.28	1,366
Marine Mammals					
Aquatic and Terrestrial Mammals		1.70	484	1.19	339

a. kilograms of carbon per hectare: kgC/ha
b. kilograms of carbon: kgC
c. kilograms of carbon per hectare per year: kgC/ha/yr
d. kilograms of carbon per year: kgC/yr

Appendix C - Table 2. (continued)

REGION: 4 (Youngs Bay)
HABITAT TYPE: 4 (tidal flats)
AREA (hectares): 1,020

BIOLOGICAL GROUPS	Standing Crop[a]	Total Biomass[b]	Productivity[c]	Total Productivity[d]
Phytoplankton				
Benthic Primary Producers	184	187,680	341	347,820
Marsh Plants				
Zooplankton	nd	nd	nd	nd
Epibenthic Organisms	0.33	336	2.78	2,836
Benthic Infauna	6.78	6,915	25.9	26,449
Fish	1.53	1,561	0.77	785
Birds	Included in low marsh habitat type, Region 4.			
Marine Mammals	Included in water column habitat type, Region 3.			
Aquatic and Terrestrial Mammals	nd	nd	nd	nd

a. kilograms of carbon per hectare: kgC/ha
b. kilograms of carbon: kgC
c. kilograms of carbon per hectare per year: kgC/ha/yr
d. kilograms of carbon per year: kgC/yr

Appendix C - Table 2. (continued)

REGION: 4 (Youngs Bay)
HABITAT TYPE: 5 (demersal slope)
AREA (hectares): 680

BIOLOGICAL GROUPS	Standing Crop[a]	Total Biomass[b]	Productivity[c]	Total Productivity[d]
Phytoplankton				
Benthic Primary Producers				
Marsh Plants				
Zooplankton				
Epibenthic Organisms	nd	nd	nd	nd
Benthic Infauna	14.9	10,179	28.5	19,386
Fish	0.98	666	0.49	333
Birds				
Marine Mammals	Included in water column habitat type, Region 3.			
Aquatic and Terrestrial Mammals				

a. kilograms of carbon per hectare: kgC/ha
b. kilograms of carbon: kgC
c. kilograms of carbon per hectare per year: kgC/ha/yr
d. kilograms of carbon per year: kgC/yr

Appendix C - Table 2. (continued)

REGION: 5 (Mid-estuary Shoals)
HABITAT TYPE: 1 (water column)
AREA (hectares): 5,094

BIOLOGICAL GROUPS	Standing Crop[a]	Total Biomass[b]	Productivity[c]	Total Productivity[d]
Phytoplankton	1.31	6,673	508	2,587,752
Benthic Primary Producers				
Marsh Plants				
Zooplankton	nd	nd	nd	nd
Epibenthic Organisms				
Benthic Infauna				
Fish	nd	nd	nd	nd
Birds	nd	nd	nd	nd
Marine Mammals	Included in water column habitat type, Region 3.			
Aquatic and Terrestrial Mammals				

a. kilograms of carbon per hectare: kgC/ha
b. kilograms of carbon: kgC
c. kilograms of carbon per hectare per year: kgC/ha/yr
d. kilograms of carbon per year: kgC/yr

Appendix C - Table 2. (continued)

REGION: 5 (Mid-estuary Shoals)
HABITAT TYPE: 4 (tidal flats)
AREA (hectares): 1,293

BIOLOGICAL GROUPS	Standing Crop[a]	Total Biomass[b]	Productivity[c]	Total Productivity[d]
Phytoplankton				
Benthic Primary Producers	68.6	88,700	130	168,090
Marsh Plants				
Zooplankton	nd	nd	nd	nd
Epibenthic Organisms	0.28	362	2.42	2,943
Benthic Infauna	1.02	1,319	4.79	6,194
Fish	4.41	5,702	2.21	2,858
Birds	nd	nd	nd	nd
Marine Mammals	Included in water column habitat type, Region 3.			
Aquatic and Terrestrial Mammals				

a. kilograms of carbon per hectare: kgC/ha
b. kilograms of carbon: kgC
c. kilograms of carbon per hectare per year: kgC/ha/yr
d. kilograms of carbon per year: kgC/yr

Appendix C - Table 2. (continued)

REGION: 5 (Mid-estuary Shoals)
HABITAT TYPE: 5 (demersal slope)
AREA (hectares): 3,645

BIOLOGICAL GROUPS	Standing Crop[a]	Total Biomass[b]	Productivity[c]	Total Productivity[d]
Phytoplankton				
Benthic Primary Producers				
Marsh Plants				
Zooplankton				
Epibenthic Organisms	0.44	1,604	3.76	13,705
Benthic Infauna	0.53	1,933	1.94	7,071
Fish	0.36	1,312	0.18	656
Birds				
Marine Mammals	Included in water column habitat type, Region 3.			
Aquatic and Terrestrial Mammals				

a. kilograms of carbon per hectare: kgC/ha
b. kilograms of carbon: kgC
c. kilograms of carbon per hectare per year: kgC/ha/yr
d. kilograms of carbon per year: kgC/yr

Appendix C - Table 2. (continued)

REGION: 6 (Grays Bay)
HABITAT TYPE: 1 (water column)
AREA (hectares): 3,512

BIOLOGICAL GROUPS	Standing Crop[a]	Total Biomass[b]	Productivity[c]	Total Productivity[d]
Phytoplankton	13	45,656	392	1,376,704
Benthic Primary Producers				
Marsh Plants				
Zooplankton	nd	nd	nd	nd
Epibenthic Organisms				
Benthic Infauna				
Fish	0.57	2,002	0.29	1,018
Birds	Included in low marsh habitat type, Region 6.			
Marine Mammals	Included in water column habitat type, Region 7.			
Aquatic and Terrestrial Mammals				

a. kilograms of carbon per hectare: kgC/ha
b. kilograms of carbon: kgC
c. kilograms of carbon per hectare per year: kgC/ha/yr
d. kilograms of carbon per year: kgC/yr

