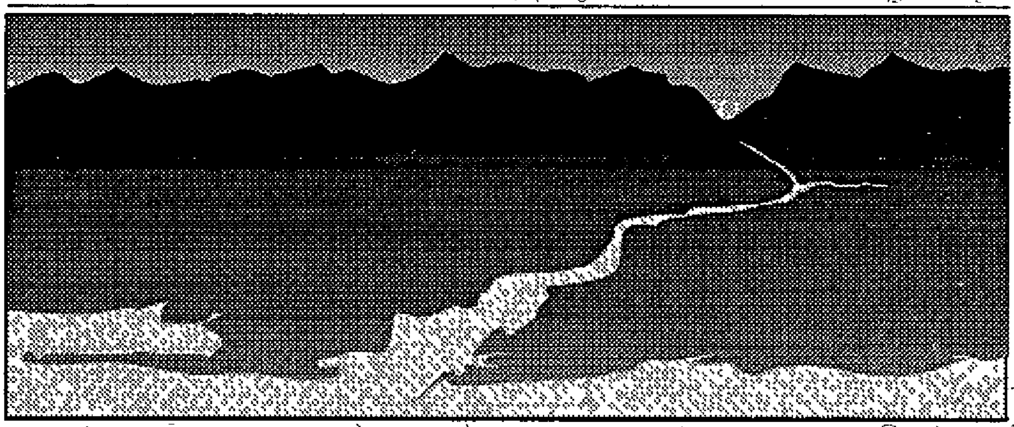
FINAL REPORT
VOLUME I

LOWER COLUMBIA RIVER



BI-STATE PROGRAM

RECONNAISSANCE SURVEY OF THE LOWER COLUMBIA RIVER

TASK 1: SUMMARY OF EXISTING DATA AND PRELIMINARY IDENTIFICATION OF PROBLEM AREAS AND DATA GAPS

MAY 13, 1992

Prepared By:

TETRA TECH

In Association With:

DAVID EVANS AND ASSOCIATES
EVS CONSULTANTS

TETRA TECH

TC 8526-01
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VOLUME I

RECONNAISSANCE SURVEY OF THE LOWER COLUMBIA RIVER

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MAY 13, 1992

Prepared For:

The Lower Columbia River
Bi-State Water Quality Program

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Reconnaissance Survey of the Lower Columbia River
Sampling Plan
Tetra Tech/David Evans ands Associates/EVS Consultants
TC-8526-06
10/29/91

Reconnaissance Survey of the Lower Columbia River
Laboratory Data Report
Volume 6 Dioxin and Furan Data for Tissues
Tetra Tech/Keystone/NEA
4/92

Reconnaissance Survey of the Lower Columbia River
Task 1 Summary of Existing Data and
Preliminary Identification of Problem Areas and Data Gaps
Tetra Tech/David Evans ands Associates/EVS Consultants
TC-8526-01
5/13/92

Jeremy Buck

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CONTENTS

FIGURES

TABLES

ACKNOWLEDGEMENTS

This document was prepared by Tetra Tech, Inc. for the Lower Columbia River Bi-State Committee. Dr. Ted Turk of Tetra Tech served as the Project Manager for all work conducted on the lower Columbia River project. Mr. Gary Braun of Tetra Tech served as the Task Manager for all work conducted as part of Task 1: Initial Data Review and Synthesis. Ms. Cordelia Shea of Oregon Department of Environmental Quality (ODEQ) and Mr. Neil Aaland of Washington State Department of Ecology (WDOE), served as technical/contract monitors for the Bi-State Program. Funding for the project was provided to the Bi-State Program by WDOE, ODEQ, public ports in Washington and Oregon, and the Northwest Pulp and Paper Association.

Several individuals contributed to sections in this document. Ms. Margie Mulholland and Dr. Lynne Krasnow performed data collection and initial evaluation of all the collected studies. Mr. Tad Deshler was the primary author of the water quality section. Dr. Mahmood Shivji and Ms. Mulholland were primarily responsible for the sediment quality section. Dr. Krasnow was the primary author of the benthic infauna section. Mr. Deshler and Mr. Braun were authors of the fish community section. Mr. Glen St. Amant, Mr. Deshler, and Mr. Braun authored the bioaccumulation section and Mr. St. Amant and Dr. Shivji were responsible for the bioassay section. Technical review was performed by Mr. Gary Braun with final review by Dr. Turk. Ms. Eva Weaver performed technical editing. All graphics were produced by Ms. Kim Shaty. Word processing and report production were provided by Ms. Lisa Fosse, Ms. Kelly Robinson, and Ms. Rosemary O'Brien. Members of the Bi-State Program Steering Committee, the Scientific Resource Pannel, and EVS Consultants provided helpful guidance and comments on an earlier draft.

LIST OF ACRONYMS

AOX	Adsorbable Organic Halides
BCP	Bioconcentration Factor
BNA	Base/Neutral/Acid Semivolatile Organics
CN	Cyanide
CONV	Conventional Water Quality Parameters
CREDDP	Columbia River Estuary Data Development Program
DO	Dissolved Oxygen
EAR	Elevation Above Reference
EHW	Extremely Hazardous Waste
EIS	Environmental Impact Statement
FL	Fork Length
GIS	Geographic Information System
MDL	Method Detection Limit
MLLW	Mean Lower Low Water
NCBP	National Contaminant Biomonitoring Program
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NUTS	Nutrients
ODEQ	Oregon Department Environmental Quality
OSF&W	Oregon Department of Fish and Wildlife
PAH	Polycyclic Aromatic Hydrocarbons
PCBs	Polychlorinated Biphenyls
PSEP	Puget Sound Estuary Program
QA	Quality Assurance
RM	River Mile
TCDD	Tetrachlorodibexzodioxin
TCDF	Terachlorodbenxofuran
TM	Trace Metal
TOC	Total Organic Carbon
TVS	Total Volatile Solids
U.S. EPA	U.S. Environmental Protection Agency
U.S. COE	U.S. Army Corps of Engineers
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
WDF	Washington Department of Fisheries
WDOE	Washington Department of Ecology

EXECUTIVE SUMMARY

This report details the findings of a study on the existing water quality data of the lower Columbia River, from the Bonneville Dam to the river mouth. The summary presented here provides a very brief overview of the report findings. A more detailed summary of the activities and results associated with this task are presented in a spearate report entitled, *Task 1. Final Summary Report.*

Based on the existing data, with its may limitations and qualifications, an assessment of the overall health of the loweer Columbia River is not feasibile. Because of the limitations of the existing data, the lower Columbia River does not appear to be severely degraded. However, only a small subset of contaminants were measured at most locations. Many unmeasured compounds may exist in the river. Additionally, the geographic coverage for all data types was limited at best. Therefore, an assessment of the overall water quality in the Columbia River based on this data is biased toward those areas where sampling has occurred and does not account for those areas not sampled.

This study—and basis of these conclusions—is one of seven tasks undertaken as part of the Reconnaissance Survey of the lower Columbia River, initiated by the Bi-State Lower Columbia River Water Quality Program. The Bi-State Program was established to assess the overall water quality of the river. The role of this study in the program is to summarize existing data on water, sediment, and biological conditions in the lower Columbia River to identify potential problem areas and data gaps. This information will assist in the design of the reconnaissance survey sampling plan.

To accomplish this task, a wide range of data sources and agency information was researched for the lower river areas. As the data were obtained, each document was catalogued and loaded into a library database. The studies were then separated by data type and evaluated against established criteria, such as appropriate field collection methods, quality assurance procedures, and parameters measured.

The next step in this task was to establish an approach for evaluating the existing data and identifying potential problem areas in the river. This approach, called a technical framework, is presented in an earlier report. The technical framework is a set of procedures that define the types of data that should be evaluated, the contaminants of concern, and the procedures for establishing reference values against which problem areas were to be identified. Procedures for identifying data gaps were also established and explained.

Data from the water column, sediments, benthic (bottom-dwelling) animals, fish, toxicity test (bioassays), and tissue concentrations of contaminants (bioaccumulation) are evaluated in this report. Each data type is summarized by examining existing data for each of four major and ten minor divisions of the lower river. Within each segment, potential problem areas and data gaps are identified by applying the technical framework established in the earlier report.

Results of the problem area identification analyses for each data type are presented as a three-tiered ranking scheme as follows:

- High priority (contaminant exceeds the established screening level)
- Medium priority (contaminant is detected, but the concentration does not exceed the screening level)
- Low priority (contaminant is not detected at the location).

Generally, two limitations weakened the analyses for each data type: 1) adequate data were often not available, and 2) data from different studies were difficult to compare because of temporal and spatial differences and the types of parameters studied. Many data types were not useful for identifying problem areas or assessing the general water quality of the study area. Instead, data were most useful for identifying data gaps (Table ES-1). Although the sediment data were particularly useful, even the best data were still too limited, however, to make a scientifically valid evaluation of sediment conditions on the river.

Potential high-priority problem areas were identified from fewer than ten sediment locations in the entire lower river (Table ES-2). Most of these sites were located in the industrialized areas of Longview and Portland/Vancouver. Fish tissue contaminant concentrations also indicated several high-priority locations, but these spots were located throughout the study area. Dioxins/furans, the pesticide DDE, PCBs, and mercury were the contaminants detected most frequently at these locations (Table ES-2).

Results of the existing data summaries and synthesis were used to assist in the design of the sampling plan, which is Task 6 of Bi-State Program's assessment of water quality in the lower Columbia River. Information on problem areas and data gaps were used to design the reconnaissance survey for that sampling plan.

TABLE ES-1. DATA GAPS IDENTIFIED IN THE LOWER COLUMBIA RIVER

Media	Segment
Water Quality	General Data Gap
Sediment	
Dioxins and Furans Resin Acids	1A
Dioxins and Furans Resin Acids	1C
Resin Acids	2A
Metals Pesticides PAHs PCBs Dioxins and Furans Resin Acids	2B
Resin Acids	3A
Metals Pesticides PAHs PCBs	3B
Benthic Infauna	General Data Gap
Fish Communities	General Data Gap
Bioaccumulation	Limited Data Gap
Bioassays	General Data Gap

TABLE ES-2. HIGH-PRIORITY PROBLEM AREAS IDENTIFIED THE LOWER COLUMBIA RIVER		
Media	Segment	Compound
Water Quality		
Metals Bacteria	2A	Cadmium, Copper
Pesticides	2C	Heptachlor
Metals	3B	Chromium
Sediment		
Metals[a] Pesticides[b] PAHs	1A	Cadmium, Copper, Lead All pesticides Total PAHs
Metals Pesticides	1B	Cadmium Total DDT, Chlordane, Dieldrin, Other Pesticides
Pesticides	1C	Total DDT
Pesticides Dioxins and Furans	2A	Total DDT All Forms (congeners)
Pesticides PAHs PCBs Dioxins and Furans Resin Acids	2C	All Pesticides Total PAHs Total PCBs All Forms Total Resin Acids
Dioxins and Furans	3A	Total HpCDD and OCDD
Metals Pesticides Dioxins and Furans Resin Acids	4A	Copper, Lead Total DDT, DDD, DOE, DOT Total TCDF, Total HxCDF, Total HxCDD, Total HpCDF, Total HpCDD, OCDF, OCDD Total Resin Acids
Metals	4B	Manganese
Fish Tissue		
Pesticides	1A and 1B 2A and 2B 3A and 3B 4A and 4B	TCDF, TCDD TCDF, TCDD, DDE TCDF, TCDD, DDE TCDF, TCDD, DDE
PCBs	4A	Total PCBs

1.0 INTRODUCTION

The Lower Columbia River Bi-State Water Quality Program has been established to assess the ecological health of the lower Columbia River from the mouth to Bonneville Dam [River Mile (RM) 146]. The Bi-State Program was formed at the direction of the legislatures from the states of Oregon and Washington. The states formed an Interstate Agreement that directs a four-year water quality program to characterize water quality in the lower Columbia River, identify water quality problems, determine whether beneficial uses are impaired, and develop solutions to problems found in the river below Bonneville Dam. The goal of the first-year studies is to establish the technical framework for determining the water quality and biological health of the lower Columbia River. This technical framework will serve as the basis for directing further study efforts in the following years.

To accomplish this goal, the Bi-State Program identified several activities to be performed as part of the first year study. These include:

- Review and synthesize existing information on water, sediments, biota, contaminant sources, and beneficial uses to characterize the river system
- Identify study protocols and implement a reconnaissance survey of the river to provide an initial assessment of the river's health and provide a basis for determining and prioritizing further study needs
- Select and implement a data management system as a tool for use in on-going work
- Identify and prioritize future study needs and directions.

The Bi-State Program further divided these activities into a series of tasks. One of the tasks identified as part of the study (Task 1: Initial Data Review and Synthesis) was to perform a technical review of the existing studies and data to determine the water, biological, and sediment quality status of the river. This report is one of the work products identified in Task 1.

Task 1: Initial Data Review and Synthesis, has been divided into five main work products. These are: 1) work plan, 2) list of materials to evaluate, 3) assessment ranking framework, 4) preliminary problem area and data gap identification report (this document), and 5) a final task report summarizing all task activities. Prior to this report, draft and final versions of the work plans, list of materials evaluated, and the ranking framework have been submitted to the Bi-State Steering Committee. The data summaries and preliminary problem area and data gap identifications contained in this report are based on these previous work products and on information compiled, evaluated, and analyzed during Steps 2-6 of the work plan.

1.1 PURPOSE

The following are the objectives of this report are

- To synthesize the information that has been compiled and technically reviewed on existing studies and relevant data to characterize (to the extent possible) the water, biological, and sediment quality status of the lower Columbia River

- To use these data summaries to identify potential problem areas

- To identify current and on-going studies in the study area

- To identify data gaps, and

- To incorporate the results of this report into the design of the sampling plan for the reconnaissance survey (Task 6). Evaluation of the existing data provides a synthesis of the historical data and allows an initial assessment of the water quality in the lower Columbia River. Review of the existing data is essential for establishing areas with adequate coverage and areas with large data gaps. This information is also basic to designing the reconnaissance survey sampling plan to focus resources in the highest priority areas and to avoid duplication of effort with past and ongoing studies.

1.2 SCOPE AND APPROACH

As discussed above, this report is based on the information collected, compiled, evaluated, and analyzed as part of Steps 2–6 of Task 1 (as described in the work plan). These steps included. 1) literature search and data compilation, 2) development of an assessment ranking framework, 3) data evaluation, 4) data management, and 5) data summaries. Each of these steps are described below.

1.2.1 Literature Search and Data Compilation

The existing data for the lower Columbia River are compiled in this step to provide input to all the tasks. The types of information compiled include:

- Water column quality (i.e., toxic contaminants, microbial concentrations, and conventional parameters)
- Levels of toxic contaminants in sediments
- Bioaccumulation of toxic substances in fish, shellfish, birds, mammals, and other wildlife
- Benthic macroinvertebrate populations and community structure
- Bioassay data from tests conducted with water or sediments.

In addition to these types of data several other types of information were identified and collected for use in Tasks 2, 3, and 5 as appropriate. This included information on drainage patterns, land use for the area surrounding and discharging into the river, and pollutant loading data for present-day sources of both conventional pollutants and toxic contaminants. Pollutant loading data an historical sources of toxic contamination were also compiled.

Studies identified by McConnell (1990) served as the starting point for the literature review component of the data compilation step. A library and bibliography of documents and data pertaining to the Columbia River have been prepared and are maintained at Tetra Tech for use throughout the project. Documents and information on past and ongoing studies were brought in from a wide variety of sources that included all those listed in the *List of Material to Evaluate* report.

The result of the literature search is a library database of all literature collected, as well as a list of contacts from the various agencies that provide data or information. The library database has been developed using dBase IV software and contains a complete citation, as well as a list of keywords that represent the content of the reference in the context of the Bi-State Program. The database allows searches on both citation and keyword information.

Over 160 documents pertaining to the lower Columbia River were collected and evaluated for use in this report In general, data from 1980 to present were included in the evaluation, with older studies included where warranted. This limitation was imposed in an effort to evaluate only the most pertinent data.

1.2.2 Problem Area and Data Gap Identification Ranking Framework

To identify potential problem areas and data gaps, a set of specific rules were defined that establish a preliminary framework for assessing data gaps and identifying potential problem areas. These rules are presented in the *Problem Area and Data Gap Identification Ranking Framework* report. Because the extent and availability of existing data was not known when the framework was developed, it includes rules and procedures for media (e.g., bacteria concentrations, fish histopathology, bioassays) where little or no data exist. However, by establishing rules before evaluating the data, the rules can be applied consistently wherever appropriate. Exceedances of the established rules indicate a potential problem area and suggest the need for more detailed investigations as part of the reconnaissance survey (Task 6).

Data gaps were identified as part of the framework for media, or variables within a medium, where little or no data are present. The preliminary framework document specified specific procedures to be used to identify values that would be used as screening levels for each media. For example, for water, the screening level values were identified as the most conservative value among federal, Washington, or Oregon water quality criteria. For media where there were no criteria available (e.g., sediments, tissue contaminant concentrations), several hierarchical procedures (e.g., use of established reference sites, background levels, effects-based levels) were identified so that a screening level could be identified so that priorities could be identified for each individual data value. Once these screening levels were identified, then each data value would be compared to it.

In the preliminary framework, this comparison would have occurred through the calculation of an elevation above reference (EAR) value (difference from screening levels or reference conditions). Exceedance of the screening level indicated a potential problem area and the magnitude of the difference allowed priorities to be assigned among all the values (e g., a very high EAR received a high priority). Calculation and implementation of the EAR approach requires that sufficient data be available.

Unfortunately, for the lower Columbia River, adequate data do not exist for most parameters or locations, so the EAR approach was not utilized in the evaluation and synthesis of the existing data. Instead, a more informal procedure was utilized for ranking and assigning priorities to the data.

A problem identification approach similar to that used for the Puget Sound Estuary Program (PSEP) (Tetra Tech 1988a;b) was modified and adapted for use in the Bi-State Program. While the goal of the action-level criteria developed for the PSEP Toxic Action Plans was to identify, characterize, and remediate toxic problem areas, the framework developed for the Bi-State Program differs. It is intended to help in making choices among possible sampling locations to apply the limited resources of the reconnaissance survey (Task 6) and to assist in characterizing existing water quality conditions in the river. Therefore, no action-levels were established (as was done for PSEP) in this framework. (See the preliminary framework document for more details on the PSEP framework). Instead, each parameter for each medium was placed into one of three priority categories - high, medium, or low - based on detected values and exceedance of established screening levels. In most instances if the compound was undetected, it was placed in the low-priority category. If a compound was detected but the concentration was below the screening level, it was placed in the medium-priority category. Finally, if a compound was detected at concentrations greater than the established screening level, it was placed in the high-priority category indicating a potential problem area. When a compound was not detected, but the detection limit was so high that after assuming a concentration of only half the detection limit, it exceeded the screening level, then it too was placed into the high priority category. However, its placement into the high-priority category does not indicate that it is a potential problem. Rather, its placement indicates that there is sufficient uncertainty about the compound at that location to identify it as a significant data gap. Exceptions to these general rules will be discussed within each section where appropriate. Areas with little or no data were identified as data gaps.

1.2.3 Data Evaluation

For this document, after the initial compilation of all relevant documents, each document was evaluated to determine its suitability for inclusion in the study. In general, this evaluation was limited to those studies conducted after 1980. However, long-term studies where data were available to provide historical perspective, such as the U.S. Geological Survey (USGS) study at Warrendale (RM 141), have also been included. The accepted data sets represent recent data that are potentially suitable for characterizing environmental contamination and effects. The compiled data have been reviewed for quality (i.e., appropriate sample collection and handling methods, analytical protocols, and QA procedures) and pertinence to the project (e.g., date of record, spatial coverage, variables measured, apparent trends). A list and brief summaries of the evaluation of each data source was prepared. If it was determined that limitations in the above characteristics caused the data to be of questionable value in meeting the program objectives, these data were not considered further in the information review or for the Task 6 sampling plan design

1.2.4 Data Management

For this document, data identified as useful and appropriate in the above steps have been entered into EXCEL spreadsheets. Each spreadsheet (e.g., one for each class of compounds for each media) has been organized by river segment as defined in Task 3 (Review of Physical and Hydrologic Characteristics). Within each segment, all of the stations from all acceptable studies have been listed. For each station, all pertinent parameters collected or measured at that station (e.g., location, sediment type, chemicals measured) have been included. Organizing and compiling the data into river segments allows summary statistics to be calculated and comparisons among river segments to be made (see Section 3.0). In addition to the environmental data, the sampling stations and collection sites have been loaded into dBase files and converted into a GIS format. Several maps were produced from these files including base maps with study and station locations plotted and a base map with the potential problem areas identified.