Appendix C - Table 2. (continued)

REGION: 6 (Grays Bay)
HABITAT TYPE: 2 (high marsh/swamp)
AREA (hectares): 299

BIOLOGICAL GROUPS	Standing Crop[a]	Total Biomass[b]	Productivity[c]	Total Productivity[d]
Phytoplankton				
Benthic Primary Producers				
Marsh Plants	4,200	1,255,800	4,220	1,261,780
Zooplankton				
Epibenthic Organisms				
Benthic Infauna				
Fish				
Birds	Included in low marsh habitat type, Region 6.			
Marine Mammals				
Aquatic and Terrestrial Mammals	2.21	661	1.54	460

a. kilograms of carbon per hectare: kgC ha
b. kilograms of carbon: kgC
c. kilograms of carbon per hectare per year: kgC/ha/yr
d. kilograms of carbon per year: kgC/yr

Appendix C - Table 2. (continued)

REGION: 6 (Grays Bay)
HABITAT TYPE: 3 (low marsh)
AREA (hectares): 274

BIOLOGICAL GROUPS	Standing Crop[a]	Total Biomass[b]	Productivity[c]	Total Productivity[d]
Phytoplankton				
Benthic Primary Producers	104	28,496	266	72,884
Marsh Plants	2,060	564,440	2,370	649,380
Zooplankton				
Epibenthic Organisms				
Benthic Infauna				
Fish				
Birds (includes habitat types 1, 2, and 4 of Region 6)	0.56	1,455	0.42	1,059
Marine Mammals				
Aquatic and Terrestrial Mammals	1.70	466	1.19	326

a. kilograms of carbon per hectare: kgC/ha
b. kilograms of carbon: kgC
c. kilograms of carbon per hectare per year: kgC/ha/yr
d. kilograms of carbon per year: kgC/yr

Appendix C - Table 2. (continued)

REGION: 6 (Grays Bay)
HABITAT TYPE: 4 (tidal flats)
AREA (hectares): 1,978

BIOLOGICAL GROUPS	Standing Crop[a]	Total Biomass[b]	Productivity[c]	Total Productivity[d]
Phytoplankton				
Benthic Primary Producers	61.2	121,054	127	251,206
Marsh Plants				
Zooplankton	nd	nd	nd	nd
Epibenthic Organisms	0.63	1,246	5.68	11,234
Benthic Infauna	4.38	8,664	20.0	39,560
Fish	0.84	1,661	0.42	831
Birds	Included in low marsh habitat type, Region 6.			
Marine Mammals	Included in water column habitat type, Region 7.			
Aquatic and Terrestrial Mammals				

a. kilograms of carbon per hectare: kgC/ha
b. kilograms of carbon: kgC
c. kilograms of carbon per hectare per year: kgC/ha/yr
d. kilograms of carbon per year: kgC/yr

Appendix C - Table 2. (continued)

REGION: 6 (Grays Bay)
HABITAT TYPE: 5 (demersal slope)
AREA (hectares): 1,820

BIOLOGICAL GROUPS	Standing Crop[a]	Total Biomass[b]	Productivity[c]	Total Productivity[d]
Phytoplankton				
Benthic Primary Producers				
Marsh Plants				
Zooplankton				
Epibenthic Organisms	0.28	510	2.36	4,294
Benthic Infauna	4.42	8,044	20.5	37,328
Fish				
Birds				
Marine Mammals	Included in water column habitat type, Region 7.			
Aquatic and Terrestrial Mammals				

a. kilograms of carbon per hectare: kgC/ha
b. kilograms of carbon: kgC
c. kilograms of carbon per hectare per year: kgC/ha/yr
d. kilograms of carbon per year: kgC/yr

Appendix C - Table 2. (continued)

REGION: 7 (Cathlamet Bay)
HABITAT TYPE: 1 (water column)
AREA (hectares): 6,036

BIOLOGICAL GROUPS	Standing Crop[a]	Total Biomass[b]	Productivity[c]	Total Productivity[d]
Phytoplankton	18.0	108,648	619	3,736,284
Benthic Primary Producers				
Marsh Plants				
Zooplankton	nd	nd	nd	nd
Epibenthic Organisms				
Benthic Infauna				
Fish	0.60	3,622	0.30	1,811
Birds	Included in low marsh habitat type, Region 7.			
Marine Mammals	Incidental			
Aquatic and Terrestrial Mammals				

a. kilograms of carbon per hectare: kgC/ha
b. kilograms of carbon: kgC
c. kilograms of carbon per hectare per year: kgC/ha/yr
d. kilograms of carbon per year: kgC/yr

Appendix C - Table 2. (continued)

REGION: 7 (Cathlamet Bay)
HABITAT TYPE: 2 (high marsh/swamp)
AREA (hectares): 2,036

BIOLOGICAL GROUPS	Standing Crop[a]	Total Biomass[b]	Productivity[c]	Total Productivity[d]
Phytoplankton				
Benthic Primary Producers				
Marsh Plants	3,450	7,024,200	3,720	7,573,920
Zooplankton				
Epibenthic Organisms				
Benthic Infauna				
Fish				
Birds	Included in low marsh habitat type, Region 7.			
Marine Mammals				
Aquatic and Terrestrial Mammals	2.21	4,500	1.54	3,135

a kilograms of carbon per hectare: kgC/ha
b kilograms of carbon: kgC
c kilograms of carbon per hectare per year: kgC/ha/yr
d kilograms of carbon per year: kgC/yr

Appendix C - Table 2. (continued)

REGION: 7 (Cathlamet Bay)
HABITAT TYPE: 3 (low marsh)
AREA (hectares): 1,823

BIOLOGICAL GROUPS	Standing Crop[a]	Total Biomass[b]	Productivity[c]	Total Productivity[d]
Phytoplankton				
Benthic Primary Producers	71.1	129,615	145	264,335
Marsh Plants	2,090	3,810,070	2,470	4,502,810
Zooplankton				
Epibenthic Organisms				
Benthic Infauna				
Fish				
Birds (includes habitat types 1, 2, and 4 of Region 7)	0.58	2,275	0.38	1,370
Marine Mammals				
Aquatic and Terrestrial Mammals	1.70	3,099	1.19	2,169

a. kilograms of carbon per hectare: kgC/ha
b. kilograms of carbon: kgC
c. kilograms of carbon per hectare per year: kgC/ha/yr
d. kilograms of carbon per year: kgC/yr

Appendix C - Table 2. (continued)

REGION: 7 (Cathlamet Bay)
HABITAT TYPE: 4 (tidal flats)
AREA (hectares): 2,703

BIOLOGICAL GROUPS	Standing Crop[a]	Total Biomass[b]	Productivity[c]	Total Productivity[d]
Phytoplankton				
Benthic Primary Producers	62.4	168,667	134	362,202
Marsh Plants				
Zooplankton	nd	nd	nd	nd
Epibenthic Organisms	nd	nd	nd	nd
Benthic Infauna	5.15	13,920	13.0	35,247
Fish	nd	nd	nd	nd
Birds	Included in low marsh habitat type, Region 7.			
Marine Mammals	Included in water column habitat type, Region 7.			
Aquatic and Terrestrial Mammals				

a. kilograms of carbon per hectare: kgC/ha
b. kilograms of carbon: kgC
c. kilograms of carbon per hectare per year: kgC/ha/yr
d. kilograms of carbon per year: kgC/yr

Appendix C - Table 2. (continued)

REGION: 7 (Cathlamet Bay)
HABITAT TYPE: 5 (demersal slope)
AREA (hectares): 3,197

BIOLOGICAL GROUPS	Standing Crop[a]	Total Biomass[b]	Productivity[c]	Total Productivity[d]
Phytoplankton				
Benthic Primary Producers				
Marsh Plants				
Zooplankton				
Epibenthic Organisms	nd	nd	nd	nd
Benthic Infauna	9.04	28,900	13.8	44,215
Fish	2.44	7,800	1.22	3,900
Birds				
Marine Mammals	Included in water column habitat type, Region 7.			
Aquatic and Terrestrial Mammals				

a. kilograms of carbon per hectare: kgC/ha
b. kilograms of carbon: kgC
c. kilograms of carbon per hectare per year: kgC/ha/yr
d. kilograms of carbon per year: kgC/yr

Appendix C - Table 2. (continued)

REGION: 7 (Cathlamet Bay)
HABITAT TYPE: 6 (channel bottom)
AREA (hectares): 895

BIOLOGICAL GROUPS	Standing Crop[a]	Total Biomass[b]	Productivity[c]	Total Productivity[d]
Phytoplankton				
Benthic Primary Producers				
Marsh Plants				
Zooplankton				
Epibenthic Organisms	0.08	71.6	0.70	626
Benthic Infauna	nd	nd	nd	nd
Fish	0.31	277	0.16	143
Birds				
Marine Mammals	Included in water column habitat type, Region 7.			
Aquatic and Terrestrial Mammals				

a. kilograms of carbon per hectare: kgC/ha
b. kilograms of carbon: kgC
c. kilograms of carbon per hectare per year: kgC/ha/yr
d. kilograms of carbon per year: kgC/yr

Appendix C - Table 2. (continued)

REGION: 8 (Fluvial Region)
HABITAT TYPE: 1 (water column)
AREA (hectares): 3,203

BIOLOGICAL GROUPS	Standing Crop[a]	Total Biomass[b]	Productivity[c]	Total Productivity[d]
Phytoplankton	28.9	92,567	716	2,293,348
Benthic Primary Producers				
Marsh Plants				
Zooplankton	7.40	23,702	74.1	237,342
Epibenthic Organisms				
Benthic Infauna				
Fish/Larval Fishes	0.37/2.0	1,185/6,406	0.19/2.0	608/6,406
Birds	Included in low marsh habitat type, Region 8.			
Marine Mammals	Included in water column habitat type, Region 7.			
Aquatic and Terrestrial Mammals				

a. kilograms of carbon per hectare: kgC/ha
b. kilograms of carbon: kgC
c. kilograms of carbon per hectare per year: kgC/ha/yr
d. kilograms of carbon per year: kgC/yr

Appendix C - Table 2. (continued)

REGION: 8 (Fluvial Region)
HABITAT TYPE: 2 (high marsh/swamp)
AREA (hectares): 449

BIOLOGICAL GROUPS	Standing Crop[a]	Total Biomass[b]	Productivity[c]	Total Productivity[d]
Phytoplankton				
Benthic Primary Producers				
Marsh Plants	6,010	2,698,490	6,010	2,698,490
Zooplankton				
Epibenthic Organisms				
Benthic Infauna				
Fish				
Birds	Included in low marsh habitat type, Region 8.			
Marine Mammals				
Aquatic and Terrestrial Mammals	2.21	992	1.54	691

a. kilograms of carbon per hectare: kgC/ha
b. kilograms of carbon: kgC
c. kilograms of carbon per hectare per year: kgC/ha/yr
d. kilograms of carbon per year: kgC/yr

Appendix C - Table 2. (continued)

REGION: 8 (Fluvial Region)
HABITAT TYPE: 3 (low marsh)
AREA (hectares): 174

BIOLOGICAL GROUPS	Standing Crop[a]	Total Biomass[b]	Productivity[c]	Total Productivity[d]
Phytoplankton				
Benthic Primary Producers	128	22,272	287	49,938
Marsh Plants	3,110	541,140	311	54,114
Zooplankton				
Epibenthic Organisms				
Benthic Infauna				
Fish				
Birds (includes habitat types 1, 2, and 4 of Region 8)	0.58	911	0.38	506
Marine Mammals	Incidental			
Aquatic and Terrestrial Mammals	1.70	296	1.19	207

a. kilograms of carbon per hectare: kgC/ha
b. kilograms of carbon: kgC
c. kilograms of carbon per hectare per year: kgC/ha/yr
d. kilograms of carbon per year: kgC/yr