1.2.5 Data Summaries and Synthesis

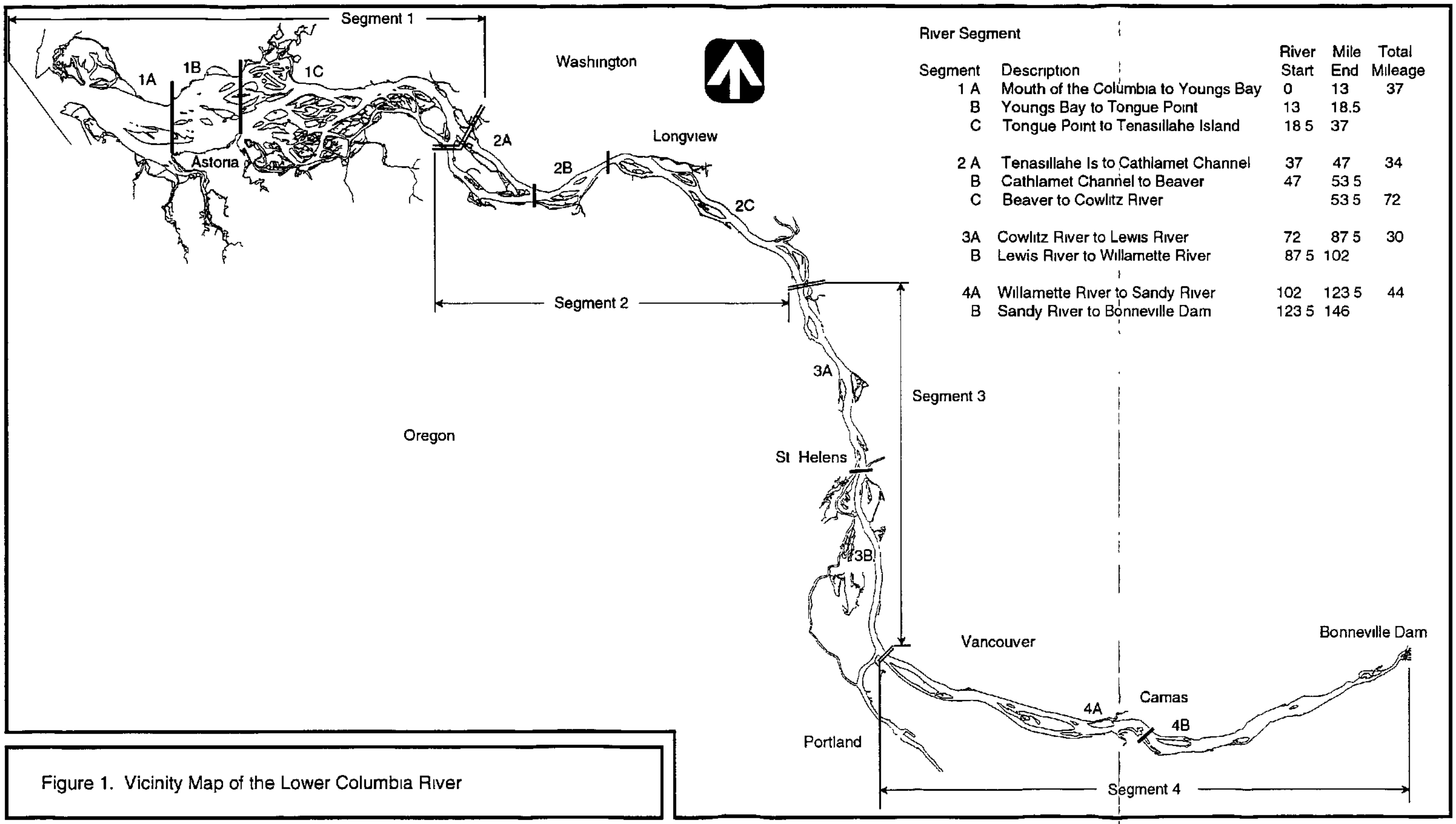
Data summaries comprise the bulk of this report. These summaries are provided for each medium and are organized by river segment. For each medium, a summary of the data reviewed and the data accepted has been included. A discussion of the accepted data by river segment and by individual parameter is included. These summaries include tables of stations and parameters measured at each station by river segment. Spatial distributions and comparisons are included where sufficient data were available. Identification of detected compounds and comparison of contaminants that exceed screening level criteria are discussed. Any apparent trends in the data are also included in these sections. The ranking framework, as identified in the preliminary framework report, has been applied only to data where sufficient data exists. All other media and measured parameters are described more informally. Identification of potential problem areas and data gaps have also been made using the preliminary framework for only a limited suite of indicators because the lack of sufficient data.

1.3 RIVER SEGMENTATION

To aid evaluation and synthesis of existing data, the river has been subdivided into four major and 10 minor segments (Figure 1). The purpose of the segmentation is to subdivide the river system into sections with similar characteristics to better identify the physical processes responsible for contaminants transport. Areas with similar flow and morphologic features are grouped into the same segment. Therefore, major segment designations are based on confluences with major tributaries or the break between riverine and estuarine portions between segments 1 and 2. Subsegments were generally based on major geographic features along the river. An extensive discussion of the rationale and features of each segment can be found in the Task 3 report *Review of Hydraulic, Hydrologic, Sediment Transport, and Geomorphic Characteristics of the Lower Columbia River.*

1.4 REPORT ORGANIZATION

The report is organized into three main sections. Section 1.0 (this section) provides an overview of the project. Section 2.0 is organized by medium type to provide a summary and analysis of the existing data for each medium. This approach treats each medium independently so that media for which little data are available do not inhibit analyses of media with sufficient data. Each media section is organized into three sections that include: 1) a discussion of the data selection and review methods; 2) a segment-by-segment review of the accepted data; and 3) an interpretation of and conclusions for the data for that medium. As part of Section 3.0, of the problem areas and data gaps for each media are assessed. In addition, the ranking framework combines the data from all the media to set priorities and make recommendations for the design of the reconnaissance survey sampling plan, and attempts to assess of the overall health of the lower Columbia River based on the existing data.



River Segment

Segment	Description	River Start	Mile End	Total Mileage
1 A	Mouth of the Columbia to Youngs Bay	0	13	37
B	Youngs Bay to Tongue Point	13	18.5	
C	Tongue Point to Tenasillahe Island	18 5	37	
2 A	Tenasillahe Is to Cathlamet Channel	37	47	34
B	Cathlamet Channel to Beaver	47	53 5	
C	Beaver to Cowlitz River		53 5	72
3A	Cowlitz River to Lewis River	72	87 5	30
B	Lewis River to Willamette River	87 5	102	
4A	Willamette River to Sandy River	102	123 5	44
B	Sandy River to Bonneville Dam	123 5	146	

Figure 1. Vicinity Map of the Lower Columbia River

2.0 DATA SUMMARIES

Data on a broad range of measures of water quality in the lower Columbia River are summarized in the following sections. The data summaries are organized according to the major environmental media reviewed:

- Water column (i.e., conventionals, trace metals, pesticides and PCBs)
- Sediment contamination
- Benthic macroinvertebrate communities
- Fish communities
- Bioaccumulation (i.e., fish and wildlife)
- Sediment toxicity bioassays.

Each section on environmental conditions includes 1) a general overview of the methods and data used and 2) data summary sections for each river segment. The methods and data review section gives the rationale for selecting indicator variables, the available data for analysis, sampling station locations, selection of values to represent screening levels, and a description of the methods used to assign a ranking (i.e., high, medium, or low) at each location. The segment-by-segment descriptions discuss the results of the analyses and generally summarize the existing data. The final section for each media synthesizes and interprets the data and provides some conclusions about potential problem areas and data gaps. It also attempts to evaluate the health of the system for that specific medium.

2.1 WATER COLUMN

2.1.1 Data Selection and Review Methods

More than 30 studies, reports, and databases were reviewed to identify useful data to characterize water quality in the Columbia River (Table 1). Studies reviewed include all of those listed in the McConnell Report (1990) as well as some additional studies in which further

TABLE 1. EVALUATION OF EXISTING WATER QUALITY STUDIES (Page 1 of 2)							
Reference	Accepted	SC[a]	SH[a]	QA[a]	AM[a]	Parameters[b]	Comments
City of Portland, Bureau of Environmental Services (1989)	No	NI[c]	NI	NI	NI	Conv, Nuts, Coliform, CHL, TM, BNA, VOC, Pest/PCB, O&G, Dioxin	No raw data; Columbia Slough
Blahm and McConnell (1979)	No	A[c]	A	A	A	Temp, DO, pH, Turb	Mainly biology study
Buchman (1987)	No	NI	NI	NI	NI		Review No original data
U S. COE (1979)	Yes	A	A	A	A	Conv, Nuts, TM, Pest, PCB, PCN	1 Columbia River Station
Durkin et al. (1981)	No	A	A	A	A	Turb, pH, Temp, Salinity, Cond.	Mainly a fish survey Conv. parameters only
Fuhrer and Evans (1990)	No	NI	NI	NI	NI	PP, TM	Review of elutriate method
Fuhrer (1984)	No	A	A	A	A	BNA, TM, Pest, PCB, PCN	Pacific Ocean water only
Fuhrer and Horowitz (1989)	No	A	A	A	A	TM, Nuts	Pacific Ocean water only
Fuhrer and Rinella (1983a)	Yes	A	A	A	A	Nuts, TM, Pest, PCB, Phenols	11 WQ stations on Columbia River
Fuhrer (1989)	Yes	A	A	A	A	TM, Nuts	CRM 100.5
USGS (1990b)	Yes	NI/A	NI/A	NI/A	NI/A	Conv, Nuts, Ions, TM, Coliform	Warrendale, OR 1972-89 monitoring data
USGS (1990a)	Yes	NI/A	NI/A	NI/A	NI/A	Conv, Nuts, Ions, TM, Coliform	Bradwood, OR monitoring data from 1973-80
Haushild et al. (1975)	Yes	A	A	A	A	Radionuclides	Vancouver
Hines et al. (1978)	No	NI	NI	NI	NI		Dilution model. No original data
Hubbard et al. (1989)	Yes	A	A	A	A	Conv, Nuts, Ions, TM, Coliform	Warrendale
Intergovernmental Resource Center (1987)	No	NI	NI	NI	NI	Conv, Nuts	Clark County drainage areas. No Columbia River data
Ogden Beeman and Assoc., Inc. (1986)	No	NI	NI	NI	NI	DO, Turb, pH, Temp, Solids	Conv only
ODEQ (1990a)	No					Program plan. No data	

TABLE 1 EVALUATION OF EXISTING WATER QUALITY STUDIES
(Page 2 of 2)

Reference	Accepted	SC[a]	SH[a]	QA[a]	AM[a]	Parameters[b]	Comments
ODEQ (1990b)	No	NI	NI	NI	NI		Status report general information and trends. No data
Somers (1988a)	No	A	A	A	A	Conv, Nuts, PP, TM, BNA, Coliform	Drainage ditch. No Columbia River stations
Somers (1988b)	No	A	A	A	A	Conv, Nuts, Coliform	Coweeman watershed storm survey
Somers (1989)	No	A	A	A	A	Conv, Coliform	Horseshoe Lake, Lewis River
Somers (1988c)	No	A	A	A	A	Conv, Nuts, Coliform	Arkansas watershed
U.S. EPA Storet Database (1991)	Yes	NI/A	NI/A	NI/A	NI/A	Conv, Nuts, Ions, TM, Coliform	3 Columbia River stations with data over time
Tetra Tech, Inc. (1976)	No	NI	NI	NI	NI	TM	No original data. Ranges only
Toombs et al. (1984)	No	A	A	A	A	Radionuclides	Summary data only
PGE (1990)	No	NI	NI	NI	NI	Radionuclides	No data for Columbia River station
USGS (1991)	Yes	NI/A	NI/A	NI/A	NI/A	Conv, Nuts, Ions, TM, Coliform, PHYTOPL	2 Columbia River stations with monitoring data
WDOE (1989)	No						Programmatic summary No data
Young (1988)	Yes	A	A	A	A	Conv, TM, AOX, Chloroform, Resin Acids, PCBs, Phenols	Monitoring study
Russ Fetrow Engineering, Inc (1989)	No	A	A	A	A	Conv, Nuts, Ions, TM, Tannin & Lignin	Redakovich Slough

[a] SC = Sample Collection, SH = Sample Handling, QA = Quality Assurance procedures, AM = Analytical Methods.

[b] Conv = Conventionals, Nuts = Nutrients, CHL = Chloryphyll *a*, TM - Total metals, BNA = Base/neutral/acid semivolatile organic compounds, VOC = Volatile organic compounds, Pest/PCB = Pesticides and PCBs, O&G = Oil and grease, Temp = Temperature (°C), DO = Dissolved oxygen, Turb = Turbidity, PCN = Polychlorinated napthalenes, Cond = Conductivity, PP = Priority pollutants, PHYTOPL = Phytoplankton, AOX = Aliphatic organic halides

[c] ND = No data, A = Acceptable.

information was available. Two databases were reviewed to identify water quality sampling stations. Two database dumps were supplied by the USGS and one by the U.S. Environmental Protection Agency (U.S. EPA). Data for some sampling stations were entered in both databases.

The following criteria were used to accept studies, reports, and data contained in databases in this data summary:

- Original raw data were included in the study. Summary and review data were not included in this data summary, although they were examined and are available for review.

- Sample collection, sample handling, quality assurance, and analytical methods were adequate to ensure data accuracy and precision.

- Sample stations were located in the lower Columbia River proper. Water quality data from lower Columbia River tributaries were available but were summarized in Task 2 of the lower Columbia River Reconnaissance Survey.

- Data were reported for chemical parameters in addition to measurements of pH, temperature, dissolved oxygen, turbidity, and other conventionals.

Eleven studies, reports, and databases were accepted on the basis of the above criteria (Table 2). Roughly 26 sampling stations with water chemistry data were identified from accepted studies (Table 2). The locations of these sampling stations are shown in Figures 2-5. Nearly all of the water quality stations identified represent single sampling events. Long-term data on ions, nutrients, conventional water quality parameters, trace metals, and bacteria were compiled by the USGS from water quality stations located at Bradwood, OR (1973-80), Warrendale, OR (1972-90), and Beaver Army Terminal in Oregon (1990-91). Water quality data collection has been discontinued at Bradwood and will probably be discontinued at Warrendale within the next year (McKenzie, S., 12 February 1992, personal communication). Beaver Army Terminal is the location of the new USGS water quality monitoring station. Sampling has continued at Warrendale to provide a synoptic comparison to data collected from the new site at Beaver Army Terminal.

TABLE 2. WATER QUALITY STUDIES WITH USEFUL DATA				
Reference	Number of Sampling Stations	Study Date	Station Locations	Parameters Measured[a]
Fuhrer & Rinella (1983a)	11	1980	Tansy Point, Col. R. Area D, Baker Bay; Tongue Pt., Col R. Mile 32.7, 65.8, 70.8, 71 4, 145.7	Nuts, TM, Pest, PCB, Phenols
Fuhrer (1989)	1	7/83	Col R Mile 100.5	Nuts, TM
Young (1989)	6	1989	Col. R. Miles 107, 114,117,120,120,121	Conv, Coliform, Resin Acids, Metals AOX, TM, PCB, Phenols
USGS (1990a)	1	1973-80	Bradwood, OR	Conv, Nuts, Ions, TM, Coliform
USGS (1990b)	1	1972-89	Warrendale, OR	Conv, Nuts, Ions, TM, Coliform
USGS (1991)	2		Beaver Army Terminal, Warrendale, OR	Conv, Nuts, Ions, TM, Coliform
U S EPA Storet Database	3	1991	Col. R. 1 Mile above Will. R. Confluence;	Ions, Nuts, Conv, TM, Coliform
U.S. EPA Storet Database		1980-91	Warrendale;	Ions, Nuts, Conv, TM, Coliform
U.S. EPA Storet Database		1990-91	Beaver Army Terminal	Ions, Nuts, Conv, TM, Coliform
Toombs et al. (1984)	4	1962-77	Col. R., Rooster Rock, Goble, Beaver Army Terminal, Astoria	Radionuclides
U S. COE (1979)	1	5/77	CRM 100.8	Conv, Nuts, Pest, TM, PCN, PCB
Hubbard et al. (1989)	1	1990	Warrendale	Conv, Ions, Nuts, TM, Coliform
Haushild et al. (1975)	1	1964-66	Vancouver	Radionuclides

[a] Conv = Conventionals, Nuts = Nutrients, CHL = Chloryphyla, TM - Total metals, BNA = Base/neutral/acid semivolatile organic compounds, VOC = Volatile organic compounds, Pest/PCB = Pesticides and PCBs, O&G = Oil and grease, Temp = Temperature (°C), DO = Dissolved oxygen, Turb = Turbidity, PCN = Polychlorinated napthalenes, Cond = Conductivity, PP = Priority pollutants, PHYTOPL = Phytoplankton, AOX = Aliphatic organic halides