Appendix C - Table 2. (continued)

REGION: 8 (Fluvial Region)
HABITAT TYPE: 4 (tidal flats)
AREA (hectares): 334

BIOLOGICAL GROUPS	Standing Crop[a]	Total Biomass[b]	Productivity[c]	Total Productivity[d]
Phytoplankton				
Benthic Primary Producers	57.3	19,138	138	46,092
Marsh Plants				
Zooplankton	nd	nd	nd	nd
Epibenthic Organisms	0.12	40	0.98	328
Benthic Infauna	6.03	2,014	17.58	5,872
Fish	0.54	180	0.27	90
Birds	Included in low marsh habitat type, Region 8.			
Marine Mammals	Included in water column habitat type, Region 7.			
Aquatic and Terrestrial Mammals				

a. kilograms of carbon per hectare: kgC/ha
b. kilograms of carbon: kgC
c. kilograms of carbon per hectare per year: kgC/ha/yr
d. kilograms of carbon per year: kgC/yr

Appendix C - Table 2. (continued)

REGION: 8 (Fluvial Region)
HABITAT TYPE: 5 (demersal slope)
AREA (hectares): 958

BIOLOGICAL GROUPS	Standing Crop[a]	Total Biomass[b]	Productivity[c]	Total Productivity[d]
Phytoplankton				
Benthic Primary Producers				
Marsh Plants				
Zooplankton				
Epibenthic Organisms	0.06	57.4	0.48	460
Benthic Infauna	3.05	2,343	5.59	5,354
Fish	0.60	575	0.30	287
Birds				
Marine Mammals	Included in water column habitat type, Region 7.			
Aquatic and Terrestrial Mammals				

a. kilograms of carbon per hectare: kgC/ha
b. kilograms of carbon: kgC
c. kilograms of carbon per hectare per year: kgC/ha/yr
d. kilograms of carbon per year: kgC/yr

Appendix C - Table 2. (continued)

REGION: 8 (Fluvial Region)
HABITAT TYPE: 6 (channel bottom)
AREA (hectares): 1,976

BIOLOGICAL GROUPS	Standing Crop[a]	Total Biomass[b]	Productivity[c]	Total Productivity[d]
Phytoplankton				
Benthic Primary Producers				
Marsh Plants				
Zooplankton				
Epibenthic Organisms	0.06	119	0.44	870
Benthic Infauna	8.55	16,900	10.12	20,000
Fish	0.43	850	0.22	435
Birds				
Marine Mammals	Included in water column habitat type, Region 7.			
Aquatic and Terrestrial Mammals				

a. kilograms of carbon per hectare: kgC/ha
b. kilograms of carbon: kgC
c. kilograms of carbon per hectare per year: kgC/ha/yr
d. kilograms of carbon per year: kgC/yr

APPENDIX D

Worksheets for environmental assessments

(referred to in Chapter 3)

Worksheet 1. Changes in areas of estuarine habitat types resulting from management activity

Proposed activity:_______________

Site affected:_______________

Region:_______________

Habitat type (Fig 4)	A. hectares before change	B. hectares after change	C. hectares gained or lost (A-B: loss B-A: gain)	D. hectares in region (Table 1)	E. % gain or loss (C/Dx100)
WC					
HM					
LM					
TF					
DS					
CB					

Worksheet 2. Changes in biomass and productivity resulting from loss or gain of estuarine habitat type area (see page 26)

Site affected: ______________

Region: ______________

Habitat type: ______________

# of hectares lost or gained: ______________

Biological Group	Standing Crop[a]	Change in biomass[b]	Productivity per unit area[c]	Change in productivity[d]
PRIMARY PRODUCERS				
Phytoplankton				
Benthic Primary Producers				
Marsh Plants				
Total Primary Producers				
CONSUMERS				
Zooplankton				
Epibenthic Organisms				
Benthic Infauna				
Total Consumers				

a. Kilograms of carbon per hectare
b. Kilograms of carbon
c. Kilograms of carbon per hectare per year
d. Kilograms of carbon per year

Worksheet 3a. Regional summary of change in biomass

Site affected: ______________

Region: ____________________

Biological Group	A. Total biomass[a] change (sum all habitat types)	B. Total biomass[a] in region (Appendix C, Table 2)	C. % gain or loss (A/Bx100)
PRIMARY PRODUCERS			
Phytoplankton			
Benthic Primary Producers			
Marsh Plants			
Total Primary Producers			
CONSUMERS			
Zooplankton			
Epibenthic Organisms			
Benthic Infauna			
Total Consumers			

a. Kilograms of carbon

Worksheet 3b. Regional summary of change in productivity

Site affected: ______________

Region: ____________________

Biological Group	A. Total productivity[a] change (sum all habitat types)	B. Total productivity[a] in region (Appendix C, Table 2)	C. % gain or loss (A/Bx100)
PRIMARY PRODUCERS			
Phytoplankton			
Benthic Primary Producers			
Marsh Plants			
Total Primary Producers			
CONSUMERS			
Zooplankton			
Epibenthic Organisms			
Benthic Infauna			
Total Consumers			

a. Kilograms of carbon per year

Worksheet 4. Major species directly dependent on estuarine habitat type (see Appendix C, Table 1)

Site affected: ________________

Region: ____________________

Habitat type: _________________

Phytoplankton	Benthic Primary Producers	Marsh Plants	Zooplankton	Epibenthic Organisms	Benthic Infauna

Worksheet 5. Major species indirectly dependent on estuarine habitat type (see Appendix C, Table 1)

Site affected: ____________________

Region: ____________________

Habitat type: ____________________

Zooplankton	Fish	Birds	Marine Mammals	Aquatic and Terrestrial Mammals

APPENDIX E

Tables for environmental assessments

(referred to in Chapter 5)

Table 1

Worksheet 1. Changes in areas of estuarine habitat types resulting from management activity