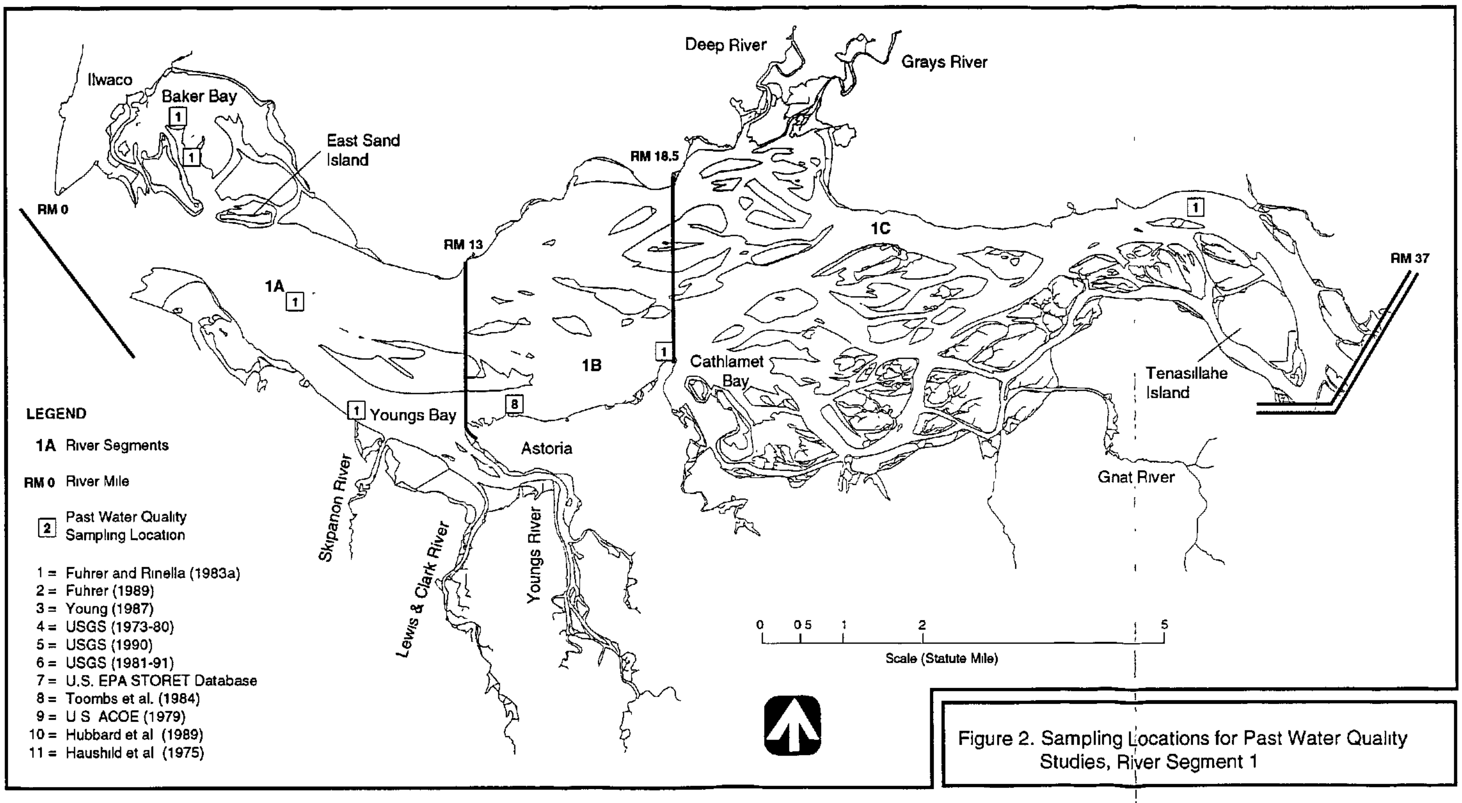


Figure 2. Sampling Locations for Past Water Quality Studies, River Segment 1

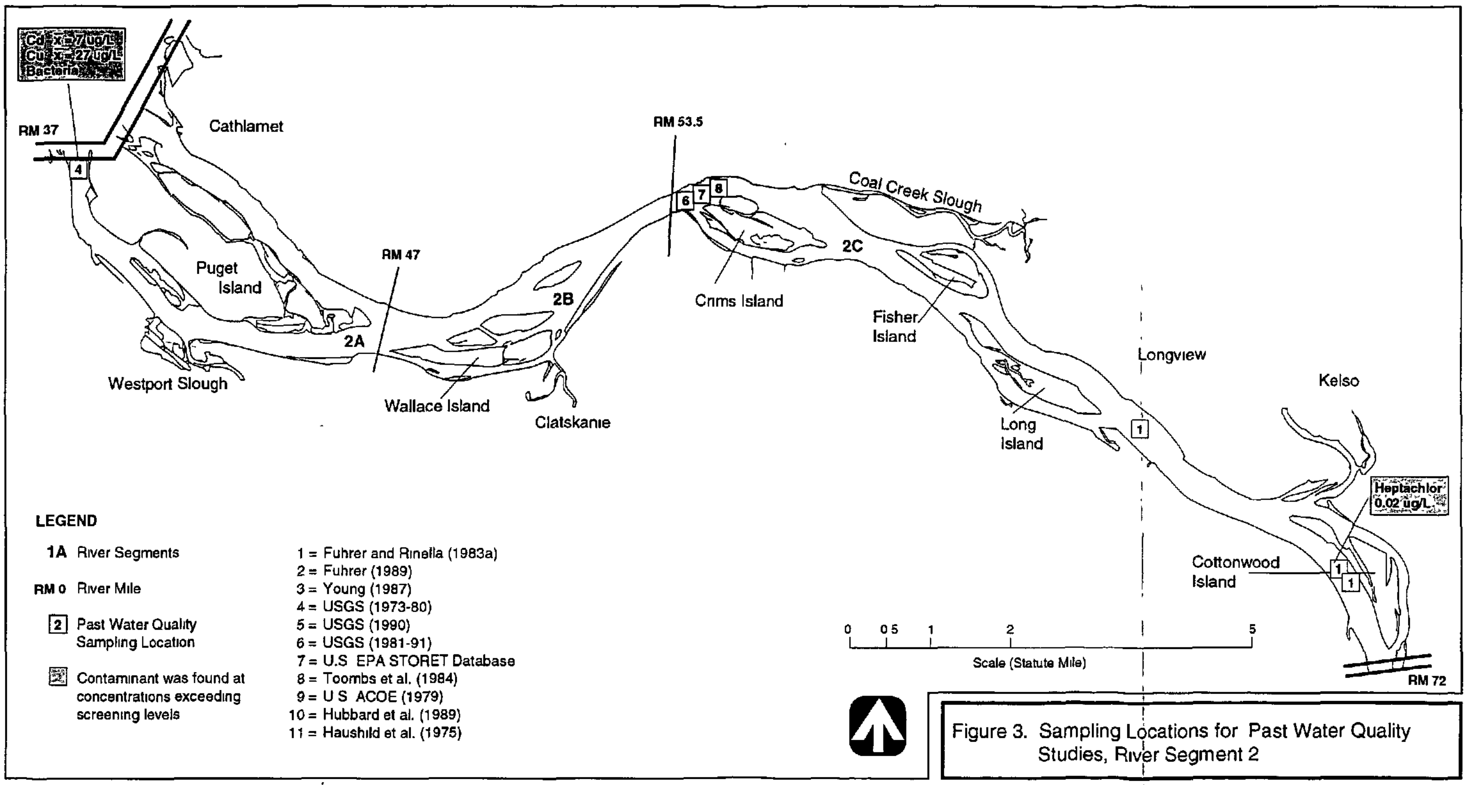


Figure 3. Sampling Locations for Past Water Quality Studies, River Segment 2

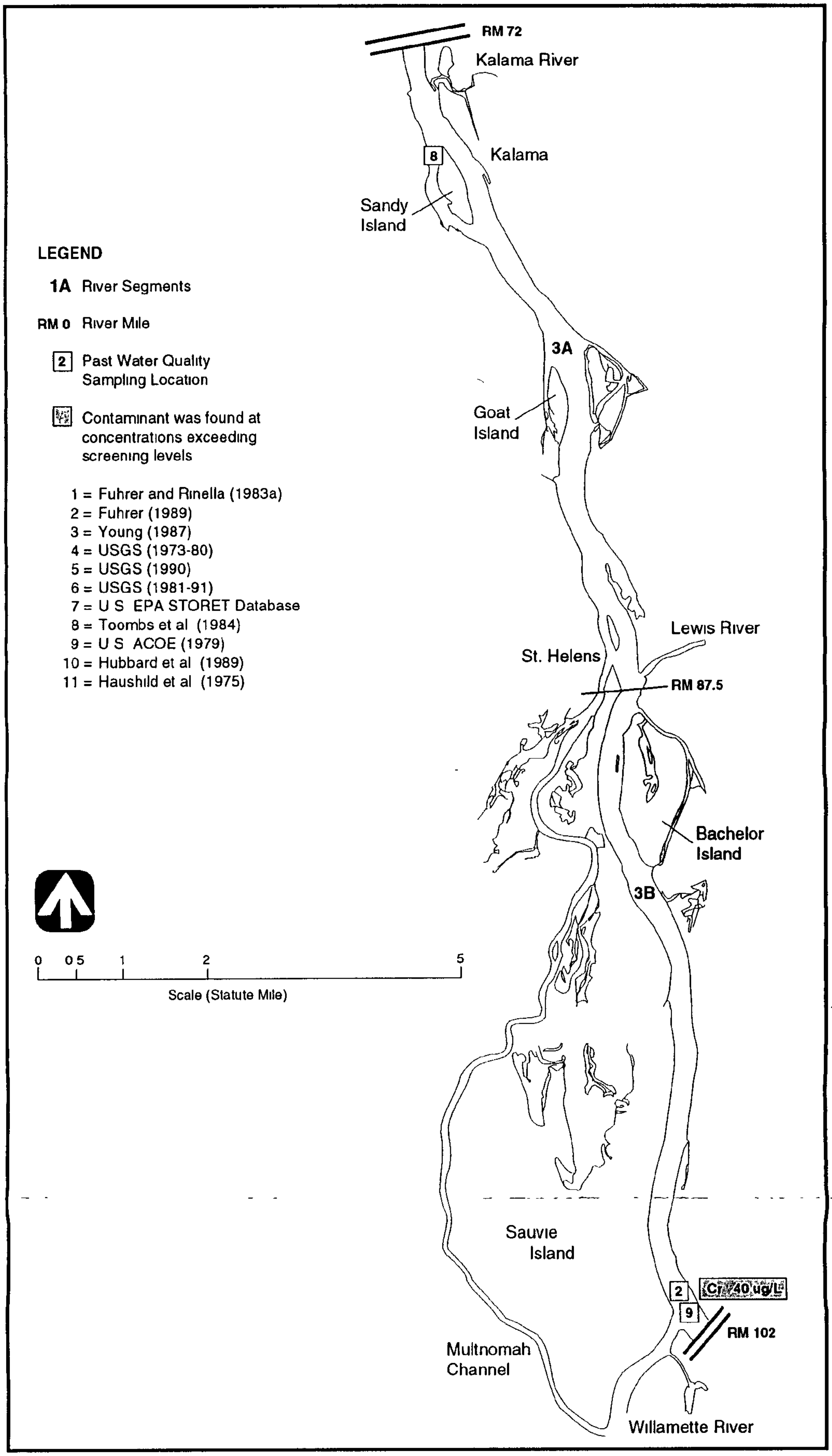


Figure 4. Sampling Locations for Past Water Quality Studies, River Segment 3

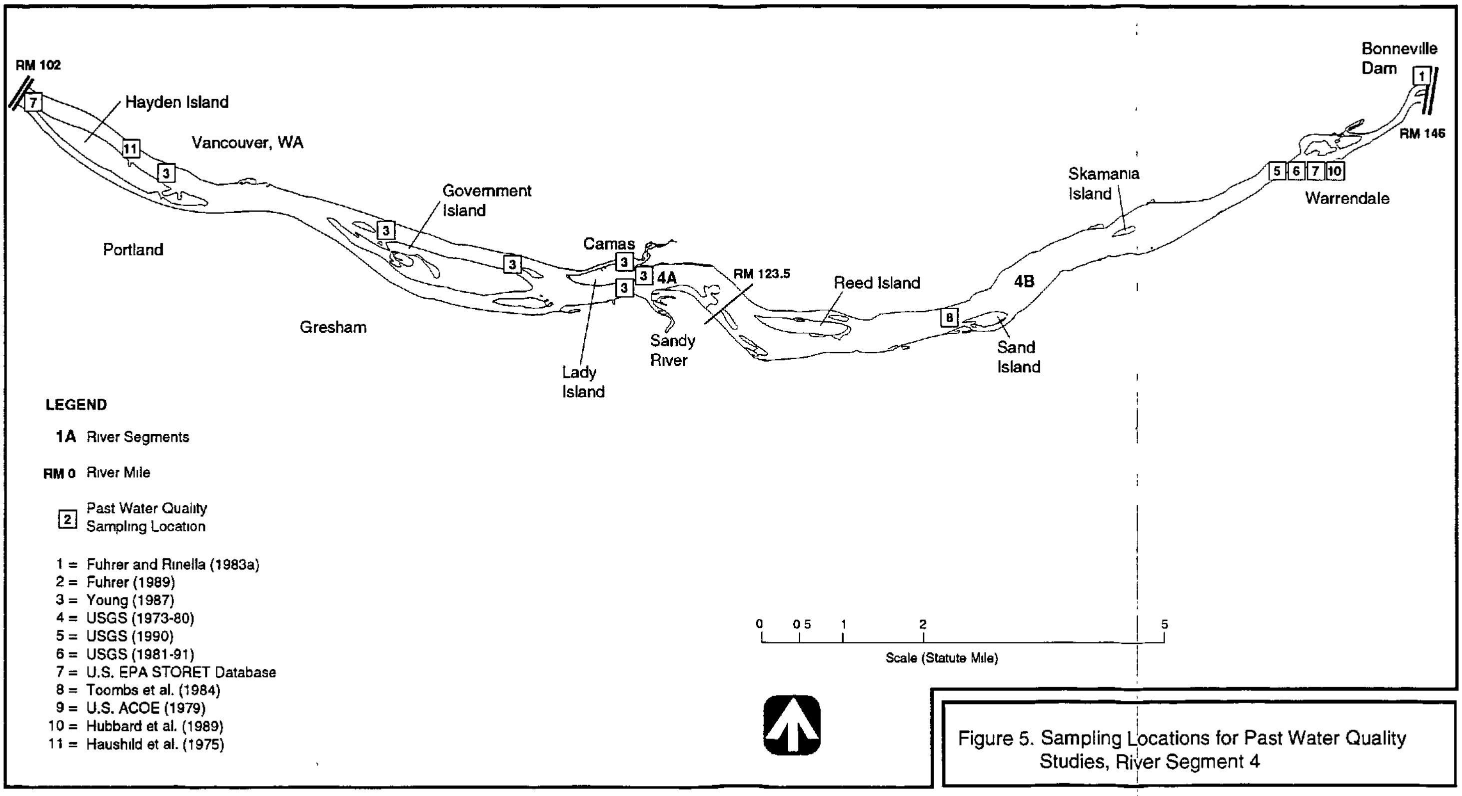


Figure 5. Sampling Locations for Past Water Quality Studies, River Segment 4

Over 200 chemical parameters have been measured in the accepted studies of lower Columbia River water quality and are listed in Appendix A. Chemical data were grouped into the following general categories:

- Conventional water quality parameters (CONV), ions, and nutrients (NUTS)
- Bacteria
- Trace metals (TM) and cyanide (CN)
- Phenols and aliphatic organic halides (AOX)
- Pesticides and PCBs
- Resin acids
- Radionuclides.

Two of the accepted studies contain data on radionuclide concentrations in the water column of the Columbia River (Haushild et al. 1973; Toombs et al. 1984). Both studies attempted to characterize the impact of the U.S Atomic Energy Commission Reservation at Hanford, WA to radionuclide concentrations in the lower Columbia River. The last data reviewed on individual radionuclide concentrations are from 1973. While radionuclides were detected in water samples, in no case were the concentrations in exceedance of federal water quality standards (Toombs et al. 1984). Radionuclide data continue to be collected quarterly at four stations (Astoria, Beaver Army Terminal, Goble, and Rooster Rock). In general, only natural background levels of radiation were detected at these sites (Parris, R., 27 March 1992, personal communication). Because there has been no indication in the last 20 years that radionuclides in the lower Columbia River are present at levels that could adversely impact human or ecological health, radionuclides will not be discussed further in this data summary.

All data from accepted studies were entered into a spreadsheet and sorted by river mile and river segment. The compiled data are listed by compound class in tables in Appendix A. Seven water quality stations were identified in river segment 1, five in river segment 2, three in river segment 3, and 11 in river segment 4.

To identify potential problem areas, existing state and federal water quality criteria were used as screening levels to evaluate the data from accepted studies (Table 3). Exceedance of the criteria indicated a potential problem. Marine water quality criteria were obtained from the U.S. EPA Goldbook (1986;1987) and are provided for comparison. The freshwater acute and chronic water quality criteria are from both the Washington and Oregon regulations. When the state regulations for a given parameter differ from each other, the lower of the two values is reported.

TABLE 3. SUMMARY OF PROPOSED SCREENING LEVEL FRESHWATER AND MARINE WATER QUALITY CRITERIA FOR THE LOWER COLUMBIA RIVER
(Page 1 of 5)

Pollutant	Concentrations (μg/L)			
	Marine		Freshwater	
	Acute	Chronic	Acute	Chronic
Acenaphthene	970[a]	710[a]	1,700[a]	520[a]
Acrolein	55[a]	--[b]	68[a]	21[a]
Acrylonitrile	--[b]	--[b]	7,550[a]	2,600[a]
Aldrin	0.71[c]	0.0019[f]	2.5[c]	0.00192[f]
Ammonia (unionized NH_3)	0.233[d]	0.035[e]	--[g,h]	--[g,h]
Antimony	[d]	--[b]	9,000[a]	1,600[a]
Arsenic	--[b]	--[b]	--	--
Pentavalent	2,319[a]	--[b]	850[a]	48[a]
Trivalent	69[d]	36[e]	360	190
Asbestos	--[b]	--[b]	--	--
Benzene	5,100[a]	700[a]	5,300[a]	--
Benzidine	--[b]	--[b]	2,500[a]	--
Beryllium	--[b]	--[b]	130[a]	5.3[a]
Cadmium	43[d]	9.3[e]	3.9[g]	1.1[g]
Carbon tetrachloride	50,000[a]	--[b]	35,200[a]	--
Chlordane	0.09[c]	0.004[f]	2.4[c]	0.0043[f]
Chlorinated benzenes	160[a]	129[a]	250[a]	50[a]
Hexachlorobenzene	160[a]	129[a]	--	--
Chlorinated ethanes				
Dichloroethane 1.2	113,000[a]	--[b]	118,000[a]	20,000[a]
Hexachloroethane	940[a]	--[b]	980[a]	540[a]
Penthachloroethane	390[a]	281[a]	7,240[a]	1,100[a]
Tetrachloroethane 1,1,2,2	9,020[a]	--[b]	--	2,400[a]
Trichloroethane 1,1,1	31,200[a]	--[b]	--	--
Trichloroethane 1,1,2	--[b]	--[b]	--	9,400[a]
Chlorinated ethylenes				
Dichloroethylenes	224,000[a]	224,000[a]	11,600[a]	--
Tetrachloroethylene	10,200[d]	450[a]	5,280[a]	840[a]
Trichloroethylene	2,000[a]	--[b]	45,000[a]	21,900[a]
Chlorinated naphthalene	7.5[a]	--[b]	1,600[a]	--

TABLE 3. SUMMARY OF PROPOSED SCREENING LEVEL FRESHWATER AND MARINE WATER QUALITY CRITERIA FOR THE LOWER COLUMBIA RIVER
(Page 2 of 5)

Pollutant	Concentrations (µg/L)			
	Marine		Freshwater	
	Acute	Chronic	Acute	Chronic
Chlorinated phenols				
Chlorophenol 2	--[b]	--[b]	4,300[a]	2,000[a]
Chlorophenol 4	29,700[a]	--[b]	--	--
Dichlorophenol 2,4	--[b]	--[b]	2,020	365
Penthachlorophenol (penta)	13[d]	7.9[e]	20[h]	13[h]
Tetrachlorophenol 2,3,5,6	440[a]	--[b]	--	--
Trichlorophenol 2,4,6	--[b]	--[b]	--	970
Chloride	--	--	860 Oh[d]	230 Oh[e]
Chlorine	13[d]	7.5[e]	19.0	11 0
Chloroalkyl ethers	--[b]	--[b]	238,000[a]	--
Chloroethyl ether (bis-2)	--[b]	--[b]	--	--
Chloroform	--[b]	--[b]	28,900[a]	1,240[a]
Chloroisopropyl ether (bis-2)	--[b]	--[b]	--	--
Chloromethyl ether (bis)	--[b]	--[b]	--	--
Chlorpyrifos	0.011[d]	0 0056[e]	0 083	0 041
Chromium				
Hexavalent	1,100[d]	50[e]	16	11
Trivalent	10,300[a]	--[b]	1,700[g]	210[g]
Copper	2.9[d]	2.9[e]	18[g]	12[g]
Cyanide	1.0[d]	1.0[e]	22	5.2
DDT	0 13[c]	0.001[f]	1.1	0 001
DDT Metabolites				
DDD	3 6[a]	--[b]	0.06[a]	--
DDE	14[a]	--[b]	1,050[a]	--
Demeton	--[b]	0.1	--	0 1
Dichlorobenzenes	1,970[a]	--[b]	1,120[a]	763[a]
Dichlorobenzidines	--[b]	--[b]	--	--
Dichloropropanes	10,300[a]	3,040[a]	23,000[a]	5,700[a]
Dichloropropenes	790[a]	--[b]	6,060[a]	244[a]
Dieldrin	0.71[c]	0.0019[f]	2.5	0.0019

TABLE 3. SUMMARY OF PROPOSED SCREENING LEVEL FRESHWATER AND MARINE WATER QUALITY CRITERIA FOR THE LOWER COLUMBIA RIVER
(Page 3 of 5)

Pollutant	Concentrations (μg/L)			
	Marine		Freshwater	
	Acute	Chronic	Acute	Chronic
Dimethylphenol 2,4	--[b]	--[b]	2,120[a]	--
Dinitrotoluenes	590[a]	370[a]	330[a]	230[a]
Dinitrotoluene 2,4	590[a]	370[a]	--	--
Dioxin (2,3,7,8-TCDD)	--[b]	--[b]	0.01[a]	0.0001[a]
Diphenylhydrazine 1,2	--[b]	--[b]	270[a]	--
Dissolved oxygen	>6 mg/L		>8 mg/L	
Endosulfan	0.034[c]	0.087[f]	0.22[a]	0.056[a]
Endrin	0.037[c]	0.0023[f]	0.18	0.0023
Ethylbenzene	430[a]	[a]	32,000[a]	--
Fecal coliform	100/100 mL		14/100 mL	
Fluoranthene	40[a]	16[a]	3,980[a]	--
Guthion	--[b]	0.01	--	0.01
Haloethers	--[b]	--[b]	360[a]	122[a]
Halomethanes	12,000[a]	6,400[a]	11,000[a]	--
Heptachlor	0.053[c]	0.0036[f]	0.52	0.0038
Hexachlorobutadiene	32[a]	--[b]	90[a]	9.3[a]
Hexachlorocyclohexane (HCH)				
HCH-alpha	--[b]	--[b]	--	--
HCH-beta	--[b]	--[b]	--	--
Lindane (HCH-gamma)	0.16[c]	--[b]	2.0	0.08
HCH (mixture of isomers)	0.34[a]	--[b]	--	--
Hexachlorocyclopentadiene	7.0[a]	--[b]	7.0[a]	5.2[a]
Isophorone	12,900[a]	--[b]	117,000[a]	--
Lead	140[d]	5.6[e]	82[g]	3.2[g]
Malathion	--[b]	0.1	--	0.1
Manganese	--[b]	--[b]	--	--
Mercury	2.1[d]	0.025[e]	2.4	0.12
Methoxychlor	--[b]	0.03	--	0.03

TABLE 3. SUMMARY OF PROPOSED SCREENING LEVEL FRESHWATER AND MARINE WATER QUALITY CRITERIA FOR THE LOWER COLUMBIA RIVER
(Page 4 of 5)

Pollutant	Concentrations (μg/L)			
	Marine		Freshwater	
	Acute	Chronic	Acute	Chronic
Mirex	--[b]	0.001	--	0.001
Napthalene	2,350[a]	--[b]	2,300[a]	620[a]
Nickel	75[c]	8.3[f]	1,400[g]	160[g]
Nitrobenzene	6,680[a]	--[b]	27,000[a]	--
Nitrophenols	4,850[a]	--[b]	230[a]	150[a]
Dinitrophenols	4,850[a]	--[b]	--	--
Dinitro-o-cresol 2,4	4,850[a]	--[b]	--	--
Nitrosamines	3,300,000[a]	--[b]	--	--
Nitrosodibutylamine	3,300,000[a]	--[b]	5,850[a]	--
Nitrosodiethylamine	3,300,000[a]	--[b]	--	--
Nitrosodimethylamine	3,300,000[a]	--[b]	--	--
Nitrosodiphenylamine	3,300,000[a]	--[b]	--	--
Nitrosopyrrolidine	3,300,000[a]	--[b]	--	--
Parathion	--[b]	--[b]	0 065	0 013
pH	6 5-8.5		7.0-8.5	
Phenol	5,800[a]	--[b]	10,200[a]	2,560[a]
Phosphorous (elemental)	--[b]	0.1	--	--
Phthalate esters	2,944[a]	3 4[a]	940[a]	3[a]
Dibutylphthalate	--[b]	--[b]	--	--
Diethylphthalate	--[b]	--[b]	--	--
Dimethylphthalate	--[b]	--[b]	--	--
Di-2-ethylhexylphthalate	--[b]	--[b]	--	--
Polychlorinated biphenyls	10[a]	0.03[f]	2.0	0 014
Polynuclear aromatic hydrocarbons	300[a]	--[b]	--	--
Selenium (inorganic selenite)	410[c]	54[f]	260	35
Silver	2 3[c]	--[b]	4.1[g]	0 12
Sulfur (hydrogen sulfide, H_2S)	--[b]	2[f]	--	2 0
Temperature °C	≤18°C		≤16°C	
Thallium	2,130[a]	--[b]	1,400[a]	--
Toluene	6,300[a]	5,000[a]	17,500[a]	--

TABLE 3. SUMMARY OF PROPOSED SCREENING LEVEL FRESHWATER AND MARINE WATER QUALITY CRITERIA FOR THE LOWER COLUMBIA RIVER
(Page 5 of 5)

Pollutant	Concentrations (µg/L)			
	Marine		Freshwater	
	Acute	Chronic	Acute	Chronic
Toxaphene	0.21[d]	0.0002[e]	0.73	0.0002
Turbidity	≤5 NTU above background			
Vinyl chloride	--[b]	--[b]	--	--
Zinc	95[d]	86[e]	120[g]	110[g]

[a] Data insufficient to derive criteria. Value presented is the lowest observed effect level (LOEL). These concentrations represent apparent threshold levels for acute and/or chronic toxic affects, and are intended to convey information about the degree of toxicity of a pollutant in the absence of established criteria.

[b] Criterion has not been established for marine water quality.

[c] Not to be exceeded at any time.

[d] Maximum 1-h average. Not to be exceeded more than once every 3 years

[e] Maximum 96-h (4-day) average. Not to be exceeded more than once every 3 years.

[f] Maximum 24-h average. Not to be exceeded more than once every 3 years.

[g] Hardness dependent criteria (100 mg/L used).

[h] pH dependent criteria (7.8 pH used).

References: Goldbook=U.S. EPA 1986; Update No. 2=U.S. EPA 1987)

Water quality data for the Columbia River are limited. Very few water quality studies that include water chemistry measurements have been conducted on the lower Columbia River. Given the dynamic nature of the Columbia River, temporal measurements of water quality are critical in assessing the overall health of the water body. Because time-series (long-term) data for water quality are available only from the USGS stations, the data from these studies will be emphasized in the summaries below.

2.1.2 Review of Accepted Data

2.1.2.1 Data Summary: River Segment 1. Seven different water quality stations have been sampled in river segment 1 which meet the minimum criteria for data integrity described in Section 2.1.1. All of these stations were sampled in 1980 as part of a USGS study (Fuhrer and Rinella 1983a). The study was designed to provide reconnaissance data for several lower Columbia River dredging operation locations. Five of the stations were located in river segment 1A, while one station was located in each of river segments 1B and 1C. In addition to conventional parameters and nutrients, water samples from these stations were analyzed for dissolved metals, phenols, and pesticides. Most of the metals were detected at or just above the method detection limit, with the exception of iron (19–140 ug/L), manganese (10–40 ug/L), and zinc (20–42 ug/L). The method detection limit (MDL) for these metals was 10 ug/l. None of the pesticides were detected, while the concentration of dissolved phenols ranged from 3–8 ug/L.

No conclusions about temporal trends in water quality in river segment 1 are possible given the lack of any time-series data from this segment.