Proposed activity: Fill to above tidal level

Site affected: Alder Cove

Region: Youngs Bay

Habitat type (Fig 4)	A. hectares before change	B. hectares after change	C. hectares gained or lost (A-B: loss B-A: gain)	D. hectares in region (Table 1)	E. % gain or loss (C/Dx100)
WC	5.50	0	5.50 (loss)	1277	0.4%(loss)
HM	8.95	0	8.95 (loss)	185	4.8%(loss)
LM	30.05	0	30.05 (loss)	285	10.5%(loss)
TF	62.84	0	62.84 (loss)	1,020	6.2%(loss)
DS	not present				
CB	not present				

Table 2a

Worksheet 2. Changes in biomass and productivity resulting from loss or gain of estuarine habitat type area (see page 26)

Site affected: Alder Cove

Region: Youngs Bay

Habitat type: Water column

# of hectares lost or gained: 5.50 lost

Biological Group	Standing Crop[a]	Change in biomass[b]	Productivity per unit area[c]	Change in productivity[d]
PRIMARY PRODUCERS				
Phytoplankton	3.78	20.8(loss)	318	1,749(loss)
Benthic Primary Producers				
Marsh Plants				
Total Primary Producers		20.8(loss)		1,749(loss)
CONSUMERS				
Zooplankton	nd	nd	nd	nd
Epibenthic Organisms				
Benthic Infauna				
Total Consumers				

a. Kilograms of carbon per hectare
b. Kilograms of carbon
c. Kilograms of carbon per hectare per year
d. Kilograms of carbon per year

Table 2b

Worksheet 2. Changes in biomass and productivity resulting from loss or gain of estuarine habitat type area (see page 26)

Site affected: Alder Cove

Region: Youngs Bay

Habitat type: High marsh/swamp

# of hectares lost or gained: 8.95 lost

Biological Group	Standing Crop[a]	Change in biomass[b]	Productivity per unit area[c]	Change in productivity[d]
PRIMARY PRODUCERS				
Phytoplankton				
Benthic Primary Producers				
Marsh Plants	3,190	28,550(loss)	3,310	29,624(loss)
Total Primary Producers		28,550(loss)		29,624(loss)
CONSUMERS				
Zooplankton				
Epibenthic Organisms				
Benthic Infauna				
Total Consumers				

a. Kilograms of carbon per hectare
b. Kilograms of carbon
c. Kilograms of carbon per hectare per year
d. Kilograms of carbon per year

Table 2c

Worksheet 2. Changes in biomass and productivity resulting from loss or gain of estuarine habitat type area (see page 26)

Site affected: Alder Cove

Region: Youngs Bay

Habitat type: Low marsh

# of hectares lost or gained: 30.05 lost

Biological Group	Standing Crop[a]	Change in biomass[b]	Productivity per unit area[c]	Change in productivity[d]
PRIMARY PRODUCERS				
Phytoplankton				
Benthic Primary Producers	296	8,895(loss)	695	20,885(loss)
Marsh Plants	7,020	210,951(loss)	7,020	210,951(loss)
Total Primary Producers		219,846(loss)		231,836(loss)
CONSUMERS				
Zooplankton				
Epibenthic Organisms				
Benthic Infauna				
Total Consumers				

a. Kilograms of carbon per hectare
b. Kilograms of carbon
c. Kilograms of carbon per hectare per year
d. Kilograms of carbon per year

Table 2d

Worksheet 2. Changes in biomass and productivity resulting from loss or gain of estuarine habitat type area (see page 26)

Site affected: Alder Cove

Region: Youngs Bay

Habitat type: Tidal flats

# of hectares lost or gained: 62.84 lost

Biological Group	Standing Crop[a]	Change in biomass[b]	Productivity per unit area[c]	Change in productivity[d]
PRIMARY PRODUCERS				
Phytoplankton				
Benthic Primary Producers	184	11,562(loss)	341	21,428(loss)
Marsh Plants				
Total Primary Producers		11,562(loss)		21,428(loss)
CONSUMERS				
Zooplankton				
Epibenthic Organisms	0.33	21(loss)	2.78	175(loss)
Benthic Infauna	6.78	426(loss)	25.9	1,627(loss)
Total Consumers		447(loss)		1,802(loss)

a. Kilograms of carbon per hectare
b. Kilograms of carbon
c. Kilograms of carbon per hectare per year
d. Kilograms of carbon per year

Table 3a

Worksheet 3a. Regional summary of change in biomass

Site affected: Alder Cove

Region: Youngs Bay

Biological Group	A. Total biomass[a] change (sum all habitat types)	B. Total biomass[a] in region (Appendix C, Table 2)	C. % gain or loss (A/Bx100)
PRIMARY PRODUCERS			
Phytoplankton	21(loss)	4,827	0.4%(loss)
Benthic Primary Producers	20,457(loss)	272,040	7.5%(loss)
Marsh Plants	239,501(loss)	2,590,850	9.2%(loss)
Total Primary Producers	259,979(loss)	2,867,717	9.1%(loss)
CONSUMERS			
Zooplankton	nd		
Epibenthic Organisms	21(loss)	336	6.3%(loss)
Benthic Infauna	426(loss)	17,094	2.5%(loss)
Total Consumers	447(loss)	17,430	2.6%(loss)

a. Kilograms of carbon

Table 3b

Worksheet 3b. Regional summary of change in productivity

Site affected: Alder Cove

Region: Youngs Bay

Biological Group	A. Total productivity[a] change (sum all habitat types)	B. Total productivity[a] in region (Appendix C, Table 2)	C. % gain or loss (A/Bx100)
PRIMARY PRODUCERS			
Phytoplankton	1,749(loss)	406,086	0.4%(loss)
Benthic Primary Producers	42,313(loss)	545,895	7.8%(loss)
Marsh Plants	240,575(loss)	2,613,050	9.2%(loss)
Total Primary Producers	284,637(loss)	3,565,031	8.0%(loss)
CONSUMERS			
Zooplankton	nd	nd	nd
Epibenthic Organisms	175(loss)	2,836	6.2%(loss)
Benthic Infauna	1,627(loss)	45,835	3.5%(loss)
Total Consumers	1,802(loss)	48,671	3.7%(loss)

a. Kilograms of carbon per year

Table 4a

Worksheet 4. Major species directly dependent on estuarine habitat type (see Appendix C, Table 1)

Site affected: Alder Cove

Region: Youngs Bay

Habitat type: Water column

Phytoplankton	Benthic Primary Producers	Marsh Plants	Zooplankton	Epibenthic Organisms	Benthic Infauna
Asterionella formosa			Not applicable		
Fragilaria crotonensis					
Melosira granulata					
Melosira italica					

Table 4b

Worksheet 4. Major species directly dependent on estuarine habitat type (see Appendix C, Table 1)

Site affected: Alder Cove

Region: Youngs Bay

Habitat type: High marsh/swamp

Phytoplankton	Benthic Primary Producers	Marsh Plants	Zooplankton	Epibenthic Organisms	Benthic Infauna
		Athyrium felix-femina			
		Carex obnupta			
		Lathyrus palustris			
		Lonicera involucrata			
		Oenanthe sarmentosa			
		Picea sitchensis			
		Potentilla pacifica			
		Rubus spectabilis			
		Salix hookeriana			

Table 4c

Worksheet 4. Major species directly dependent on estuarine habitat type (see Appendix C, Table 1)

Site affected: Alder Cove

Region: Youngs Bay

Habitat type: Low marsh

Phytoplankton	Benthic Primary Producers	Marsh Plants	Zooplankton	Epibenthic Organisms	Benthic Infauna
	No data	Agrostis alba			
		Alisma plantago-aquatica			
		Carex lyngbyei			
		Eleocharis palustris			
		Oenanthe sarmentosa			
		Scirpus validus			
		Typha angustifolia			

Table 4d

Worksheet 4. Major species directly dependent on estuarine habitat type (see Appendix C, Table 1)

Site affected: Alder Cove

Region: Youngs Bay

Habitat type: Tidal flats

Phytoplankton	Benthic Primary Producers	Marsh Plants	Zooplankton	Epibenthic Organisms	Benthic Infauna
	Achnanthes hauckiana			Ectinosomatidae	*Corophium salmonis*
	Achnanthes lemmermanni			Laophontidae	*Hobsonia florida*
	Diatoma tenue			*Microarthridion littorale*	*Macoma balthica*
	Fragilaria pinnata			*Scottolana canadensis*	*Neanthes limnicola*
	Gyrosigma fasciola			*Tachidius triangularis*	Oligochaeta
	Navicula cryptocephala			*Crangon franciscorum*	Rhynchocoela
	Navicula gregaria			Balanomorpha	Turbellaria
	Nitzschia hungarica			*Cyclops bicuspidatus*	
	Nitzchia palea			*Cyclops vernalis*	
	Nitzschia sigma			*Diaptomus* sp.	
				Eurytemora affinis	

Table 5a

Worksheet 5. Major species indirectly dependent on estuarine habitat type (see Appendix C, Table 1)

Site affected: Alder Cove

Region: Youngs Bay

Habitat type: Water column

Zooplankton	Fish	Birds	Marine Mammals	Aquatic and Terrestrial Mammals
No data	Alosa sapidissima	Aechmophorus occidentalis	Eumetopias jubatus	
	Clupea harengus pallasi	Ardea herodias	Phoca vitulina	
	Gasterosteus aculeatus	Larus californicus	Zalophus californianus	
	Hypomesus pretiosus	Larus canus		
	Oncorhynchus kisutch	Larus delawarensis		
	Oncorhynchus tshawytscka	Phalacrocorax auritus		
	Spirinchus thaleichthys	Anser platyrhynchos		
	Thaleichthys pacificus			

Table 5b

Worksheet 5. Major species indirectly dependent on estuarine habitat type (see Appendix C, Table 1)

Site affected: Alder Cove

Region: Youngs Bay

Habitat type: High marsh/swamp

Zooplankton	Fish	Birds	Marine Mammals	Aquatic and Terrestrial Mammals
		Ardea herodias		*Castor canadensis*
		Cistothorus palustris		*Myocastor coypus*
		Corvus brachyrhynchus		*Ondatra zibethicus*
		Geothlypis trichas		*Lutra canadensis*
		Hirunda rustica		*Procyon lotor*
		Iridoprocne bicolor		
		Porzana carolina		
		Tachycineta thalassina		
		Anser platyrhynchos		

Table 5c

Worksheet 5. Major species indirectly dependent on estuarine habitat type (see Appendix C, Table 1)

Site affected: Alder Cove

Region: Youngs Bay

Habitat type: Low marsh

Zooplankton	Fish	Birds	Marine Mammals	Aquatic and Terrestrial Mammals
		Ardea herodias		*Castor canadensis*
		Cistothorus palustris		*Myocastor coypus*
		Corvus brachyrhynchus		*Ondatra zibethicus*
		Geothlypis trichas		*Lutra canadensis*
		Hirunda rustica		*Procyon lotor*
		Iridoprocne bicolor		
		Porzana carolina		
		Tachycineta thalassina		
		Anser platyrhynchos		

Table 5d

Worksheet 5. Major species indirectly dependent on estuarine habitat type (see Appendix C, Table 1)

Site affected: Alder Cove

Region: Youngs Bay

Habitat type: Tidal flats

Zooplankton	Fish	Birds	Marine Mammals	Aquatic and Terrestrial Mammals
	Citharichthys stigmaeus	Ardea herodias	Eumetopias jubatas	Myocastor coypus
	Cottus asper	Calidris mauri	Phoca vitulina	Ondatra zibethicus
	Cymatogaster aggregata	Calidris minutilla	Zalophus californianus	Lutra canadensis
	Leptocattus arinatus	Corvus brachyrhynchus		Procyon lotor
	Mylocheilus caurinus	Hirunda rustica		
	Parophrys vetulus	Larus californicus		
	Platichthys stellatus	Larus canus		
		Larus delawarensis		
		Larus glaucescens		
		Larus occidentalis		
		Anser platyrhynchos		