2.1.2.2 Data Summary: River Segment 2. Five water quality stations sampled in river segment 2 have been included in the summary data tables (see Appendix A). Two of the three USGS stations described above are located in this segment. The USGS station at Bradwood (RM 39) was sampled from 1973–80, at a frequency ranging from monthly to semi-annually depending on the parameter. The newly-established USGS station at Beaver Army Terminal (RM 53.6) in Section 2C, was sampled four times in 1990–91. More recent data have been collected but are not yet available. Finally, three stations from RM 65 to 70 (river segment 2C) were sampled in 1980 by USGS (Fuhrer and Rinella 1983a) for the reconnaissance survey of dredging operation locations. In addition to conventional parameters and nutrients, all stations were analyzed for dissolved metals, with the exception of the Bradwood station, which was measured for total recoverable metals. Values for total metals are typically higher than values for dissolved metals, although there is no standard quantitative relationship between the two methods. The stations at Bradwood and the Beaver Army Terminal were measured for fecal coliform and streptococci bacteria. One station at RM 70.8 was also measured for dissolved phenols and pesticides.

Total recoverable metals collected from Bradwood show no consistent trend between 1973–79. Chromium, arsenic, and mercury were not generally detected, while zinc, lead, cadmium, and copper were almost always detected. Mean concentrations of cadmium and copper for the period from October 1978 to September 1979 exceeded the water quality criteria (Figure 3, Appendix A).

Metals data were collected from the Beaver Army Terminal on two occasions. The variability between these two samples, taken almost four months apart, is very small. With the exception of barium, iron, and strontium, all the other metals sampled were undetected. At the three other river segment 2C stations, only copper, iron, and lead were detected.

The bacterial abundance values obtained at Bradwood were quite variable, ranging from an undetectable amount of fecal coliform (<1 colony/100mL) in November to 4,500 colonies/ 100 mL of fecal streptococci, also in November. These results are from single monthly grab samples, and are generally considered to be highly variable. Bacterial abundances at the Beaver Army Terminal were generally low, with no value being over 26 colonies/100 mL.

At the river segment 2 station analyzed for organics, dissolved phenol was detected at 12 ug/L. This concentration is at least 50 percent higher than any sample analyzed from river segment 1. All pesticides were undetected, with the exception of heptachlor, 2,4–D, and 2,4–DP, which were all detected just above the MDL of 0.01 ug/L. Heptachlor concentration (0.02 ug/L) exceeded the water quality criteria (0.0038 ug/L) in 1980.

Temporal trends in water quality in river segment 2 can be evaluated by examining the USGS data from both Bradwood and Beaver Army Terminal. The metals data from Bradwood is not easily compared to the other USGS metals data because the Bradwood values are for total recoverable metals, while the other USGS data is for dissolved metals. Starting in 1992, the USGS will use the total recoverable metals method at Beaver Army Terminal. Although sampling did not take place simultaneously at Bradwood and Beaver Army Terminal, the sampling at the Warrendale reference station overlapped both of the other USGS stations. In general, conventional water quality variables such as dissolved oxygen (DO), nitrate/nitrite, and total phosphorous are of similar magnitude at all three stations (Figure 6). Considerable seasonal variation exists in DO for all three stations, but the range of values has not changed in the last 20 years. A similar trend exists for dissolved nitrite/nitrate at Beaver Army

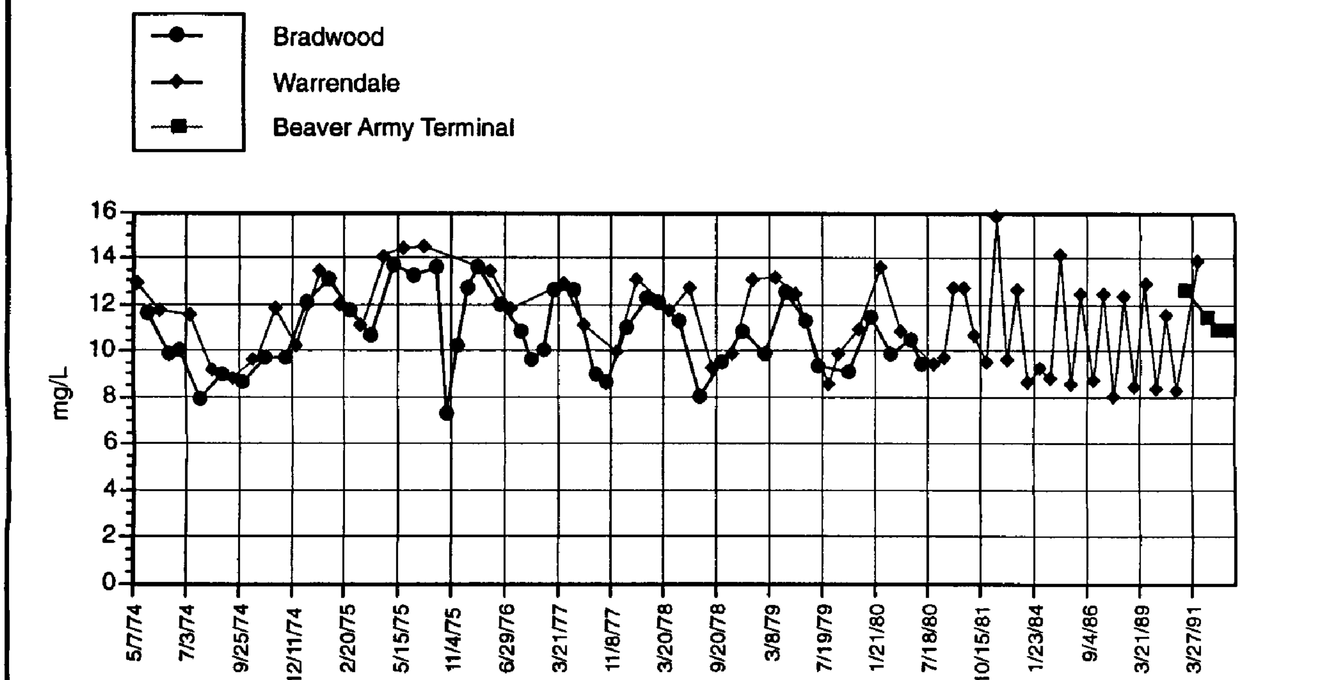


Figure 6. Dissolved Oxygen Concentrations from USGS Water Quality Monitoring Stations at Warrendale, Beaver Army Terminal, and Bradwood, 1974-1991

Terminal as compared to Warrendale (Figure 7). The seasonal variation is evident and the range of values for Beaver Army Terminal is contained within the range of Warrendale values.

Temporal plots of fecal coliform bacteria for the three USGS stations show that the Bradwood results are considerably higher than either Beaver Army Terminal or Warrendale (Figure 8). The results at Bradwood should not be considered indicative of the entire lower Columbia River, because data collected simultaneously from Warrendale show consistently low values.

2.1.2.3 Data Summary: River Segment 3. Only two water quality stations in river segment 3 have produced data that are included in the summary data tables (see Appendix A). One station was sampled at RM 101 in October 1983 by USGS (Fuhrer 1989), while the other was sampled by the U.S. COE at RM 101 in May 1977 (U.S. COE 1979). In addition to several conventional and nutrient variables, the USGS study collected data for total metals. With the exception of barium, iron, and zinc, all metals were detected near or at the detection limits The U S COE study collected data for dissolved N-NH_4, dissolved metals, and pesticides Copper, iron, lead, chromium, and zinc were all detected, while arsenic, manganese, and mercury were undetected. Only chromium concentrations from segment 3 are greater than the maxima seen in segments 1 and 2. The chromium concentration exceeds the water quality criteria. All pesticides were undetected at the U.S. COE station.

No conclusions about temporal trends in water quality in river segment 3 are possible given the lack of any time-series data from this segment.

2.1.2.4 Data Summary: River Segment 4. Data from eight different water quality stations in segment 4A and three different water quality stations in segment 4B are presented in the summary data tables (see Appendix A). One station, located near Portland at RM 102.5, was sampled three times in February and March 1991. Six stations in Segment 4A were sampled in August 1989 by the James River Corporation as part of their National Pollutant Discharge Elimination System (NPDES) monitoring requirements (Young 1989). These stations were located at the I-5 Bridge (RM 107), the I-205 Bridge (RM 114), Hassalo Rock (RM 117), two at the Camas Outfall (RM 120), and at Parker's Landing (RM 121). The two stations in Segment 4B were at Warrendale (RM 141) and just below the Bonneville Dam (RM 145.7). Both the Warrendale data and the Bonneville data were collected by the USGS, but have been reported in different studies (USGS 1990b; and Fuhrer and Rinella 1983a, respectively).

In addition to conventional parameters and nutrients, samples from the Portland station were analyzed for dissolved iron and manganese. These data were retrieved from the STORET database. The metals were undetected for all but one of the three manganese samples.

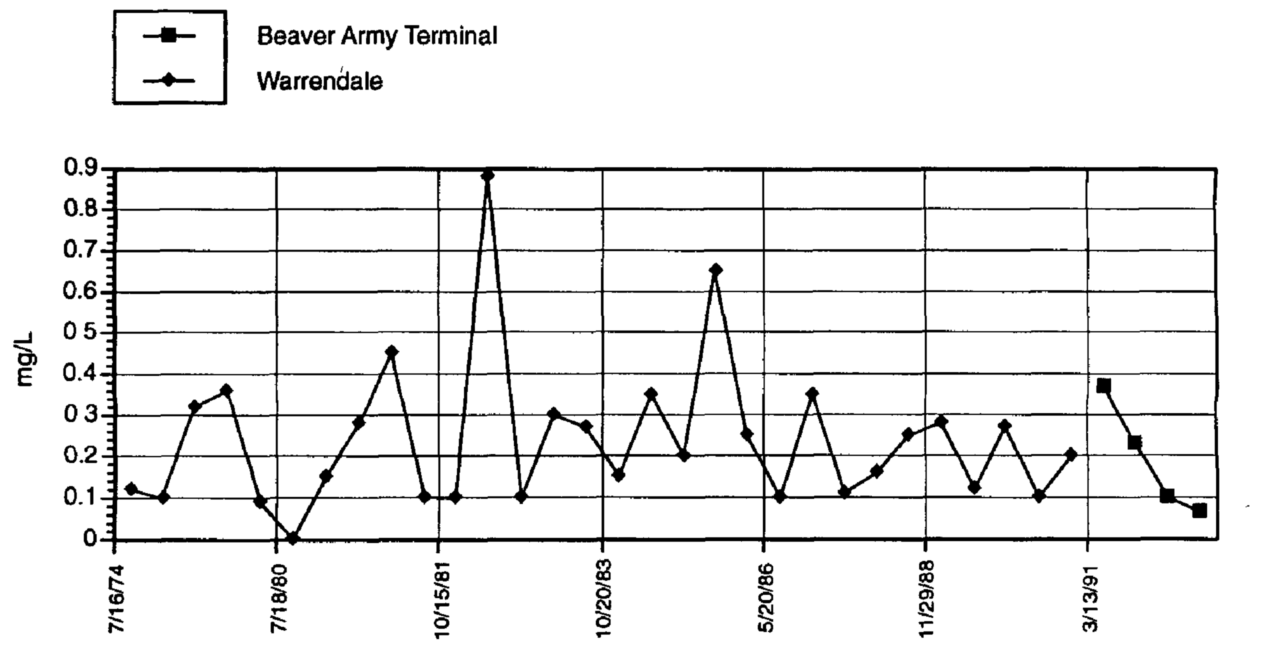


Figure 7. Dissolved Nitrate/Nitrite Concentrations from USGS Water Quality Monitoring Stations at Warrendale and Beaver Army Terminal, 1974-1991

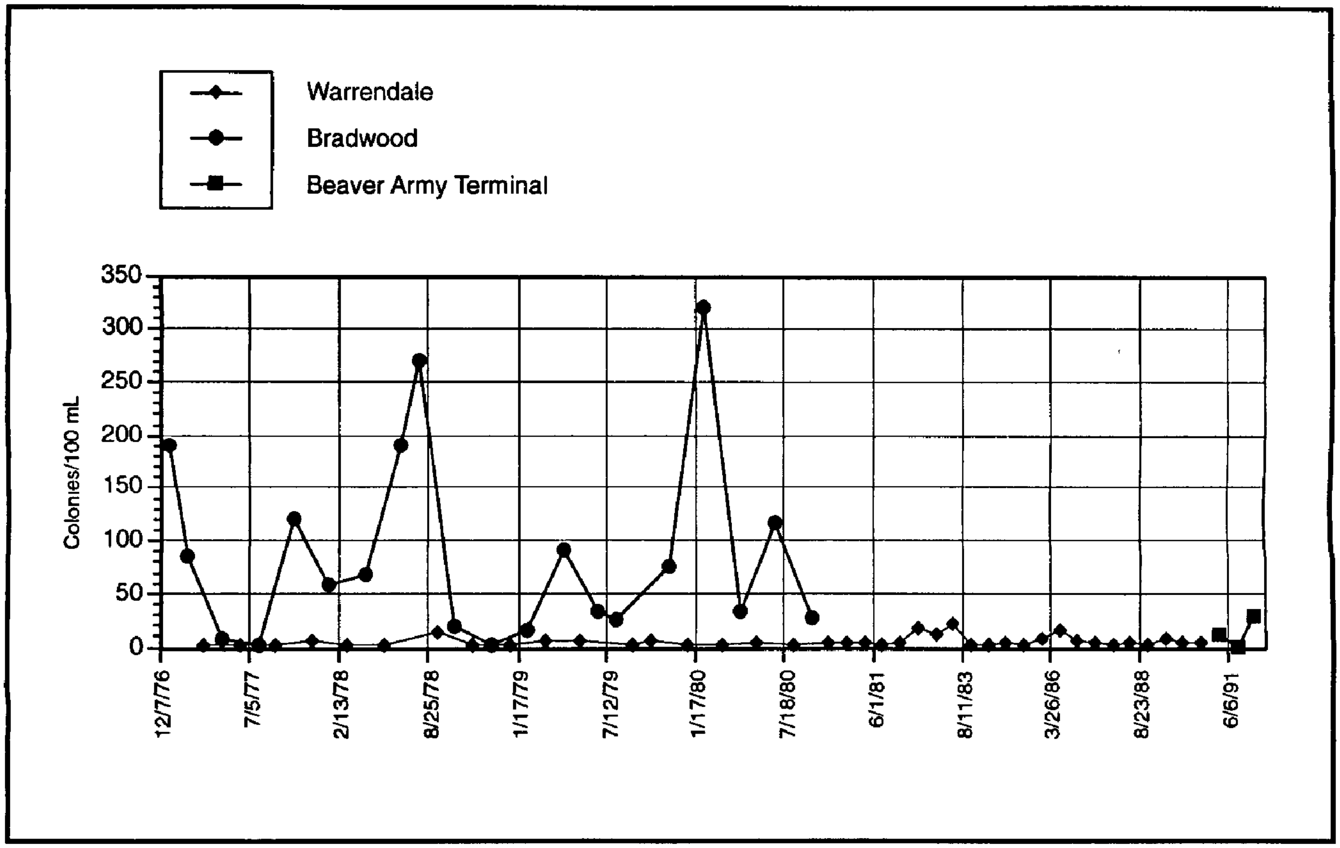


Figure 8. Fecal Coliform Bacteria Abundances from USGS Water Quality Monitoring Stations at Warrendale, Beaver Army Terminal, and Bradwood, 1976-1991

The James River Corp. monitoring stations were measured for conventional parameters and nutrients, dissolved metals, adsorbable organic halogens (AOX), resin acids, and chlorinated resin acids. Samples were taken at each station from surface water and from mid-depth. Only barium, manganese, and iron were detected. AOXs were measured at 18–106 ug/L, with the highest values being at the two bridge stations and Hassalo Rock. The AOX values at the Camas outfall were only 20–40 percent as high as the bridge samples, perhaps indicating a more significant source of AOX downstream from the Camas outfall. No resin acids or chlorinated resin acids were detected at any of the monitoring stations.

The USGS station at Warrendale has been sampled consistently since 1973. Only the last year of available data are included in Appendix A. For trace metals, beryllium, chromium, and mercury were not detected in any of the four samples analyzed. Copper and manganese were detected in all of the samples, while arsenic, cadmium, lead, nickel, and zinc were detected in only a portion of the samples. The detection limit for these metals ranged from 0.1 ug/L for mercury to 3 ug/L for zinc. Most metals had a detection limit of 1 ug/L. The dissolved metals data from Warrendale are considered suspect because of probable contamination from the sampler (McKenzie, S., 12 February 1992, personal communication).

Bacterial abundances at Warrendale were generally low, with no value being over 13 colonies/100 mL. Fecal coliform data from the entire sampling history at Warrendale also indicate consistently low values (Figure 8).

The Bonneville Dam station was sampled in 1980 for conventional parameters, nutrients, dissolved metals, and pesticides. Only boron and iron were detected. None of the pesticides were detected.

The USGS station at Warrendale represents the most complete data set for temporal trends of water quality on the lower Columbia River. As discussed, several conventional parameters have been plotted and compared to data from the other USGS stations at Bradwood and Beaver Army Terminal (see Figures 6, 7, and 8).

2.1.3 Data Synthesis and Conclusions

Only limited water quality data are available for the lower Columbia River. Many of the stations sampled were meant to characterize a potential point source of pollution. Priority pollutants are generally not detected in the lower Columbia River water samples. This does not necessarily mean that these pollutants are not present in the water column. Because of the dynamic nature of the water body, documentation of any "hot spots" with respect to water quality have been difficult to obtain. Many of the pollutants which are discharged to the main stem of the river are quickly diffused over a relatively large area. The analytical methods commonly used to measure priority pollutants are not generally sensitive enough to detect the pollutants presumably present in the small sample volume.

Much of the total recoverable metals data collected at the USGS station at Bradwood, Oregon in the 1970s would have exceeded the current freshwater criteria (see Table 3). Because no data have been collected from this station since 1980, it is difficult to assess current water quality at the site. None of the data collected at any other site on the river since 1980 have exceeded the chronic freshwater criteria, with the exception of one mercury value which barely exceeded the criteria at a dredged disposal station located in river segment 1A (Fuhrer and Rinella 1983a). One of the metals analyzed, beryllium (MDL = 10 g/L), had a method detection limit that exceeded the criteria.

Based on the available water quality data, data are insufficient to identify consistent trends in federal and state water quality criteria in Columbia River water. The longest time-series data available are from the USGS station at Warrendale in river segment 4, where no violations of water quality were noted. Two factors, however, preclude assuming the lack of water quality violations at Warrendale can be extrapolated to the entire lower Columbia River. First, organic priority pollutants have never been measured at Warrendale. These compounds represent important ecological and human health hazards. The dynamic nature of the water body and the small volume of water typically sampled at a station, make detection of "hot spots" of organic contamination very difficult. Second, Warrendale is located upstream of most industrial development that might adversely impact water quality. One would not expect that the water quality at Warrendale is representative of the water quality of the industrial regions near Camas/Washougal, Portland/Vancouver, Longview/Kelso, and Kalama, Washington.

The establishment of a reference station is an important component of any assessment of water quality over a large reach of river. The USGS station at Warrendale was originally conceived as a reference station. Because no data on organic compounds have been collected at this site and the water sampler has probably contributed significant contamination to the samples analyzed for dissolved metals, the validity of the Warrendale site as a reference site is questionable (McKenzie, S., 12 February 1992, personal communication). However, Warrendale is located upstream of most of the point sources of pollution on the lower Columbia River, as discussed above, which makes it the most likely candidate for a reference station for the purposes of this data review.

Although there are insufficient data available to identify consistent trends in Columbia River water quality with respect to federal and state water quality criteria, a more informal criterion has been used to identify and prioritize problem areas with respect to pollutant levels. Because many of the metals and organic compounds for which analyses have been performed are not typically detected in lower Columbia River water samples, the detected values take on increased importance. Though almost all of the detected values do not exceed the freshwater water quality criteria given in Table 3 (see Section 2.1.2), the presence of measurable levels of contaminants in the small volume of a typical water sample can be thought of as a "hot spot" relative to pristine conditions.

An attempt was made to prioritize potential problem areas based on existing water quality data. Since the areal coverage of historical water quality data from the lower Columbia River is sporadic, each individual station was considered separately. In this evaluation, data from each measured parameter at a given water quality station were compared against the detection limit and the water quality criteria presented in Table 3. Data from thirteen parameters were examined. Ten of these were metals (arsenic, beryllium, cadmium, chromium, copper, lead, manganese, mercury, nickel, and zinc), while the others were total PCBs, total pesticides (both taken as sums if individual compounds were analyzed), and fecal coliform bacteria. Only the last available year of data was examined for stations from which a time-series is available. If no detected values were available for a given parameter at a given station, that "area" or station was given a low priority for that parameter. If one or more values were above the detection limit but not above the chronic water quality criteria for freshwater, then that station was given a medium priority for that parameter. Finally, if one or more values were above the chronic water quality criteria, then that station was given a high priority for that parameter. Table 4 summarizes the results of this evaluation of the water quality data from the accepted studies (according to the criteria established in Section 2.1.1). If two or more parameters caused a given station to be classified as medium- or high-priority, then the overall station priority was given as medium or high, respectively, in Table 1. Otherwise, the station was classified as low priority.