Table 6a

Worksheet 1. Changes in areas of estuarine habitat types resulting from management activity

Proposed activity: Deepened channel

Site affected: Channel

Region: Estuarine Channels

Habitat type (Fig 4)	A.hectares before change	B.hectares after change	C.hectares gained or lost (A-B:loss B-A:gain)	D.hectares in region (Table 1)	E.% gain or loss (C/Dx100)
WC	0	161	161(gain)	7,437	2.2%(gain)
HM					
LM					
TF					
DS					
CB	0	161	161(gain)	5,854	2.8%(gain)

Table 6b

Worksheet 1. Changes in areas of estuarine habitat types resulting from management activity

Proposed activity: Deepened Channel

Site affected: Channel

Region: Fluvial

Habitat type (Fig 4)	A. hectares before change	B. hectares after change	C. hectares gained or lost (A-B:loss B-A:gain)	D. hectares in region (Table 1)	E. % gain or loss (C/Dx100)
WC	161	0	161(loss)	3,203	5.0%(loss)
HM					
LM					
TF					
DS					
CB	161	0	161(loss)	1,976	8.1%(loss)

Table 7a

Worksheet 2. Changes in biomass and productivity resulting from loss or gain of estuarine habitat type area (see page 26)

Site affected: Channel

Region: Estuarine Channels

Habitat type: Water column

# of hectares lost or gained: 161 gained

Biological Group	Standing Crop[a]	Change in biomass[b]	Productivity per unit area[c]	Change in productivity[d]
PRIMARY PRODUCERS				
Phytoplankton	20.4	3,284(gain)	502	80,822(gain)
Benthic Primary Producers				
Marsh Plants				
Total Primary Producers		3,284(gain)		80,822(gain)
CONSUMERS				
Zooplankton	21.9	3,526(gain)	218	35,098(gain)
Epibenthic Organisms				
Benthic Infauna				
Total Consumers		3,526(gain)		35,098(gain)

a. Kilograms of carbon per hectare
b. Kilograms of carbon
c. Kilograms of carbon per hectare per year
d. Kilograms of carbon per year

Table 7b

Worksheet 2. Changes in biomass and productivity resulting from loss or gain of estuarine habitat type area (see page 26)

Site affected: Channel

Region: Estuarine Channels

Habitat type: Channel bottom

# of hectares lost or gained: 161 gained

Biological Group	Standing Crop[a]	Change in biomass[b]	Productivity per unit area[c]	Change in productivity[d]
PRIMARY PRODUCERS				
Phytoplankton				
Benthic Primary Producers				
Marsh Plants				
Total Primary Producers				
CONSUMERS				
Zooplankton				
Epibenthic Organisms	0.26	42(gain)	2.27	365(gain)
Benthic Infauna	0.99	159(gain)	4.09	658(gain)
Total Consumers		201(gain)		1,023(gain)

a. Kilograms of carbon per hectare
b. Kilograms of carbon
c. Kilograms of carbon per hectare per year
d. Kilograms of carbon per year

Table 7c

Worksheet 2. Changes in biomass and productivity resulting from loss or gain of estuarine habitat type area (see page 26)

Site affected: Channel

Region: Fluvial

Habitat type: Water column

# of hectares lost or gained: 161 lost

Biological Group	Standing Crop[a]	Change in biomass[b]	Productivity per unit area[c]	Change in productivity[d]
PRIMARY PRODUCERS				
Phytoplankton	28.9	4,653(loss)	716	115,276(loss)
Benthic Primary Producers				
Marsh Plants				
Total Primary Producers		4,653(loss)		115,276(loss)
CONSUMERS				
Zooplankton	7.41	1,193(loss)	74.1	11,930(loss)
Epibenthic Organisms				
Benthic Infauna				
Total Consumers		1,193(loss)		11,930(loss)

a. Kilograms of carbon per hectare
b. Kilograms of carbon
c. Kilograms of carbon per hectare per year
d. Kilograms of carbon per year

Table 7d

Worksheet 2. Changes in biomass and productivity resulting from loss or gain of estuarine habitat type area (see page 26)

Site affected: Channel

Region: Fluvial

Habitat type: Channel bottom

# of hectares lost or gained: 161 lost

Biological Group	Standing Crop[a]	Change in biomass[b]	Productivity per unit area[c]	Change in productivity[d]
PRIMARY PRODUCERS				
Phytoplankton				
Benthic Primary Producers				
Marsh Plants				
Total Primary Producers				
CONSUMERS				
Zooplankton				
Epibenthic Organisms	0.06	10(loss)	0.44	71(loss)
Benthic Infauna	8.55	1,376(loss)	10.1	1,626(loss)
Total Consumers	8.61	1,386(loss)	10.5	1,697(loss)

a. Kilograms of carbon per hectare
b. Kilograms of carbon
c. Kilograms of carbon per hectare per year
d. Kilograms of carbon per year