The majority of the water quality stations from which acceptable data are available have been classified as medium-priority (Table 4). Most of the stations classified as medium- or high-priority, however, have not been sampled within the last ten years. Water quality in a dynamic system such as the lower Columbia River is dependent solely on an active pollutant sources, unlike sediment quality, which is also affected by previous pollutant sources in the form of sediment deposition. Thus, water quality measurements of ten or more years ago are only applicable to present day water quality if the pollutant sources in the two times are equivalent. Since pollutant sources, both point and non-point, have changed considerably in

TABLE 4 PRIORITIZATION OF PROBLEM AREAS BASED ON DETECTED VALUES AND EXCEEDANCES OF WATER QUALITY CRITERIA IN THE LOWER COLUMBIA RIVER
(Page 1 of 2)

Map Reference	Station	River Mile	Last Sampled	Parameter Specific Priority[a]			Overall Priority[b]
				High	Medium	Low	
1	Tansy Point[c]	10	1980	None	Cu, Pb, Mn, Zn	As, Be[d], Cd, Cr, Hg, Ni, PCB, Pest	Medium
1	Baker Bay 1[c]	5	1980	None	Cu, Pb, Mn, Zn	As, Be[d], Cd, Cr, Hg, Ni, PCB, Pest	Medium
1	Baker Bay 2[c]	5	1980	None	Cu, Pb, Mn, Ni, Zn	As, Be[d], Cd, Cr, Hg, PCB, Pest	Medium
1	Area D[c]	7	1980	None	Cr, Cu, Pb, Mn, Hg, Ni, Zn	As, Be[d], Cd[e], PCB, Pest	Medium
1	Tongue Point[c]	18	1980	None	Cu, Pb, Mn, Ni	As, Be[d], Cd, Cr, Hg, Zn, PCB, Pest	Medium
1	Welch Island[c]	32.7	1980	None	Pb, Mn, Zn	As, Be[d], Cd, Cr, Cu, Hg, Ni, Pest, PCB	Medium
4,7	Bradwood[f]	39	1979	Cd, Cu, Bact	As, Pb, Zn	Cr[d]	High
6,7	Beaver Army Terminal[f]	54	1991	None	Cu, Mn, Zn, Bact	As, Be, Cd, Cr, Pb, Hg, Ni	Medium
1	Slaughter's Channel[c]	65.8	1980	None	Cu, Pb, Mn	Be[d], Cd, Zn	Medium
1	Cottonwood Island 1[c]	70.8	1980	Heptachlor	Cu, Pb, Pest, 2,4-D, 2,4-DP, 2,4,5-T	As, Be[d], Cd, Cr, Mn, Hg, Ni, Zn, PCB	Medium
1	Cottonwood Island 2[c]	71.4	1980	None	Cr, Pb, Ni	As, Be[d], Cd, Cu, Mn, Hg, Zn	Medium
2	Morgan Channel[g]	100.5	1983	None	As, Cu, Pb, Ni, Zn	Cd[e], Cr	Medium
9	Vancouver[h]	102	1977	Cr	Cu, Pb, Zn	As, Mn, Hg, PCB, Pest	Medium
7	Willamette River[f]	103	1991	None	Mn	None	Low
3	I-5 Bridge 6A[i]	107	1989	None	None	As, Be, Cd, Cr, Cu, Pb, Mn[e], Hg, Ni, Zn	Low
3	I-205 Bridge[i]	114	1989	None	None	As, Be, Cd, Cr, Cu, Pb, Mn[e], Hg, Ni, Zn	Low

TABLE 4. PRIORITIZATION OF PROBLEM AREAS BASED ON DETECTED VALUES AND EXCEEDANCES OF WATER QUALITY CRITERIA IN THE LOWER COLUMBIA RIVER
(Page 2 of 2)

Map Reference	Station	River Mile	Last Sampled	Parameter Specific Priority[a]			Overall Priority[b]
				High	Medium	Low	
3	Hassalo Rock[i]	117	1989	None	None	As, Be, Cd, Cr, Cu, Pb, Mn[e], Hg, Ni, Zn	Low
3	Camas Outfall[i]	120	1989	None	None	As, Be, Cd, Cr, Cu, Pb, Mn[e], Hg, Ni, Zn	Low
3	Parker's Landing[i]	121	1989	None	None	As, Be, Cd, Cr, Cu, Pb, Mn[e], Hg, Ni, Zn	Low
5,6,7,10	Warrendale[d]	141	1991	None	As, Cd, Cu, Pb, Mn, Ni, Zn	Be, Cr, Hg, Bact	Medium

[a] If one or more values was above detection limits or exceeded chronic water quality criteria, that parameter was placed in the medium or high priority category, respectively.

[b] If two or more parameters were placed in the medium or high priority category, the overall priority was given as medium or high, respectively.

[c] Fuhrer and Rinella (1983a)

[d] MDL greater than the applicable water quality criteria.

[e] MDL two orders of magnitude less than other analyses for this parameter.

[f] U.S. EPA Storet Database (1972-1991)

[g] Fuhrer (1989)

[h] U.S. COE (1979)

[i] Young (1989)

the last decade, both in character and quantity, water quality measurements of more than 10 years ago are of limited utility in assigning priorities for present and future sampling locations.

Of the data collected within the last three years, only the USGS stations at Beaver Army Terminal and Warrendale were classified as medium priority in Table 4. The parameters which triggered the medium priority classification were all trace metals, with the exception of bacteria at Beaver Army Terminal. The sampling apparatus used at Warrendale and Beaver Army Terminal has most likely been a source of considerable metals contamination, making the dissolved metals data from these two stations suspect (McKenzie, S., 12 February 1992, personal communication). By discounting the contaminated metals data from the two USGS stations, the limited data collected in the last three years lead to the conclusion that there are no water quality problem areas with respect to toxic substances on the lower Columbia River.

Given the limitations of the sampling design of most of the water quality surveys described herein, the entire lower Columbia River can be considered a data gap with respect to water quality. A considerable amount of conventional and nutrient data have been collected, but the ecological and public health ramifications of these data are still largely unknown.

2.2 SEDIMENTS

2.2.1 Data Selection and Review Methods

Forty-seven studies [including all those listed in the McConnell (1990) report], and three databases, [supplied by the USGS, U.S. COE, and the U.S. Environmental Protection Agency (EPA)] were reviewed to identify useful chemistry data for evaluating sediments in the lower Columbia River. Studies and databases were accepted for inclusion in this report only if they met the following criteria:

- Original raw data were included in the study.
- Sample collection, sample handling, quality assurance, and analytical methods were appropriate to ensure data accuracy and precision.
- Sample stations were located in the Columbia River proper.
- Data on conventional parameters, trace metals, and organic compounds were from recently sampled sediments. With the exception of data for

sediment radionuclides, studies conducted prior to 1980 were not included in this report. Additionally, only data from the uppermost layer of sediment cores were included.

- The data reported were for sediment chemical parameters, and not limited to sediment texture and grain size.

Of the 47 studies reviewed, 18 studies and 3 databases were deemed appropriate for inclusion based on the above criteria (Tables 5 and 6). Over 300 sampling stations with sediment chemistry and radionuclide data were identified from the 18 accepted studies. Each sediment sampling location identified in the lower Columbia River represents one to several sampling stations (Figures 9–12). To aid in the synthesis and interpretation of the sediment chemistry data, sampling stations in relatively close proximity to one another (generally less than 1 mile) were grouped and identified as a single, numbered location on the maps (Figures 9–12). A list of the component stations that were grouped into each sampling location is provided in Appendix B, Table B–1. Information on location (river mile), sediment type (if available), and the study reference for each station is also included in Table B–1.

The summary statistics for each location were calculated by including half the reported analytical detection limit for contaminants that were undetected at the sampling stations. The interpretation of undetected chemical values is always problematic in environmental studies. Of the three options generally used for treating such data (i.e., assuming the actual concentration equals the detection limit, half the detection limit, or zero), the use of half the detection limit has been selected as a compromise measure. Assuming that the contaminant concentration equals half of the detection limit is less conservative than assuming the concentration is equal to the detection limit (as is commonly done for regulatory purposes). However, it is a more conservative approach than assuming that because the contaminant was undetected, its concentration is equal to zero. The use of half the detection limit for data interpretation has also been accepted by ODEQ for other environmental studies in the Columbia River. Summary statistics (mean, number of samples measured, number of samples with detected contaminants) on sediment contaminant levels at each map location were calculated and are included in Appendix B, Table B–2.

Over 300 sediment chemical parameters have been measured in the accepted studies. These chemicals include all of the trace metals considered toxic, as well as representative chemicals from nearly all of the major types of toxic organic chemicals. Of these chemicals, many were detected at levels near the limits of the analytical procedures and in relatively few of the sediment samples. Many of the substances were not accurately measured, or were not meas-

TABLE 5. EVALUATION OF EXISTING SEDIMENT CHEMISTRY STUDIES (Page 1 of 3)							
Study Reference	Data Acceptable?	Sampling Collection	Sample Handling	Quality Assurance	Analytical Methods	Parameters Measured	Comments
Amspoker and McIntire (1986)	No	A[a]	A	NI	A	Phytoplankton	No chemistry
City of Portland, Bureau of Environmental Services (1989)	No	NI[b]	NI	NI	NI	TM, TOC	Summary data Columbia slough
Blahm et al (1980)	No	A	A	NI	A	Bunker C fuel residue, GS, TVS	Presence/absence only
Buchman (1987)	No	NI	NI	NI	NI	TM, PP, Pest, PCB, O&G, CN	Review paper
Durkin and Emmett (1980)	No					Sediment texture	Mainly biology
Durkin et al (1981)	No					Sediment texture	Mainly biology
Durkin et al (1979)	No	A	A	A	A	GS, TOC	Fish survey
Fox (1981)	No	NI	NI	NI	NI	GS, sed transport	Review
Fuhrer and Evans (1990)	No	A	A	A	A	PP, TM, Pest, PCB, BNA, TOC	Method summary general locations
Fuhrer (1984)	Yes	A	A	A	A	TM, GS	Recoverable CRM 0-18 2 (Cathlamet Bay)
Fuhrer (1983)	Yes	A	A	A	A	TM, GS, TVS, TOC	Extractable and total TM, Ilwaco, Baker Bay
Fuhrer and Horowitz (1989)	Yes	A	A	A	A	TM, BNA, TOC, GS, TVS, Pb210, Cs137, Ra226	Total and extractable CRM 7 5, 12 5, 18
Fuhrer and Rinella (1983a)	Yes	A	A	A	A	TM, Pest, PCB, PCN	13 Columbia River spills, lots of elutriates, Baker Bay to Bonneville
Fuhrer (1989)	No	A	A	A	A	TM, Pest, PCB, BNA	Willamette River
Haushild et al (1973)	Yes					13 Radionuclides	1964-66 (old methods?)
Haushild et al (1975)	Yes					7 Radionuclides	1962-65 (old methods?)
Hedges et al (1984)	No	A	A	A	A	Lignin, Phenols, C, N, C-3	Organic tracers
Higley et al (1983)	No	A	NI	NI	A	TOC, GS	Benthic biology baseline
Hinton et al (1990)	No	A	A	NI	A	TOC, GS, TVS	Benthic biology

TABLE 5 EVALUATION OF EXISTING SEDIMENT CHEMISTRY STUDIES
(Page 2 of 3)

Study Reference	Data Acceptable?	Sampling Collection	Sample Handling	Quality Assurance	Analytical Methods	Parameters Measured	Comments
Hubbell and Glenn (1973)	Yes	A	A	NI	A	8 Radionuclides, GS gross gamma	Old methods?
Johnson and Norton (1988)	Yes	A	A	A	A	BNA, VOC, Pest, PCB, TM, GS, TOC, CN, Resin acids	Sands
McCabe et al (1990)	No	A	NI	NI	NI	GS, TOC	Biology, CRM 64 4-70 6
McCabe and Hinton (1990a)	No	A	NI	NI	NI	GS, TVS, TOC	No chemistry, CRM 43 2
McIntire and Amspoker (1986)	No	A	A	NI	A	GS, chl a, O_2 consump	No chemistry
ODEQ (1990a)	Yes	A	A	A	A	TM, Dioxins, Furans, Pest, PCB, TOC, GS, TVS	Work Plan only No results yet
Rickert et al (1977)	No	NI	NI	NI	A	GS, 50 native element	Willamette River/Columbia River (I)
Robertson and Fix (1977)	No	A	A	NI	A	13 Radionuclides	Fine sediment, 1976 above Bonneville only
Sherwood et al (1984)	No	A	A	A	A	GS, Mineralogy	Sediment transport/mineralogy
Simenstad et al (1984)	No	NI	NI	NI	NI	GS	Flow/Sediment transport/circulation
Small (1990)	No						Sedimentation/circulation
Stevenson (1981a)	No						Abstracts No sediment chemistry
Stevenson (1981b)	No					Trace elements after St Helens	Abstracts No sediment chemistry
Toombs et al (1984)	Yes	A	A	A	A	7 Radionuclides	All of OR 4 on Columbia River
U S COE (1980)	No						Status Report No data
U S COE (1988)	No	A	NI	NI	NI	Susp Sediment, GS	GS, 1980-88 database
U S COE (1979)	No	NI	NI	NI	NI	TM, Pest, PCB, Nuts, PCN, GS, TOC, TVS, COD, O_2, Phenol	Willamette RM 9 2

TABLE 5 EVALUATION OF EXISTING SEDIMENT CHEMISTRY STUDIES (Page 3 of 3)							
Study Reference	Data Acceptable?	Sampling Collection	Sample Handling	Quality Assurance	Analytical Methods	Parameters Measured	Comments
Weyerhaeuser Paper Co (1990)	Yes	NI	NI	A	NI	TM, Pest, PCB, BNA, VOC TOC, GS, CN, Resin acids, Dioxins, Furans	Sand at outfall, no det
Young (1988)	Yes	A	NI	NI	A	TM, BNA, VOC, O&G, Sulf, GS, Ammonia	Monitoring - 6 transects, CRM 107-121
Young et al (1988)	Yes	A	A	A	A	TM, Pest, PCB, PAH, O&G, Sulf, GS, TOC, Pet, HC, NH4	Tongue Pt Harbor
U S COE	No	NI	NI	A	A	TM, Phenols, Pest, PCB, O&G, TVS, GS	Elochoman Slough
U S COE	No	NI	NI	A	A	TM, BNA, Pest, PCB, O&G, Dioxin, Furan, NH4, TOC, GS, TVS	Willamette RM 6 1 U S Moorings
U S COE	No	A	A	A	A	TM, Pest, PCB, BNA, O&G, TOC, TVS, GS	Willamette RM 7 0 Portland Harbor
U S COE	Yes	A	NI	A	A	Dioxins, Furans, TOC, TVS, GS	Columbia River & Willamette River near pulp and paper discharges
USGS (1990b)	Yes	NI	NI	NI	NI	TM, N, P, TOC, TVS, GS	Warrendale 3/73
U S COE (1991)	Yes	NI/A	NI/A	NI/A	NI/A	TM, Pest, GS, TVS, TOC, PAH, O&G	About 116 Columbia River Stations
U S EPA (1991)	Yes	NI/A	NI/A	NI/A	NI/A	TM, BNA, Pest, PCB	1 Columbia River Station
Century West Engineering Corp (1990)	Yes	A	A	A	A	Copper	Port of Vancouver after spill remediation at bulk transfer facility
Russ Fetrow Engineering, Inc (1989)	No	A	A	A	A	TM, BNA, VOC	Radakovich Slough

[a] A = Information provided and found to be acceptable

[b] NI = No information provided

TABLE 6 SEDIMENT CHEMISTRY STUDIES WITH USEFUL DATA				
Reference	Station Number	Study Date	Station Locations	Parameters
Fuhrer (1984)	11	8/82	CRM 1,8-18 Cathlamet Bay	TM, Pest, PCB, PCN
Fuhrer (1986)	8	7/83	Baker Bay & Astoria Pier Ilwaco Boat Channel	TM, TOD
Fuhrer and Horowitz (1989)	4	9/84	Cathlamet Bay, Columbia River, Skipanon River	TM, BNA, Phenols, Cresols, Isophorone, Radionuclides
Fuhrer and Rinella (1983a)	13	1980	Baker Bay Chinook, Col. River Area D, Tangy Point, Youngs Bay, Astoria Boat Basin, Col River Mile 32.7 Bonneville	Pest, PCB, TM, Nuts
Hubbell and Glenn (1973)	14	1965	CRM 2-64 (X-Sections)	Radionuclides
Johnson and Norton (1988)	11	9/87	CRM 3,56,67,75,102,105, 118,124 (near point sources)	TM, PAH, Phthalates, Isophorone, Resin Acids, BNA, Pest, PCB, VOC
Weyerhaeuser Paper Company (1990)	3	4/90	Longview CRM 63.5 Monitoring	PP (NPDES)
Young (1988)	4	9/89	Camas - CRM 107-121	PP (NPDES) - TM, BNA, VOC, O&G, pest
Young et al. (1988)	10	8/88	Col. River near Tongue Point Composites	TM, Pet, hydrocarbons, O&G, Org, Nuts, Pest, PCB
Haushild et al. (1973)	3	1964-66	Vancouver, WA	Radionuclides
USGS (1990b)	1	3173	Col River at Warrendale	Nuts, TM
U.S. EPA (1991)	1	1982-84	Col River 1 mile above Willamette River confluence CRM 1025	Pest/PCB, TM, BNA
U S COE (1980)	116	1980-81	Misc. dredging studies mostly bay/harbor, disposal & channel sites	TM, Pest/PCB, PAH
Haushild et al (1975)	37	1962-65	Col. River Cores	Radionuclides
Toombs et al. (1984)	4	1961-83	Col. River	Radionuclides
Century West Engineering Corp. (1990)	35	1990	Port of Vancouver Bulk Loading Facility (after spill remediation)	Copper
U S. COE (1990b)	10	5/90	Col. River near Pul's paper discharges	Dioxins, furans
ODEQ (1990a)	11	1990	Longview/St. Helens/James River - no results	PP, dioxins, furans

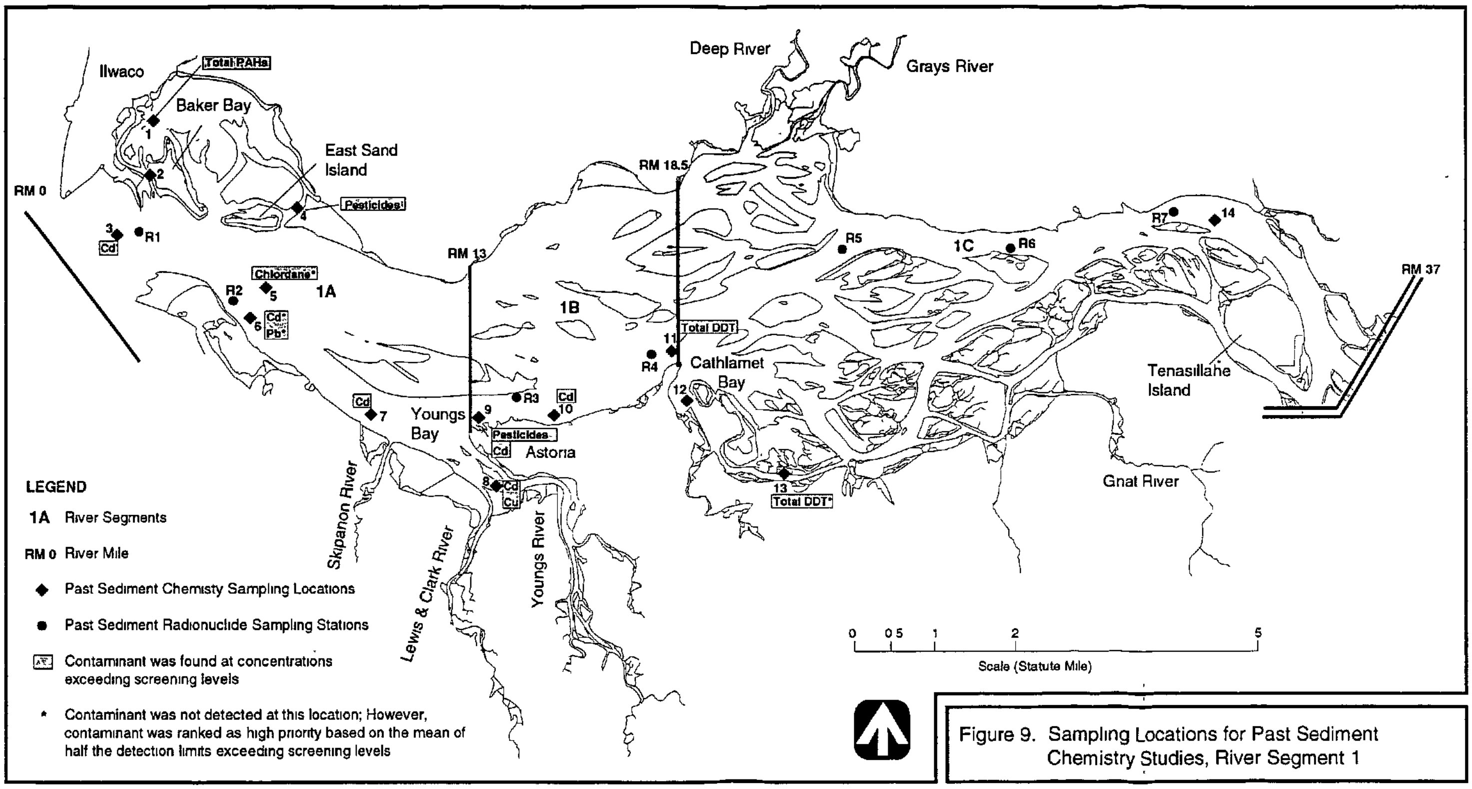


Figure 9. Sampling Locations for Past Sediment Chemistry Studies, River Segment 1

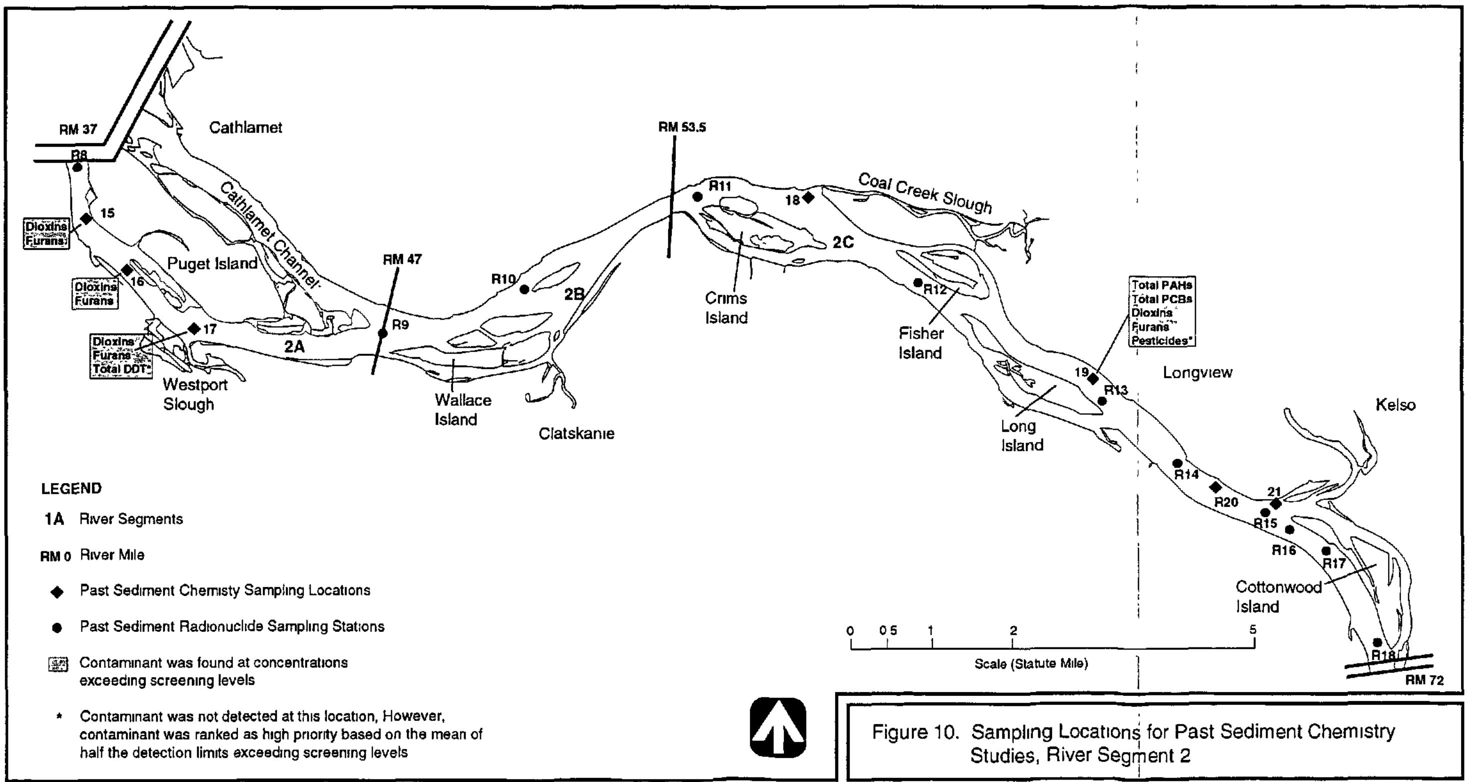


Figure 10. Sampling Locations for Past Sediment Chemistry Studies, River Segment 2

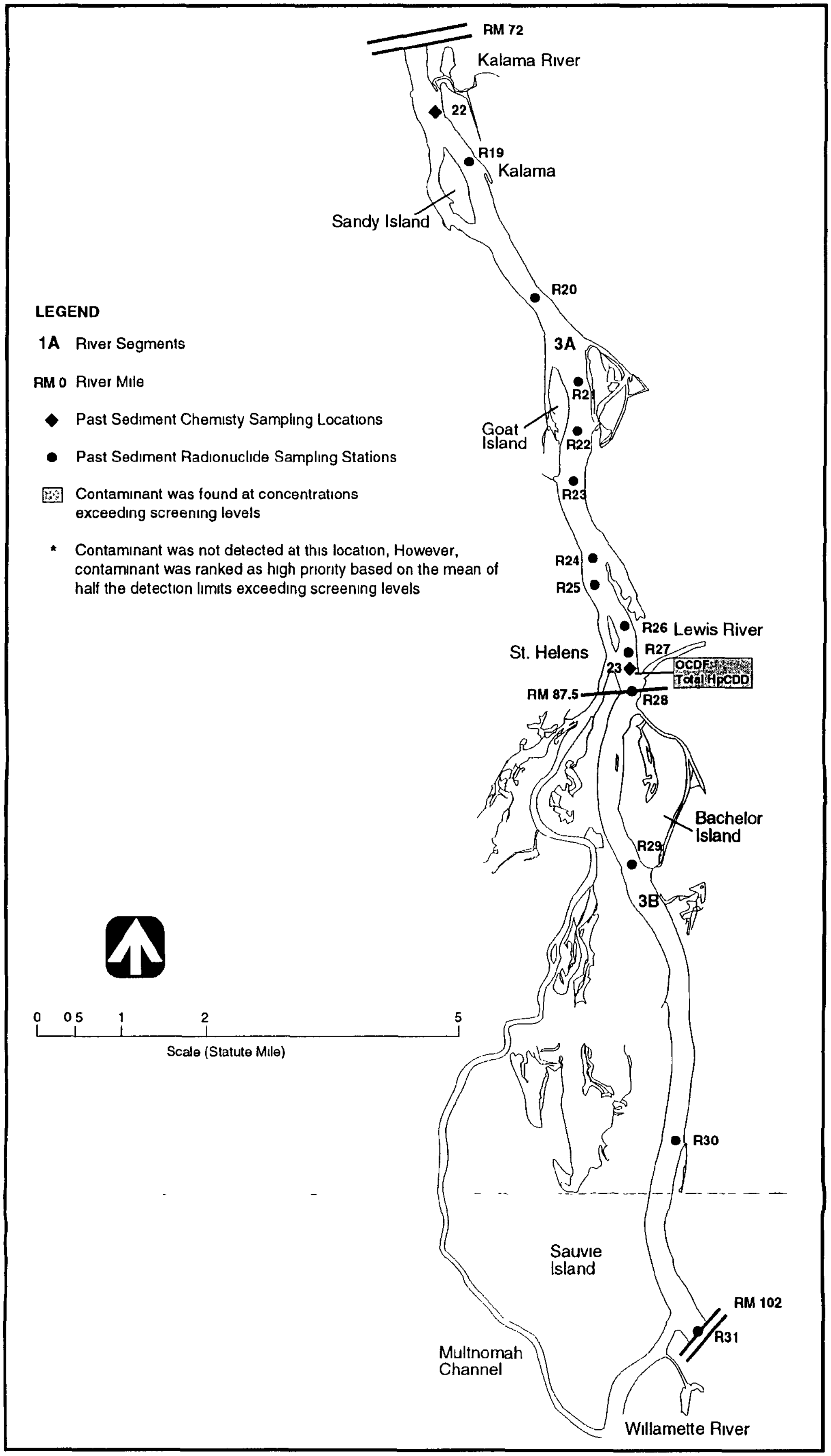
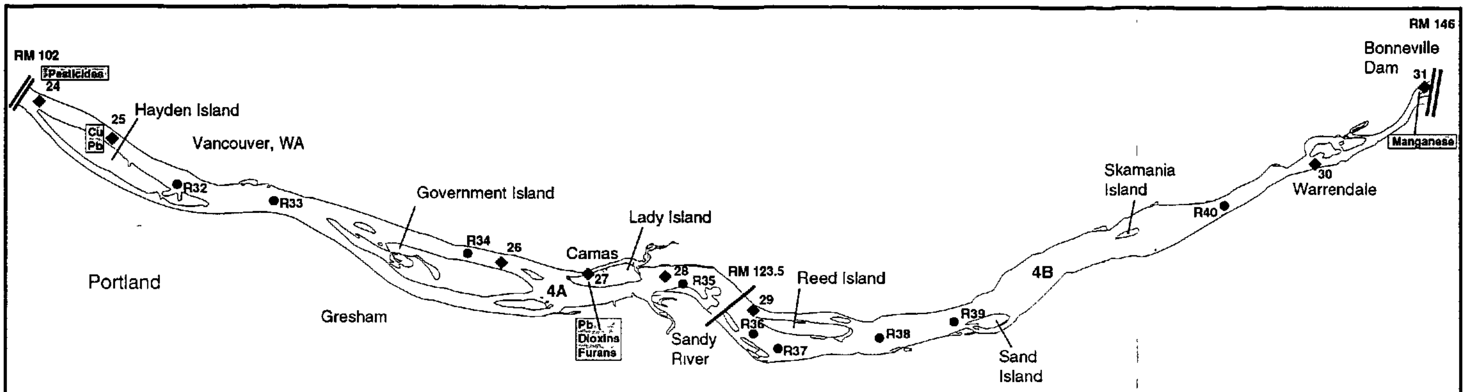


Figure 11. Sampling Locations for Past Sediment Chemistry Studies, River Segment 3



LEGEND

1A River Segments

RM 0 River Mile

◆ Past Sediment Chemisty Sampling Locations

● Past Sediment Radionuclide Sampling Stations

▭ Contaminant was found at concentrations exceeding screening levels

* Contaminant was not detected at this location, However, contaminant was ranked as high priority based on the mean of half the detection limits exceeding screening levels

0 0.5 1 2 5

Scale (Statute Mile)

Figure 12. Sampling Locations for Past Sediment Chemistry Studies, River Segment 4

ured with sufficient sensitivity in some of the studies. Therefore, only the data for selected chemicals measured with a reasonable level of accuracy by established analytical protocols are discussed in detail below Sediment chemical parameters were grouped into the following general categories for analyses:

- Conventional parameters (e g , total organic carbon, grain size, total solids, volatile solids)
- Metals
- Polycyclic aromatic hydrocarbons (PAHs)
- Other base/neutral/acid (BNA) semivolatile organics
- Pesticides
- PCBs
- Dioxin and Furans
- Resin Acids
- Radionuclides.

Although sediment BNAs (i.e., BNAs other than PAHs) were measured in six studies, they were not detected in the sediments at any of the stations sampled. Moreover, analytical detection limits were not provided in the vast majority of the measurements. In view of these observations, sediment BNA data were not used in the ranking framework developed for sampling locations.

Because the degree and distribution of chemical contaminants in sediments can be influenced by physical/chemical characteristics of the sediments (i.e., grain size and organic content), the raw sediment metals data from all the accepted studies were entered into a series of spreadsheets and sorted by river segment, river mile, and sediment grain size (where available). The raw sediment data for the four major river segments are presented in Appendix B (Tables B-3 to B-22) of this report.

No regulatory criteria exist for contaminant levels in freshwater sediments. Therefore, to obtain some measure of the relative magnitude and significance of sediment contamination in the river, we attempted to implement the procedures proposed in the earlier Task 1 report, *Problem Area and Data Gap Identification Ranking Framework* for identifying reference areas and screening levels.

Adequate reference areas for sediment chemistry have not been delineated for all segments of the lower Columbia River Few of the studies reviewed compared affected sites to reference areas. Those that did were limited in scope. Generally, the citing of reference areas was selected based on independent objectives of each study. For example, monitoring studies identified reference areas based on distance from a particular discharge. The U.S. COE database identified a number of reference areas based on the scope and areal extent of potential impacts from a particular project (U.S. COE projects were generally related to construction and dredging in the main channels, bays, and harbors). Since identified reference areas were project-specific, they can only be treated as reference areas in the context of the particular project for which they were selected. Thus, they were not considered appropriate reference areas for the river as a whole, or for the purposes of this study.

Because no appropriate reference areas could be defined, our second attempt to derive screening levels for each compound, was as proposed in the preliminary framework document. This approach involved ranking all of the values for each parameter and identifying the lowest 10th percentile as the screening level. Unfortunately, the only parameters for which there was enough data, were the metals and radionuclides, and that meant that the other parameters would be dropped from evaluation. Loss of the majority of parameters was unacceptable. Therefore, a third procedure was used to identify and set screening levels.

The third approach involved compiling data on freshwater contaminated sediment guidelines from studies throughout the U.S. and Canada (Long and Morgan 1990; WDOE 1991a). A decision was made to take the average of the effects-based guidelines (i.e., the level at which biological effects occur) to set the screening levels for the lower Columbia River. The effects-based approach provides several advantages not offered by the other two methods. Screening levels can be used to make comparisons within the system, to set relative priorities within the system, and can be used to make an assessment of the overall health of the river based on biological effects. Therefore, the effects-based screening level approach was adopted for all sediment chemistry parameters except radionuclides, and for those parameters where no effects-based levels were available. Screening levels for radionuclides were determined by ranking all the data points for each isotope and selecting the lowest 10th percentile as discussed above.

Because many of the metals and organic compounds for which analyses have been performed are not typically detected in lower Columbia River sediment samples, a more informal ranking procedure was used to identify and set priorities for problem areas. This approach differs from the elevation above reference (EAR) approach proposed in the preliminary framework document in that the detected values take on increased importance and no calculation of an EAR takes place. Instead, for most of the sediment contaminants, a combination of method detection limits (i e , those concentrations below which a particular chemical cannot be detected by a particular analytical method) and effects-based contaminant levels (i.e., those concentrations where biological impacts have been demonstrated) were used as screening levels to rank the sediment data. For example, a sampling location was ranked as a medium priority for a specific contaminant at a specific location if the contaminant was detected at that location. If, on the other hand, the mean concentration of a detected contaminant exceeded the mean of all effects-based screening levels (Long and Morgan 1990; WDOE 1991a), the location was ranked as high priority for that contaminant. The location was ranked as low priority for a particular contaminant if the contaminant was measured but undetected, unless the mean of half the detection limits at that location exceeded the effects-based screening levels. In the latter case, the location was ranked as high priority for that contaminant based on the following rationale. As discussed earlier, interpretation of undetected values is problematic. Because the contaminant could be absent or present at concentrations up to the detection limit, using half the detection limit for ranking purposes is considered an acceptable compromise. Additionally, the high priority rankings received in such cases are not meant to imply that these areas are potential problem areas, but are intended to indicate that there is sufficient uncertainty about the concentration of the compound at that location that it is identified as a significant data gap suitable for consideration in the reconnaissance survey or future studies. Such rankings are identified with an asterisk in Tables 7 and 8. Other compounds where no data were found were also identified in the high-priority category and treated as data gaps.

This approach for ranking the parameters at each of the sampling locations was used for all the sediment data with the exception of dioxins and furans. Rankings for these compounds were based solely on whether or not the compound was detected. If the compound was not detected, it was ranked as a low priority. However, if it was detected, then it was placed in the high-priority category. Treatment of dioxins and furans differently than the other compounds is justified for several reasons:

- Lack of effects-based screening levels for all their measured congeners in freshwater

TABLE 7 RELATIVE RANK FOR CHEMICALS OF CONCERN AT SEDIMENT LOCATIONS IN EACH SEGMENT OF THE LOWER COLUMBIA RIVER STUDY AREA

Segment 1A	Screening Level[b]	High[a]	Medium[c]	Low[d]
Metals (mg/kg)				
Arsenic	18.7		1,2,3,4,5,6,7,8	
Cadmium	2 7	3,6*,7,8	1,2,4,5	
Chromium	68 7		1,2,3,4,5,6,7,8	
Copper	57 3	8	1,2,3,4,5,6,7	
Iron			1,2,3,4,5,6,7,8	
Lead	33	6*	1,2,3,4,5,7,8	
Manganese	460		1,2,3,4,5,6,7,8	
Mercury	0 18		1,2,3,4,5,7,8	6
Nickel	46		1,2,3,4,5,6,7,8	
Zinc	120		1,2,3,4,5,6,7,8	
Pesticides (μg/kg)				
Total DDT	5.0	4	1	2,5,8
DDD	5 0	4	1	2,5,8
DDE	4.0	4	1	2,5,8
DDT	5.0	4	1	2,5,8
Chlordane	6.0	4,5*	1	2,8
Dieldrin	1.0	4	1	2,5,8
Other Pesticides	51.0	4	1	2,5,8
Total PAHs (μg/kg)	3,000	1	4	2,3,5,7
Total PCBs (μg/kg)	60.0		1,4	2,5,8
Dioxins and Furans (pg/g)				
Total TCDF		No data		
Total TCDD		No data		
Total PeCDF		No data		
Total PeCDD		No data		
Total HxCDF		No data		
Total HxCDD		No data		
Total HpCDF		No data		
Total HpCDD		No data		
OCDF		No data		
OCDD		No data		
Total Resin Acids		No data		

TABLE 7. RELATIVE RANK FOR CHEMICALS OF CONCERN AT SEDIMENT LOCATIONS IN EACH SEGMENT OF THE LOWER COLUMBIA RIVER STUDY AREA

Segment 1B	Screening Level[b]	High[a]	Medium[c]	Low[d]
Metals (mg/kg)				
Arsenic	18.7		9,10,11	
Cadmium	2 7	9,10		
Chromium	68 7		9,10,11	
Copper	57.3		9,10,11	
Iron			9,10,11	
Lead	33		9,10,11	
Manganese	460		9,10,11	
Mercury	0 18		9,10,11	
Nickel	46		9,10,11	
Zinc	120		9,10,11	
Pesticides (μg/kg)				
Total DDT	5 0	9,11		
DDD	5 0		9,11	
DDE	4.0		9,11	
DDT	5.0	9	11	
Chlordane	6 0	9*		11
Dieldrin	1.0	9		11
Other Pesticides	51 0	9	11	
Total PAHs (μg/kg)	3,000		11	9,10
Total PCBs (μg/kg)	60		9,11	
Dioxins and Furans (pg/g)				
Total TCDF		No data		
Total TCDD		No data		
Total PeCDF		No data		
Total PeCDD		No data		
Total HxCDF		No data		
Total HxCDD		No data		
Total HpCDF		No data		
Total HpCDD		No data		
OCDF		No data		
OCDD		No data		
Total Resin Acids		No data		

TABLE 7. RELATIVE RANK FOR CHEMICALS OF CONCERN AT SEDIMENT LOCATIONS IN EACH SEGMENT OF THE LOWER COLUMBIA RIVER STUDY AREA

Segment 1C	Screening Level[b]	High[a]	Medium[c]	Low[d]
Metals (mg/kg)				
Arsenic	18.7		12,13,14	
Cadmium	2.7		12,13,14	
Chromium	68.7		12,13,14	
Copper	57 3		12,13,14	
Iron			12,13,14	
Lead	33		12,13,14	
Manganese	460		12,13,14	
Mercury	0 18		12,13,14	
Nickel	46		12,13,14	
Zinc	120		12,13,14	
Pesticides (μg/kg)				
Total DDT	5.0	13*		12
DDD	5.0			12,13
DDE	4.0			12,13
DDT	5 0			12,13
Chlordane	6.0			12,13
Dieldrin	1.0			12,13
Other Pesticides	51.0			12,13
Total PAHs (μg/kg)	3,000		12	12,13
Total PCBs (μg/kg)	60.0			12,13
Dioxins and Furans (pg/g)				
Total TCDF		No data		
Total TCDD		No data		
Total PeCDF		No data		
Total PeCDD		No data		
Total HxCDF		No data		
Total HxCDD		No data		
Total HpCDF		No data		
Total HpCDD		No data		
OCDF		No data		
OCDD		No data		
Total Resin Acids		No data		

TABLE 7. RELATIVE RANK FOR CHEMICALS OF CONCERN AT SEDIMENT LOCATIONS IN EACH SEGMENT OF THE LOWER COLUMBIA RIVER STUDY AREA				
Segment 2A	Screening Level[b]	High[a]	Medium[c]	Low[d]
Metals (mg/kg)				
Arsenic	18 7		17	
Cadmium	2 7		17	
Chromium	68 7		17	
Copper	57 3		17	
Iron			17	
Lead	33		17	
Manganese	460		17	
Mercury	0 18		17	
Nickel	46		17	
Zinc	120		17	
Pesticides (μg/kg)				
Total DDT	5 0	17*		
DDD	5 0			17
DDE	4.0			17
DDT	5.0			17
Chlordane	6.0			17
Dieldrin	1 0			17
Other Pesticides	51 0			17
Total PAHs (μg/kg)	3,000			17
Total PCBs (μg/kg)	60 0			17
Dioxins and Furans (pg/g)				
Total TCDF		15,16,17		
Total TCDD		15,16,17		
Total PeCDF		17		15,16
Total PeCDD		17		15,16
Total HxCDF		15,17		16,17
Total HxCDD		16,17		15
Total HpCDF		15,16,17		
Total HpCDD		15,16,17		
OCDF		15,16,17		
OCDD		15,16,17		
Total Resin Acids		No data		

TABLE 7. RELATIVE RANK FOR CHEMICALS OF CONCERN AT SEDIMENT LOCATIONS IN EACH SEGMENT OF THE LOWER COLUMBIA RIVER STUDY AREA				
Segment 2B	Screening Level[b]	High[a]	Medium[c]	Low[d]
Metals (mg/kg)				
Arsenic	18.7	No data		
Cadmium	2.7	No data		
Chromium	68 7	No data		
Copper	57 3	No data		
Iron		No data		
Lead	33	No data		
Manganese	460	No data		
Mercury	0.18	No data		
Nickel	46	No data		
Zinc	120	No data		
Pesticides (µg/kg)				
Total DDT	5.0	No data		
DDD	5 0	No data		
DDE	4.0	No data		
DDT	5.0	No data		
Chlordane	6.0	No data		
Dieldrin	1.0	No data		
Other Pesticides	51.0	No data		
Total PAHs (µg/kg)	3,000	No data		
Total PCBs (µg/kg)	60.0	No data		
Dioxins and Furans (pg/g)				
Total TCDF		No data		
Total TCDD		No data		
Total PeCDF		No data		
Total PeCDD		No data		
Total HxCDF		No data		
Total HxCDD		No data		
Total HpCDF		No data		
Total HpCDD		No data		
OCDF		No data		
OCDD		No data		
Total Resin Acids		No data		

TABLE 7. RELATIVE RANK FOR CHEMICALS OF CONCERN AT SEDIMENT LOCATIONS IN EACH SEGMENT OF THE LOWER COLUMBIA RIVER STUDY AREA

Segment 2C	Screening Level[b]	High[a]	Medium[c]	Low[d]
Metals (mg/kg)				
Arsenic	18.7		18,19,20	21
Cadmium	2.7			18,19,20,21
Chromium	68 7		18,19,20,21	
Copper	57 3		18,19,20,21	
Iron			18,19,20	
Lead	33		19	18,20,21
Manganese	460		18,19,20	
Mercury	0 18		18,19	
Nickel	46		18,19,20,21	
Zinc	120		18,19,20,21	
Pesticides (μg/kg)				
Total DDT	5.0	19*		18,20,21
DDD	5.0	19*		18,20,21
DDE	4.0	19*		18,20,21
DDT	5 0	19*		18,20,21
Chlordane	6.0	19*		18,20,21
Dieldrin	1.0	19*		18,20,21
Other Pesticides	51.0	19*		18,20,21
Total PAHs (μg/kg)	3,000	19	18, 20	21
Total PCBs (μg/kg)	60.0	19		18,20,21
Dioxins and Furans (pg/g)				
Total TCDF		19		
Total TCDD		19		
Total PeCDF		19		
Total PeCDD		19		
Total HxCDF		19		
Total HxCDD		19		
Total HpCDF		19		
Total HpCDD		19		
OCDF		19		
OCDD		19		
Total Resin Acids			19	

TABLE 7. RELATIVE RANK FOR CHEMICALS OF CONCERN AT SEDIMENT LOCATIONS IN EACH SEGMENT OF THE LOWER COLUMBIA RIVER STUDY AREA				
Segment 3A	Screening Level[b]	High[a]	Medium[c]	Low[d]
Metals (mg/kg)				
Arsenic	18 7		22,23	
Cadmium	2.7		23	22
Chromium	68.7		22,23	
Copper	57.3		22,23	
Iron			22	
Lead	33		23	22
Manganese	460		22,23	
Mercury	0.18		22,23	
Nickel	46		22,23	
Zinc	120		22,23	
Pesticides (μg/kg)				
Total DDT	5.0			22
DDD	5.0			22
DDE	4.0			22
DDT	5.0			22
Chlordane	6 0			22
Dieldrin	1.0			22
Other Pesticides	51.0			22
Total PAHs (μg/kg)	3,000		22,23	
Total PCBs (μg/kg)	60.0			22
Dioxins and Furans (pg/g)				
Total TCDF				23
Total TCDD				23
Total PeCDF				23
Total PeCDD				23
Total HxCDF				23
Total HxCDD				23
Total HpCDF				23
Total HpCDD		23		
OCDF				23
OCDD		23		
Total Resin Acids		No data		