Table 8a

Worksheet 3a. Regional summary of change in biomass

Site affected: Channel

Region: Estuarine Channels

Biological Group	A. Total biomass[a] change (sum all habitat types)	B. Total biomass[a] in region (Appendix C, Table 2)	C. % gain or loss (A/Bx100)
PRIMARY PRODUCERS			
Phytoplankton	3,284(gain)	148,740	2.2%(gain)
Benthic Primary Producers			
Marsh Plants			
Total Primary Producers	3,284(gain)	148,740	2.2%(gain)
CONSUMERS			
Zooplankton	3,526(gain)	162,871	2.2%(gain)
Epibenthic Organisms	42(gain)	1,522	2.8%(gain)
Benthic Infauna	159(gain)	11,859	1.3%(gain)
Total Consumers	3,727(gain)	176,252	2.1%(gain)

a. Kilograms of carbon

Table 8b

Worksheet 3b. Regional summary of change in productivity

Site affected: Channel

Region: Estuarine Channels

Biological Group	A. Total productivity[a] change (sum all habitat types)	B. Total productivity[a] in region (Appendix C, Table 2)	C. % gain or loss (A/Bx100)
PRIMARY PRODUCERS			
Phytoplankton	80,822(gain)	3,733,374	2.2%(gain)
Benthic Primary Producers			
Marsh Plants			
Total Primary Producers	80,822(gain)	3,733,374	2.2%(gain)
CONSUMERS			
Zooplankton	35,098(gain)	1,625,728	2.2%(gain)
Epibenthic Organisms	365(gain)	13,288	2.7%(gain)
Benthic Infauna	658(gain)	44,146	1.5%(gain)
Total Consumers	36,121(gain)	1,683,162	2.1%(gain)

a. Kilograms of carbon per year

Table 9a

Worksheet 3a. Regional summary of change in biomass

Site affected: Channel

Region: Fluvial

Biological Group	A. Total biomass[a] change (sum all habitat types)	B. Total biomass[a] in region (Appendix C, Table 2)	C. % gain or loss (A/Bx100)
PRIMARY PRODUCERS			
Phytoplankton	4,653(loss)	92,567	5.0%(loss)
Benthic Primary Producers		41,410	
Marsh Plants		3,239,630	
Total Primary Producers	4,653(loss)	3,373,607	0.1%(loss)
CONSUMERS			
Zooplankton	1,193(loss)	23,702	5.0%(loss)
Epibenthic Organisms	10(loss)	216	4.6%(loss)
Benthic Infauna	1,376(loss)	21,257	6.5%(loss)
Total Consumers	2,578(loss)	45,175	5.7%(loss)

a. Kilograms of carbon

Table 9b

Worksheet 3b. Regional summary of change in productivity

Site affected: Channel

Region: Fluvial

Biological Group	A. Total productivity[a] change (sum all habitat types)	B. Total productivity[a] in region (Appendix C, Table 2)	C. % gain or loss (A/Bx100)
PRIMARY PRODUCERS			
Phytoplankton	115,276(loss)	2,293,348	5.0%(loss)
Benthic Primary Producers		96,030	
Marsh Plants		2,752,604	
Total Primary Producers	115,276(loss)	5,141,982	2.2%(loss)
CONSUMERS			
Zooplankton	11,930(loss)	237,342	5.0%(loss)
Epibenthic Organisms	71(loss)	1,658	4.3%(loss)
Benthic Infauna	1,626(loss)	31,226	5.2%(loss)
Total Consumers	13,627(loss)	270,226	5.0%(loss)

a. Kilograms of carbon per year

APPENDIX F

Sampling design and data characteristics of CREDDP biological investigations in the Columbia River Estuary

Appendix F. Sampling design and data characteristics of CREDDP biological investigations in the Columbia River Estuary.

WORK UNIT	TIME PERIOD	
WATER COLUMN PRIMARY PRODUCTION	April 1980-July 1981	Sampling Design Bi-monthly sampling at 47 stations in main estuary and bays (except Baker Bay). Variables Measured Chlorophyll *a*, suspended particles, light attenuation, chemical constituents, temperature, primary productivity, phytoplankton species composition, zooplankton grazing rates.
BENTHIC PRIMARY PRODUCTION	April 1980-September 1981	Sampling Design Monthly sampling at five sites between 1980 and April 1981. 31 survey sites sampled between May 1, 1981 and September 1, 1981. Most sampling in tidal flats and low marsh areas of bays. Variables Measured Species composition, chlorophyll *a*, biomass, primary production, organic matter in top centimeter of sediments, temperature, salinity, light intensity, oxygen consumption.
EMERGENT PLANT PRIMARY PRODUCTION	April 1980-October 1980; August 1981	Sampling Design 22 sampling sites in tidal marsh habitats. Variables Measured Plant cover and species composition; standing crop; primary productivity; decomposition.

Appendix F. (Continued)

WORK UNIT	TIME PERIOD	
ZOOPLANKTON AND LARVAL FISH	April 1980-September 1980	Sampling Design Bi-weekly distribution at 10 stations along length of main navigation channel from RM-5 to RM-23. Variables Measured Species composition, density, temperature, salinity.
BENTHIC INFAUNA	August 1980-September 1981	Sampling Design Vertical distribution at three sites; monthly to biweekly production at one tidal flat; *Corophium* life history and monthly changes in infauna at two tidal flats; distribution over whole estuary at 200 sites in September 1981. Variables Measured Species composition, density, standing crop; life history and production of *Corophium salmonis*.
EPIBENTHIC ORGANISMS	March 1980-August 1981	Sampling Design Monthly to quarterly sampling at 16 sites. Variables Measured Occurrence, density, standing crop; macroinvertebrate length and % occurrence, abundance, & biomass of stomach contents.

Appendix F. (Continued)

WORK UNIT	TIME PERIOD	
FISH	February 1980- July 1981	Sampling Design Monthly sampling at 22 trawl, 15 purse seine, 11 beach seine sites. Variables Measured Occurrence, density and standing crop; occurrence, abundance, biomass of stomach contents; lengths.
AVIFAUNA	April 1980- March 1981	Sampling Design Monthly or more frequent sampling of 72 0.8 to 5 km transects; variable circular plots; incidental sightings. Variables Measured Species composition and density.
MARINE MAMMALS	March 1980- September 1981	Sampling Design Weekly to monthly monitoring of population within and adjacent to estuary relative to species/ life history composition, distribution, and behavior. Variables Measured Occurrence & abundance overall; % occurrence of prey items; population turnover via emigration and immigration.
WILDLIFE	April 1980- May 1981	Sampling Design Land and boat transects covering 27,150 m^2. Variables Measured Occurrence, abundance, feeding sites; % frequency and composition of food items.