TABLE 7. RELATIVE RANK FOR CHEMICALS OF CONCERN AT SEDIMENT LOCATIONS IN EACH SEGMENT OF THE LOWER COLUMBIA RIVER STUDY AREA

Segment 3B	Screening Level[b]	High[a]	Medium[c]	Low[d]
Metals (mg/kg)				
Arsenic	18 7	No data		
Cadmium	2 7	No data		
Chromium	68 7	No data		
Copper	57 3	No data		
Iron		No data		
Lead	33	No data		
Manganese	460	No data		
Mercury	0 18	No data		
Nickel	46	No data		
Zinc	120	No data		
Pesticides (μg/kg)				
Total DDT	5.0	No data		
DDD	5 0	No data		
DDE	4 0	No data		
DDT	5.0	No data		
Chlordane	6.0	No data		
Dieldrin	1.0	No data		
Other Pesticides	51.0	No data		
Total PAHs (μg/kg)	3,000	No data		
Total PCBs (μg/kg)	60.0	No data		
Dioxins and Furans (pg/g)				
Total TCDF		No data		
Total TCDD		No data		
Total PeCDF		No data		
Total PeCDD		No data		
Total HxCDF		No data		
Total HxCDD		No data		
Total HpCDF		No data		
Total HpCDD		No data		
OCDF		No data		
OCDD		No data		
Total Resin Acids		No data		

TABLE 7 RELATIVE RANK FOR CHEMICALS OF CONCERN AT SEDIMENT LOCATIONS IN EACH SEGMENT OF THE LOWER COLUMBIA RIVER STUDY AREA

Segment 4A	Screening Level[b]	High[a]	Medium[c]	Low[d]
Metals (mg/kg)				
Arsenic	18.7		24,25	26,28
Cadmium	2.7		24,26,27,28	25
Chromium	68 7		24,25,26,27,28	
Copper	57 3	25	24,26,27,28	
Iron			24,25,27	
Lead	33	25,27	24,26,28	
Manganese	460		24,25,26,27,28	
Mercury	0.18		24,25,26,27,28	
Nickel	46		24,25,26,27,28	
Zinc	120		24,25,26,27,28	
Pesticides (μg/kg)				
Total DDT	5.0	24		25,26,27,28
DDD	5.0	24		25,26,27,28
DDE	4.0	24		25,26,27,28
DDT	5.0	24		25,26,27,28
Chlordane	6.0			24,25,26,27,28
Dieldrin	1.0			24,25,26,27,28
Other Pesticides	51.0		24	25,26,27,28
Total PAHs (μg/kg)	3,000		24,25,27	26,28
Total PCBs (μg/kg)	60.0		24	25,27
Dioxins and Furans (pg/g)				
Total TCDF		27		
Total TCDD				27
Total PeCDF				27
Total PeCDD				27
Total HxCDF		27		
Total HxCDD		27		
Total HpCDF		27		
Total HpCDD		27		
OCDF		27		
OCDD		27		
Total Resin Acids			25,27	

TABLE 7. RELATIVE RANK FOR CHEMICALS OF CONCERN AT SEDIMENT LOCATIONS IN EACH SEGMENT OF THE LOWER COLUMBIA RIVER STUDY AREA

Segment 4B	Screening Level[b]	High[a]	Medium[c]	Low[d]
Metals (mg/kg)				
Arsenic	18 7		29,30,31	
Cadmium	2.7		30,31	29
Chromium	68 7		29,30,31	
Copper	57 3		29,30,31	
Iron			29,30,31	
Lead	33		30,31	29
Manganese	460	31	29,30	
Mercury	0.18		30,31	29
Nickel	46		29,30,31	
Zinc	120		29,30,31	
Pesticides (μg/kg)				
Total DDT	5.0			29,31
DDD	5.0			29,31
DDE	4.0			29,31
DDT	5 0			29,31
Chlordane	6 0			29,31
Dieldrin	1 0			29,31
Other Pesticides	51 0			29,31
Total PAHs (μg/kg)	3,000		29	
Total PCBs (μg/kg)	60.0			29,31
Dioxins and Furans (pg/g)				
Total TCDF		No data		
Total TCDD		No data		
Total PeCDF		No data		
Total PeCDD		No data		
Total HxCDF		No data		
Total HxCDD		No data		
Total HpCDF		No data		
Total HpCDD		No data		
OCDF		No data		
OCDD		No data		
Total Resin Acids				29

TABLE 7. RELATIVE RANK FOR CHEMICALS OF CONCERN AT SEDIMENT LOCATIONS IN EACH SEGMENT OF THE LOWER COLUMBIA RIVER STUDY AREA

[a] High priority: any detected level or detection limit above screening level.

[b] Screening level is mean of effects-based levels (Long and Morgan 1990, WDOE 1991a).

[c] Medium priority: any detected level below the screening level.

[d] Low priority. any non-detected compound with detection limit below the screening level.

* High priority ranking is based on the mean detection limit exceeding the screening levels.

TABLE 8. RELATIVE RANKING OF RADIONUCLIDE SAMPLING STATIONS BY RIVER SEGMENT				
Radionuclides (pico curies/g)	Screening Level[a]	High[b]	Medium[c]	Low[d]
Segment 1A				
Cr-51	3.6	R1,R2		
Zn-65	2.5		R1,R2	
Sc-46	0 1	R1,R2		
Co-60	0.1	R1,R2		
Mn-54	0.1	R1,R2		
ZR-95/Nb-95	0 1	R1,R2		
Ru-106	0.1	R1,R2		
K-40	12.1		R1,R2	
Segment 1B				
Cr-51	3 6	R3,R4		
Zn-65	2.5	R3,R4		
Sc-46	0.1	R3,R4		
Co-60	0.1	R3,R4		
Mn-54	0.1	R3,R4		
ZR-95/Nb-95	0.1	R3,R4		
Ru-106	0.1	R3,R4		
K-40	12.1	R3,R4		
Segment 1C				
Cr-51	3.6	R5,R6,R7		
Zn-65	2.5	R5,R6,R7		
Sc-46	0.1	R5,R6,R7		
Co-60	0.1	R5,R6,R7		
Mn-54	0.1	R5,R6,R7		
ZR-95/Nb-95	0.1	R5,R6,R7		
Ru-106	0.1	R5,R6,R7		
K-40	12.1	R5,R6,R7		

TABLE 8. RELATIVE RANKING OF RADIONUCLIDE SAMPLING STATIONS BY RIVER SEGMENT				
Radionuclides (pico curies/g)	Screening Level[a]	High[b]	Medium[c]	Low[d]
		Segment 2A		
Cr-51	3.6	R8		
Zn-65	2.5			
Sc-46	0.1			
Co-60	0.1			
Mn-54	0.1			
ZR-95/Nb-95	0.1			
Ru-106	0.1			
K-40	12.1			
		Segment 2B		
Cr-51	3 6	R9,R10		
Zn-65	2.5	R9,R10		
Sc-46	0.1	R9,R10		
Co-60	0.1	R9,R10		
Mn-54	0 1	R9,R10		
ZR-95/Nb-95	0.1	R9,R10		
Ru-106	0.1	R9,R10		
K-40	12.1	R10	R9	
		Segment 2C		
Cr-51	3.6	R11,R12,R13,R14, R15,R16,417,418		
Zn-65	2.5	R11,R12,R13,R14, R15,R16,417,418		
Sc-46	0.1	R11,R12,R13,R14, R15,R16,417,418		
Co-60	0.1	R11,R12,R13,R14, R15,R16,417,418		
Mn-54	0.1	R11,R12,R13,R14, R15,R16,417,418		
ZR-95/Nb-95	0.1	R11,R12,R13	R15	
Ru-106	0.1	R11,R12,R13,R15		
K-40	12.1	R11,R12,R13		

TABLE 8. RELATIVE RANKING OF RADIONUCLIDE SAMPLING STATIONS BY RIVER SEGMENT				
Radionuclides (pico curies/g)	Screening Level[a]	High[b]	Medium[c]	Low[d]
		Segment 3A		
Cr-51	3.6	R19,R20,R21,R22, R23,R24,R25,R26		
Zn-65	2.5	R19,R20,R21,R22, R23,R24,R25,R26		
Sc-46	0 1	R19,R20,R21,R22, R23[a],R25,R26	R24	
Co-60	0.1	R19,R20,R21,R22,R23, R24,R25,R26,R27,R28		
Mn-54	0 1	R19,R20,R21,R22,R23, R24,R25,R26,R27,R28		
ZR-95/Nb-95	0.1			R19,R24
Ru-106	0.1	R19,424		
K-40	12.1			
		Segment 3B		
Cr-51	3.6	R31		
Zn-65	2 5	R31		
Sc-46	0.1	R31		
Co-60	0.1	R29*,R30,R31		
Mn-54	0.1	R29,R30,R31		
ZR-95/Nb-95	0.1	R31		
Ru-106	0 1	R31		
K-40	12.1			
		Segment 4A		
Cr-51	3.6	R32,R34,R35		
Zn-65	2 5	R32,R34,R35		
Sc-46	0.1	R32,R34,R35		
Co-60	0.1	R32,R33,R34,R35		
Mn-54	0.1	R32,R33,R34,R35		
ZR-95/Nb-95	0.1	R32,R35	R34	
Ru-106	0.1	R32,R34,R35		
K-40	12.1			

TABLE 8 RELATIVE RANKING OF RADIONUCLIDE SAMPLING STATIONS BY RIVER SEGMENT				
Radionuclides (pico curies/g)	Screening Level[a]	High[b]	Medium[c]	Low[d]
		Segment 4B		
Cr-51	3.6	R36,R38		
Zn-65	2 5	R36,R38		
Sc-46	0.1			R36,R38
Co-60	0.1	R36,R38		
Mn-54	0 1	R36,R37,R38,R39,R40		
ZR-95/Nb-95	0.1	R36,R38		
Ru-106	0 1	R36,R38,R40		
K-40	12.1			

[a] Screening level is the lowest 10th percentile value from range of all radionuclide values.

[b] High priority any detected level or detection limit above screening level.

[c] Medium priority· any detected level below the screening level.

[d] Low priority: any nondetected compound with a detection limit below the screening level.

* High priority ranging is based on the detection limit exceeding the screening levels.

- Sources are almost entirely anthropogenic; thus, any detected quantity exceeds natural background levels

- Considerable recent controversy surrounding the toxicities of dioxins and furans

- Public concern about the presence of these compounds in the environment

- Placing sampling locations with detected amounts of dioxins and furans in their sediments in the high-priority category ensures adequate consideration for sampling these compounds in the reconnaissance survey.

2.2.2 Review of Accepted Data

2.2.2.1 River Segment 1. Columbia River segment 1 extends from the mouth of the Columbia River (RM 0) to Tenasillahe Island at RM 38. A total of 14 sampling locations (constituting 147 sampling stations) for sediment chemistry, and seven sampling stations for sediment radionuclides were identified in river segment 1 (see Figure 9).

Segment 1A—Eight sediment chemistry locations (1–8) and two radionuclide stations were situated in segment 1A This segment constitutes the most extensively studied section of the lower Columbia River in terms of sediment contamination. Of the ten metals analyzed, most were detected at the eight locations sampled in Segment 1A (see Table 7). Categorization of the sampling locations on the basis of comparing the concentration of metals in the sediments with screening levels resulted in most locations being ranked as medium priority (i.e., metals were detected in the sediments, but at concentrations below the effects-based screening levels). Mean concentrations of cadmium at locations 3, 7, and 8 and copper at location 8 were higher than the screen levels and were ranked as high priority. Sediments from stations that compose location 3 were composed mostly of fine to medium sand, at location 7 mainly silt and medium sand, and at location 8 entirely silt. Location 6 was ranked as high priority for sediment lead and cadmium because the mean of half the detection limits for these metals exceeded screening levels, indicating a need for future evaluation.

Data for sediment pesticides only exist for five sampling locations in river segment 1A (see Table 7). All the pesticides analyzed were detected at location 1 (Ilwaco–Baker Bay), but at concentrations below screening levels. In contrast, sediments at location 4 (Chinook Channel) were ranked as high priority because they showed consistently high concentrations of all measured pesticides. Sediment types at location 4 consisted mainly of silt and fine sand. Pesticides were undetected at locations 2, 5, and 8. PCBs were detected only at locations 1 and 4, and were below screening levels in both cases. There were no data for sediment dioxin and furan levels in segment 1A.

Sediment radionuclide data from 1973 were available for two stations (R1 and R2) in segment 1A (Table 8). Radionuclides were detected at both stations, and with the exception of Zn-65 and K-40, occurred at levels that exceeded the derived screening levels.

River Segment 1B--River segment 1B contained three sediment chemistry sampling locations (9, 10, 11) and two sediment radionuclide stations (see Figure 9). Metals were detected in sediments at all three sampling locations, with mean concentrations of cadmium exceeding the screening level at locations 9 (Astoria) and 10 (around RM 15-16) (see Table 7). A range of sediment types (silt, fine and medium sand) were found at location 9. Location 10 was composed primarily of fine and medium sand.

Sediment pesticides were measured at locations 9 and 11. Mean concentrations of total DDT at both locations exceeded the screening level, with mean concentrations of several other pesticides at location 9 also showing exceedance levels (see Table 7). Location 11 was composed of several sampling stations around Tongue Point, and had a wide range of sediment grain sizes (silt to sand). Sediment PAHs were measured at all three locations (9, 10, 11), and only detected at location 11 where they occurred at concentrations below screening levels. PCBs were analyzed in sediments from locations 9 and 11, and were detected at concentrations below screening levels at both these locations.

No data on sediment dioxin, furan, and resin acid levels were available for segment 1B.

Two stations (R3 and R4) were sampled for sediment radionuclide contamination in 1973 Mean concentrations of all isotopes analyzed exceeded screening levels at both locations (see Table 8).

River Segment 1C--Three sediment chemistry sampling locations (12, 13, 14) and three radionuclide sampling stations (R5, R6, R7) were identified in river segment 1C (see Figure 9). All ten metals analyzed were detected at the three sediment chemistry locations at concentrations below screening levels (see Table 7). Pesticides and PCBs were not detected at locations 12 and 13, and were not analyzed at location 14. However, the mean of half the detection limit for Total DDT exceeded the screening level at location 13. Sediment PAHs were analyzed at locations 12 and 13, and detected only (below screening levels) at location 12 (Tongue Point).

No dioxin, furan, or resin acids data were available for sediments in segment 1C. Sediment radionuclide data collected at stations R5, R6, and R7 in 1973 indicated exceedance levels of all isotopes analyzed (see Table 8).

2.2.2.2 ***River Segment 2.*** Columbia river segment 2 extends from Tenasillahe Island (RM 38) to the confluence of the Cowlitz and Columbia rivers (RM 72). A total of seven sampling locations (constituting 26 sampling stations) for sediment chemistry and eleven sampling stations for sediment radionuclides were identified in river segment 2 (see Figure 10). Historical sediment chemistry data in this section of the lower Columbia River are generally limited (see Table 7).

River Segment 2A—Three sediment chemistry locations around Wauna (15, 16, 17, RM 39–43) and one sediment radionuclide station (R8) were sampled in segment 2A (see Figure 10). Sediment metals, pesticides, PAHs, and PCBs were only analyzed at location 17 (RM 43) (see Table 7). All ten metals analyzed were detected at this location at concentrations below screening levels. Pesticides, PAHs and PCBs were undetected at this location. The mean of half the detection limit for total DDT, however, exceeded screening levels. Dioxins and furans were detected in sediments at all three locations, although not all congeners were detected at all locations. Information on sediment types was available only for location 17, which consisted mainly of silt and very fine sand. No data were available for sediment resin acids. Radionuclide levels measured at station R8 in 1973 all exceeded screening levels (see Table 8).

River Segment 2B—No sediment chemistry data were available for this section of the river. The two stations sampled for sediment radionuclides (R9 and R10) both had exceedance levels of all isotopes analyzed (with the exception of K–40 at R9) in 1973.

River Segment 2C—Four locations (18, 19, 20, 21) were sampled for sediment chemistry and eight stations (R11–R18) were sampled for sediment radionuclides in segment 2C (see Figure 10). All four chemistry locations were ranked as medium priority for most of the metals analyzed (see Table 7). However, cadmium was not detected at any location, and lead was only detected at location 19 (Longview). Pesticides were undetected at all four locations. Despite this observation, however, location 19, was ranked as high priority given the high detection limits for all pesticides analyzed. PAHs were detected at concentrations exceeding screening levels at location 19 (6,910 ug/kg), below the screening levels at locations 18 and 20, and were undetected at location 21. PCB's were detected only at location 19, at concentrations (903 g/kg) exceeding screening levels. Dioxins, furans, and resin acids were analyzed only at location 19. All congeners of these chemicals were detected at this site (see Table 7). The sediments at location 19 consisted mostly of sand, making the high levels of organic contaminants detected here remarkable

Radionuclide contamination was measured at stations R11–R13 in 1973 and at stations R14–R18 between 1963 and 1965. Most isotopes analyzed were detected at concentrations exceeding the derived screening levels (see Table 8).

2.2.2.3 ***River Segment 3.*** Segment 3 of the lower Columbia River extends from the Cowlitz River (RM 72) to the Willamette River (RM 102). This section of the Columbia River has the least amount of sediment chemistry data available

River Segment 3A—Only two sediment chemistry locations were sited in this section of the river (see Figure 11). At location 22 (Kalama), all the metals analyzed (with the exceptions of cadmium and lead) were detected at concentrations below screening levels. All the metals were also detected below screening levels at location 23 (St. Helens) (see Table 7). Sediment pesticides and PCBs were measured only at location 22 and were all undetected. PAHs were detected at both locations 22 and 23, although at concentrations below screening levels. Dioxins and furans were only measured at location 23. Of the various congeners analyzed, only 1,2,3,4,6,7,8-Heptachlorodibenzo-p-dioxin and Octachlorodibenzo-p-dioxin were detected in sediments (medium sand) at this location. There were no data on sediment resin acids in this section of the river.

Ten stations (R19–R20) were analyzed for sediment radionuclide data in this segment of the river. Data were collected between 1963 and 1965, and not all isotopes were measured at every station. In general however, radionuclide concentrations were above screening levels for most isotopes analyzed (see Table 8). Only Co-60 and Mn-54 were analyzed at locations R27 and R28.

River Segment 3B—There were no sediment chemistry data for river segment 3B. At the three sediment radionuclide stations (R29–R31) sited here, only Co-60 and Mn-54 were measured at R29 and R30. The full suite of radionuclides (except K-40) was measured at R31. All radionuclide concentrations measured in 1963–65 were detected at concentrations exceeding screening levels (see Table 8).

2.2.2.4 ***River Segment 4.*** Columbia River segment 4 extends from the Willamette River (RM 102) to the Bonneville Dam (RM 146). A total of eight sediment chemistry locations (consisting of 19 sampling stations), and nine sediment radionuclide stations were located in this segment of the river (see Figure 12).

River Segment 4A—Five of the eight sediment chemistry locations were sited in segment 4A (see Figure 12). Most of the ten metals analyzed were detected in the sediments at these locations at concentrations below screening levels (see Table 7). Exceptions included locations 25 (Vancouver) and 27 (Camas/Camas Slough), where copper and lead concentrations (copper and lead at location 25; lead only at location 27) exceeded screening levels. Location 25 consisted mainly of sand and location 27 mainly of silt and very fine sand. High copper levels near the Port of Vancouver probably resulted from an earlier copper spill in this area. Cadmium and arsenic were undetected in the sediments at locations 25, 26, and 28 respectively. Sediment pesticides were detected only at location 24 (RM 102 - Vancouver/Columbia Slough area), with DDT and its derivatives occurring at concentrations exceeding screening levels (see Table 7). Sediments at location 24 ranged from very fine to coarse sand. PAHs were measured at locations 24-28 and detected (at concentrations below screening levels) at locations 24, 25 and 27. PCBs were measured at three locations (24, 25, and 27) and detected only at location 24 at concentrations below screening levels. Dioxins, furans and resin acids were measured only at location 27, with most congeners detected there.

Sediment radionuclides were measured during 1963-65 at four stations (R32-R35) in segment 4A. All radionuclides measured at these stations occurred at concentrations exceeding screening levels (see Table 8).

River Segment 4B—Only three sediment chemistry locations were sampled in segment 4B (see Figure 12). Most of these locations had sediment metal concentrations detected at concentrations that were below screening levels. The only exceptions were location 31 (Bonneville Dam) where manganese concentrations exceeded screening levels, and location 29 (Reed Island) where cadmium, lead, and mercury were undetected in the sediments (see Table 7). Pesticides and PCBs were measured only at locations 29 and 31, and were undetected in the sediments at these sites. PAHs and resin acids were measured only at location 29, and were detected at concentrations below the screening levels. There were no data on dioxin and furan levels in segment 4B.

Five sediment radionuclide stations (R36–R40) were located in segment 4A (see Figure 12). Only Mn–54 was measured at stations R37 and R39. With the exception Sc–46 at stations R36 and R38, all sediment radionuclides measured during 1963–65 occurred at concentrations exceeding screening levels (see Table 8).

2.2.3 Data Synthesis and Conclusions

There are limited data available to assess historical sediment quality in the entire lower Columbia River. Review of existing studies revealed that historical sediment sampling and analyses were conducted sporadically to fulfill specific objectives at specific study sites. No studies have attempted a systematic survey aimed at assessing the overall state of sediments in the entire lower Columbia River.

Historical sampling stations tended to be concentrated in bays, harbors, and main channel dredging sites. Nearly all the stations were sampled in single sampling events, with no consistency in the suite of chemical parameters measured at each site. The only exceptions were the U.S. COE's sampling sites, where specific chemical parameters were consistently measured in keeping with U.S. COE dredging program objectives.

Scientifically rigorous assessment is hampered by several factors in studying the overall sediment conditions in the lower Columbia River:

- Studies were conducted in different years (from 1980 to 1991)
- An inconsistent suite of parameters was measured at the different stations
- Detection limits for a specific contaminant varied substantially (up to two orders of magnitude) from one study to another
- No systematic studies have sampled similar sediment types at different locations, taking into account the influence of sediment geochemistry on contaminant binding. Comparison of sediment quality among stations over the entire lower river is, therefore, difficult.

Despite these drawbacks, we have attempted a very general assessment of sediment quality based on the historical data. This assessment has been facilitated by grouping various sampling stations in close geographic proximity to one other (even though they may have been sampled at different times) into a single map location (see Figures 9–12). The sediment contaminant data collected at the component stations constituting each sampling location were summarized. These data were then compared to derived screening values to obtain some measure of the relative magnitude and significance of sediment contamination in the lower Columbia River. Each sampling location was ranked as high, medium, or low priority for specific contaminants, based on comparisons of contaminant concentrations in the sediments with the derived screening levels (see Table 7). Sediment contaminants exceeding the screening levels are indicated for each sampling location in Figures 9-12

The full suite of ten metals (arsenic, cadmium, chromium, copper, iron, lead, manganese, mercury, nickel, zinc) measured in the reviewed studies were detected at most sampling locations. However, almost all metal concentrations were below the effects-based screening levels and the Washington State marine sediment quality criteria (WDOE 1991a). Detected metal concentrations exceeding the effects-based levels occurred mainly in river segments 1A and 1B at locations 3 (cadmium), 7 (cadmium), 8 (cadmium, copper), 9 (cadmium), and 10 (cadmium). Three locations in river Segment 4 also showed exceedance of specific metal screening levels (locations 25 – copper, lead; 27 – lead; 31 – manganese). No metals data were available for locations 15 and 16 in river segment 2.

Sediment pesticide residues were detected primarily in river segments 1A and 1B, at locations 1, 4, 9, and 11 Locations 4 (Chinook Channel), 9 (Astoria), and 24 (Portland–Vancouver area) contained sediment pesticide levels that exceeded the effects-based screening levels. Only one other location surveyed in the river (location 24, river segment 4) contained detected levels of pesticides.

PAHs were detected in all major segments of the lower Columbia River. Detected levels of total PAHs were found at locations 1, 4, 11, and 12 in river segment 1; locations 18, 19, and 20 in river segment 2; locations 22 and 23 in river segment 3; and locations 24, 25, 27, and 29 in river segment 4. However, only at location 1 (Ilwaco; 25,897 ug/kg) and 19 (Longview; 6,910 ug/kg) did total PAH concentrations exceed the effects-based screening levels. Expected relationships between PAH levels and sediment grain size and TOC (e.g., a positive correlation between percent fines, TOC and contaminant levels) were not evident. For example, location 1 contains mostly silt with relatively high total organic carbon (TOC) values, which is consistent with the observation of high PAH levels at these sites. In contrast, sediments at location 19 consist mainly of sand with low TOC values, but high total PAH levels. High levels of total PAHs observed at this location are most likely the result of localized input of these contaminants.

Of the 31 locations sampled for sediment chemistry, only 21 had data on sediment PCB concentrations. PCBs were detected only at locations 1, 4, 9, and 11 in river segment 1, location 19 in river segment 2, and location 24 in river segment 4. Only the sediments at location 19 (Longview) contained total PCB concentrations exceeding the effects-based screening levels (903 ug/kg).

Data on sediment dioxin and furan concentrations were available only for river segments 2, 3, and 4. Various congeners of dioxin and furan were detected at locations 15, 16, 17, and 19 in river segment 2, location 23 in river segment 3, and location 27 in river segment 4. However, sediment dioxin and furan levels were measured only at a total of six locations in the lower Columbia River—all in the vicinity of pulp and paper mill operations. Dioxins and furans were detected in the sediments at all six locations.

Resin acids were measured at only four locations in the lower Columbia River (location 19 in river segment 2; locations 25, 27, and 29 in river segment 4), and were detected at three of the four locations (19, 25, and 27). Because no effects-based screening levels exist for these compounds, the locations with detected values were ranked as medium priorities. However, two of the locations [location 19 (Longview) and 27 (Camas Slough)] had measured values an order of magnitude higher than location 25. Resin acids in sediments are consistent with the presence of pulp and paper mill operations near these locations.

Sediment radionuclides in the lower Columbia River were measured at 40 stations (see Figures 9–12). These stations have been identified separately from other sediment chemistry locations because the studies are dated (1963–1965 for river segments 2, 3, and 4, and 1973 for river segment 1 and to a limited extent segment 2). Another reason they were separated is because most stations were only sampled for radionuclides. The only recent radionuclide data in the lower Columbia River were collected by the Oregon Division of Health (G. Toombs, 18 February 1992, personal communication). These data were requested for inclusion but were not received.

Comparisons of historical sediment radionuclide levels with derived screening levels (the lowest 10th percentile) revealed that radionuclide concentrations were quite high at all the locations surveyed. With the exception of K-40 (which is a natural product), the half-lives of the various radionuclides measured in the reviewed studies are quite short. This factor, coupled with the fact that new contamination from cooling water is not being introduced from the Hanford reactors, suggests that radionuclide levels present in sediments several years ago (before 1973) may not pose a current problem in the lower Columbia River.

As stated earlier, only a very general assessment of the historical state of sediment contamination is possible in the lower Columbia River. The lack of a systematic sampling effort in strategic locations in the whole lower river, coupled with different sampling dates, substantial variation in detection limits, and inconsistencies in chemical parameters measured made interpretation of the data difficult. The most extensive sediment chemistry surveys were conducted in the estuarine regions of the river, mainly in segments 1A and 1B. Metal contamination was detected at most sampled locations in the river, but at concentrations generally below the effects-based screening levels. Data on organic compounds were limited, with relatively few locations containing detected amounts of these contaminants. Dioxin and furan compounds, however, were detected wherever they were measured. Several locations (Location 4, Chinook Channel; 8, Young's Bay; 9, Astoria; 15, 16, 17, Wauna; 19, Longview; 24, Vancouver/Portland area; 25, Vancouver; and 27, Camas) were considered high-priority areas as a result of possessing contaminant levels for at least two contaminants that exceeded the screening levels. Major data gaps occurred for river segments 2B and 3B, where no sediment chemistry data exist. Lack of sediment contaminant data for specific groups of compounds at many of the locations in the lower Columbia River also pointed to data gaps for those locations (see Table 7).

Sediments in river segment 3 were poorly characterized. Only two locations (around Kalama and St. Helens) in Segment 3 were sampled for sediment chemistry, despite the occurrence of several municipal and industrial point sources and two landfills (identified in the Task 2 report) in this segment.

With the exception of a few locations around heavily industrialized urban areas on the river (identified above), an evaluation of the historical data by comparison to the screening levels described here reveals four locations where sediment quality exceeds the screening levels. This evaluation however, was hampered by 1) the significant difficulties associated with interpreting the historical data; 2) lack of studies in depositional areas where the most contamination would be expected, and 3) the absence of toxicity-based sediment chemical criteria for all the contaminants detected in the sediments.

A systematic survey of sediments at strategic locations is strongly recommended to derive a scientifically sound assessment of current sediment contamination in the lower Columbia River. An accurate assessment of the biological and public health significance of observed sediment contamination levels awaits the establishment of acute and chronic toxicity criteria for the contaminants found in the river.

2.3 BENTHIC INFAUNA

2.3.1 Data Selection and Review Methods

Twenty-two reports describing the benthic macrofauna of the lower Columbia River were reviewed (Table 9). To date, research efforts have focused on river segment 1. Most of these studies were conducted for the Columbia River Estuary Data Development Program (CREDDP) in the early 1980s. Studies by the National Oceanic and Atmospheric Administration (NOAA) and National Marine Fisheries Service address problems associated with the effects of the disposal of dredged materials on benthic assemblages. For purposes of this historical review, reports were rejected if descriptions of methods or methods themselves were inadequate, the data were obviously flawed (e.g., apparent errors of transcription), or if no data beyond species lists were presented. An exception to these requirements is the estuary-wide distribution study conducted by Holton et al. (1984). In this study, 206 sampling sites were established over 16 strata, and 0–3 substrata based on salinity, substrate type, water depth, and current strength. Only a single sample was collected at each station but division of the study area into substrata permitted estimation of stratum means and variances. Of the 22 studies reviewed, 12 were accepted for further evaluation based on the above criteria (Table 10). Nine of the 12 studies were performed within segment 1.

2.3.1.1 Choice of Indicators. Total macrofaunal densities and the densities of dominant species (or major taxonomic groups) were the only indices consistently available in most studies (see Table 9). Diversity indices were presented by only a few authors. Species richness was not consistently reported in comparable units. Sometimes species richness was reported as the total number of taxa and other times as the mean number of taxa per site.

2.3.1.2 Available Data and Station Locations. Historical data are available for all segments of the Lower Columbia River except river segment 2B, Cathlamet Channel to Beaver (Figures 13–16).

2.3.1.3 Reference Area Data. Benthic community structure varies greatly in response to sediment type and depth. Numbers of individuals and taxa, as well as the presence or absence of certain species, are characteristic for various sediment types at a given depth stratum. Because of this variability, multiple reference conditions representing combinations of habitat depths with sediment types need to be defined for the selected benthic variables. Adequate reference areas for benthic infauna have not been delineated in any segment of the lower Columbia River. Few of the studies reviewed compared affected sites to reference areas. Those that did were limited in scope. Generally, the studies were done to generally charac-

TABLE 9 SUMMARY OF ACCEPTED BENTHIC INVERTEBRATE STUDIES
(Page 1 of 3)

Reference	Sample Type[a]	Variables[b]	Survey Period	Number of Stations	Number of Replicates	Number of Times Sampled	Comments
Blahm et al. (1980)	BI, PF, S	D, GS, TVS	6/77, 5/78, 7/78, 2/79	28	?	4	-Number of replicates taken not specified, no estimates of variance reported
Blahm & McConnell (1979)	WC, BI, ZP	D	8/76, 10/76, 1/77	18	None Described	3	-Little description of sampling methods or sites -Benthic samples taken with the same 12.5-cm Clark-Bumpus sampler as zooplankton??? (no other gear described) -Data collected during 1976-77
Century West Engineering Corp (1989)	BI	D	12/88	6	3	1	-Impact investigation, copper concentrate spill at the Port of Vancouver
Durkin et al (1981)	BI, PF, DF, DC	D, GS, TVS	10/78-11/78, 5/79	4	20	2	-Estimates of variance not reported -Self-scouring sites in the Columbia River estuary, considered for in-water disposal of dredged material
Durkin et al (1987)	BI, S, WC	D, GS, TVS	9/78, 12/78, 3/79, 6/79	24	2	4	-Only 2 reps, so no estimates of variance -Data were collected during 1978-79
Durkin & Emmett (1980)	BI, S, WC	D, GS, TVS	6/77, 9/77, 12/77, 3/78	45	2	4	-Data were collected during 1977-78
Durkin et al (1979)	BI, DF, PF	D, B, GS, TVS	8/77, 11/77, 12/77, 1/78	16	1	6	-Data were collected during 1977-78
Fox (1981)							No original data

TABLE 9. SUMMARY OF ACCEPTED BENTHIC INVERTEBRATE STUDIES
(Page 2 of 3)

Reference	Sample Type[a]	Variables[b]	Survey Period	Number of Stations	Number of Replicates	Number of Times Sampled	Comments
Enviro Science, Inc. (1983a)	BI	D	10/83	?	?	?	-Mean density and a range are presented, no sample size or estimate of variance -Specimens ID'd to Order only
Enviro Science, Inc. (1983b)	BI, S, WC	D, B, SC, H', MVA	12/82, 1/83, 2/83, 3/83	5	5	4	-Size class data for *Macoma balthica* only -Data were collected pre- during- and post- in-water disposal of dredged materials
Enviro Science, Inc. (1984)	BI, S	D, B, SC	10/83, 12/83, 1/84, 3/84	6	4	4	-Size class data for *Macoma balthica* only -Data were collected pre- during- and post- in-water disposal of dredged materials
Hinton et al. (1990)	DF, BI, S, WC	D, GS, TOC	5/76-7/77, 9/88-9/89	5	10	11	-Lots of data
Holton et al. (1984)	BI, S, WC	See below	5/80-9/81				
1. Vertical distribution of macrofauna	BI, S, WC	D, GS, VD	5/80	3	1	1	-Vertical distribution of benthic infauna at sites in Grays and Bakers Bays and Desdemona Sands
2. Baker Bay intensive study	BI, S, WC	D, SE, H', SP, J', DLOG	5/80-4/81	5	1	14	-To determine seasonal changes in density and community structure
3. *Corophium salmonis* life history study	BI, S, WC	D, SC, SE, LH	8/80	2	5	16	-Sites at Grays Bay and Desdemona Sands
4. *Corophium salmonis*-community dynamics	BI, S, WC	D, SE, SP, B	8/80-9/81	2	5	16	-Models secondary production by macrofauna

TABLE 9 SUMMARY OF ACCEPTED BENTHIC INVERTEBRATE STUDIES
(Page 3 of 3)

Reference	Sample Type[a]	Variables[b]	Survey Period	Number of Stations	Number of Replicates	Number of Times Sampled	Comments
5 Estuary-wide distribution of macrofauna	BI, S, WC	D, B, MVA, GS	9/81	102	1	1	-Canonical correlation analysis
McCabe (1991)	DF, S, DC, BI	No benthic data available yet	3/91, 6/91	14	5	2	-Progress report
McCabe & Hinton (1990a)	BI, S	D, H', J'	8/89	5	5	1	
McCabe & Hinton (1990b)	BI, S	D, GS	4/89, 9/89	20	5	2	-Benthic sampling to determine habitat requirements of white sturgeon
McCabe et al (1990)	DF, BI, S	D, H', J', GS, TVS	7/87, 11/87, 7/88, 12/88	6	5	4	
McCabe & McConnell (1989)	DC	D, SC	11/83-9/88	9	1	91	-Samples were taken monthly during 11/83-3/86, then bi-monthly during April-September/October, 4/86-9/88
McConnell et al. (1978)							-Reviewed in Hinton et al. (1990)
Monaco et al. (1990)	--	--	--	--	--	--	-Qualitative information only
Portland General Electric (1987)	BI, S	D, GS	4/84, 5/84, 7/84	18	?	3	-Qualitative description of sediments only
Sanborn (1975)	BI	D	8/73, 9/73, 4/74, 5/74, 7/74	7	1	5	-Data from 1973-74 -Samples rinsed on a 1.0-mm mesh screen

[a] Sample Types. BI = Benthic Invertebrates, DC = Decapod Crustaceans, DF = Demersal Fishes, PF = Pelagic Fishes, S = Sediments, WC = Water Conventionals (temperature, salinity, conductivity, turbidity), ZP = Zooplankton

[b] Variables: B = Biomass, D = Density (m^{-2} or m^{-3}), DLOG = Margalef's diversity, GS = Grain Size, H' = Shannon-wiener Diversity Index, J' = Pielou's Evenness Index, LH = Life History, MVA = Multivariate Analyses, SC = Size-Class Distribution, SE = Seasonality, SP = Secondary Production, VD = Vertical Distribution

TABLE 10. EVALUATION OF EXISTING BENTHIC INVERTEBRATE STUDIES (Page 1 of 2)						
Reference	Accepted	SC[a]	SH[b]	QA[c]	AM[d]	Comments
Blahm et al (1980)	Yes	A[e]	A	N[e]	N	Bunker C oil spill in 1978 R Segments 1A-4A
Blahm & McConnell (1979)	No	I[e]	N	I	N	Samples taken before, during, and after in-water disposal of dredge materials. R Segment 2C
Durkin et al. (1981)	Yes	A	A	N	N	Four self-scouring sites in lower estuary. R. Segments 1A-1C
Durkin et al. (1987)	Yes	A	A	N	A	Describes benthic communities in Cathlamet Bay, OR. R. Segment 1C
Durkin & Emmett (1980)	Yes	A	A	N	A	To provide information to USFWS on two "designated component areas," Youngs Bay and Bakers Bay. R. Segments 1A-1C
Durkin et al. (1979)	No	I	A	N	I	-Total numbers and biomass of invertebrates per station are presented -No replication of samples
Enviro Science, Inc. (1983a)	No	N	N	N	N	Sampled between piers in a potential area to be filled at Tongue Pt. R. Segment 1B
Enviro Science, Inc. (1983b)	Yes	A	A	A	A	Re. flow-lane disposal of dredged materials off Port of Astoria docks. R. Segment 1B
Enviro Science, Inc. (1984)	Yes	A	A	A	A	Re. flow-lane disposal of dredged materials off Port of Astoria docks. R. Segment 1B
Fox (1981)	No	N	N	N	N	A restatement of CREDDP data
Hinton et al. (1990)	Yes	A	A	N	A	Describes benthos at 5 currently-used dredged-material disposal sites. R. Segment 1A-1C
Holton et al. (1984)	Yes	A	A	A	A	Five subunits: -vertical distribution of infauna -intensive study at Baker Bay -*Corophium salmonis* life history -*C. salmonis* community -estuary-wide study of invert. distributions. R. Segments 1A-C and 2A
McCabe (1991)	No	A	A	N	N	Progress report, sampling results not available yet to assess benthic assemblages at Area D, proposed site for in-water disposal of dredged materials. R. Segment 1A

TABLE 10 EVALUATION OF EXISTING BENTHIC INVERTEBRATE STUDIES (Page 2 of 2)						
Reference	Accepted	SC[a]	SH[b]	QA[c]	AM[d]	Comments
McCabe & Hinton (1990a)	Yes	A	A	N	A	Describes benthos at route followed by Cathlamet Ferry (related to ACE dredging). R Segment 2A
McCabe & Hinton (1990b)	Yes	A	A	A	A	Infaunal densities at RM 28, 75, 79, 88, 95, 114, 127, 131
McCabe et al (1990)	Yes	A	A	N	A	Describes benthos near rock groins and pile dikes at Cottonwood Island R. Segment 2C
McCabe & McConnell (1989)	No	I	A	N	A	Abundance and size-class structure of Dungeness crabs (related to dredging at mouth of Columbia River) R Segment 1A
McConnell et al. (1978)	No	A	A	N	A	Reviewed in Hinton et al. (1990)
Monaco et al (1990)	No	N	N	N	N	Tabular summaries of other studies
Portland General Electric (1987)	Yes	N	N	N	N	-EIS to U S COE to fill wetlands on Hayden Island. R Segment 4A -No replication
Sanborn (1975)	No	A	A	N	N	Benthos as food for anadromous fish. R. Segments 1B, 3A, 3B, & 4A

[a] SC = Sample Collection

[b] SH = Sample Handling

[c] QA = Quality Assurance

[d] AM = Analytical Methods

[e] A = Adequate, I = Inadequate, N = No Description.

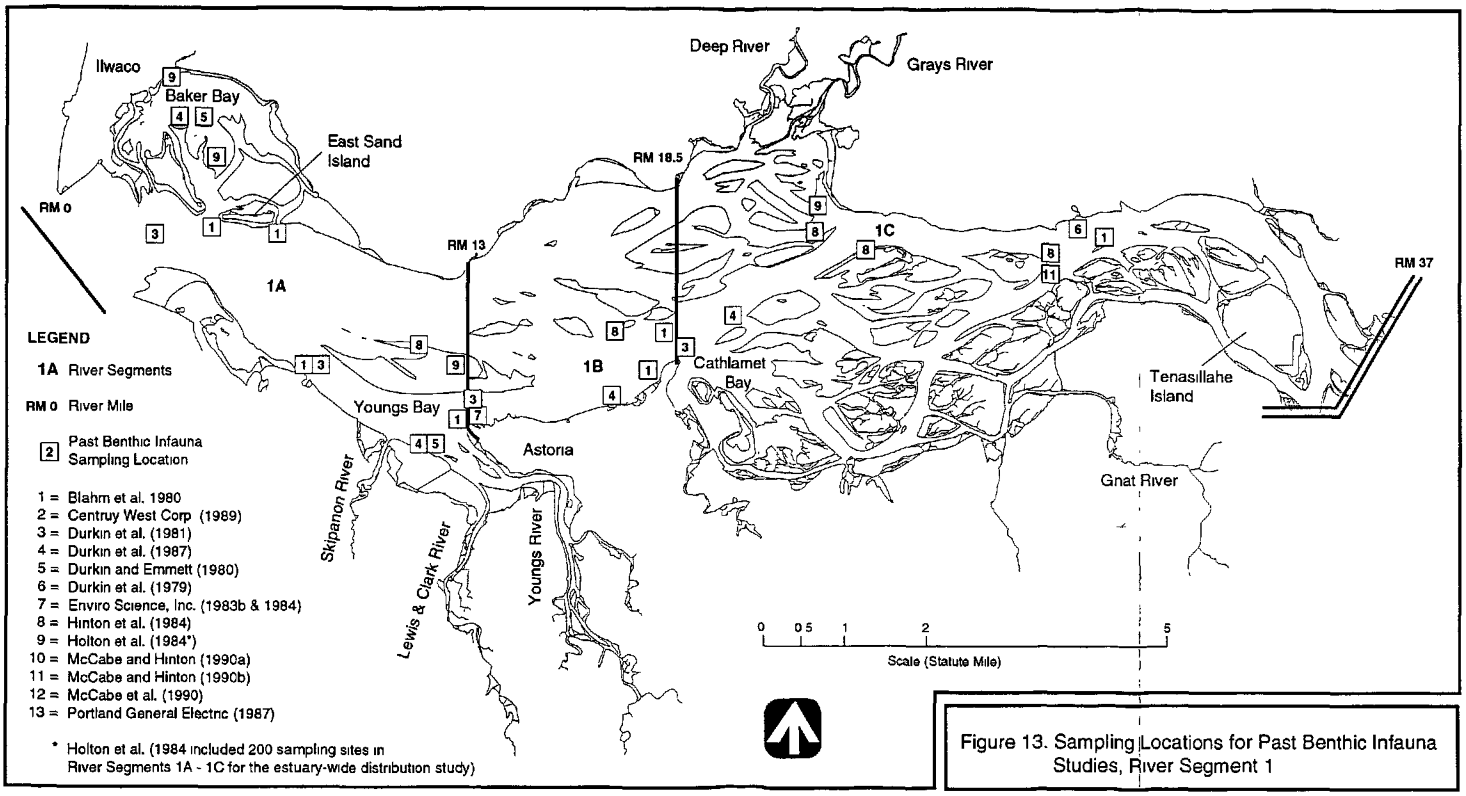


Figure 13. Sampling Locations for Past Benthic Infauna Studies, River Segment 1

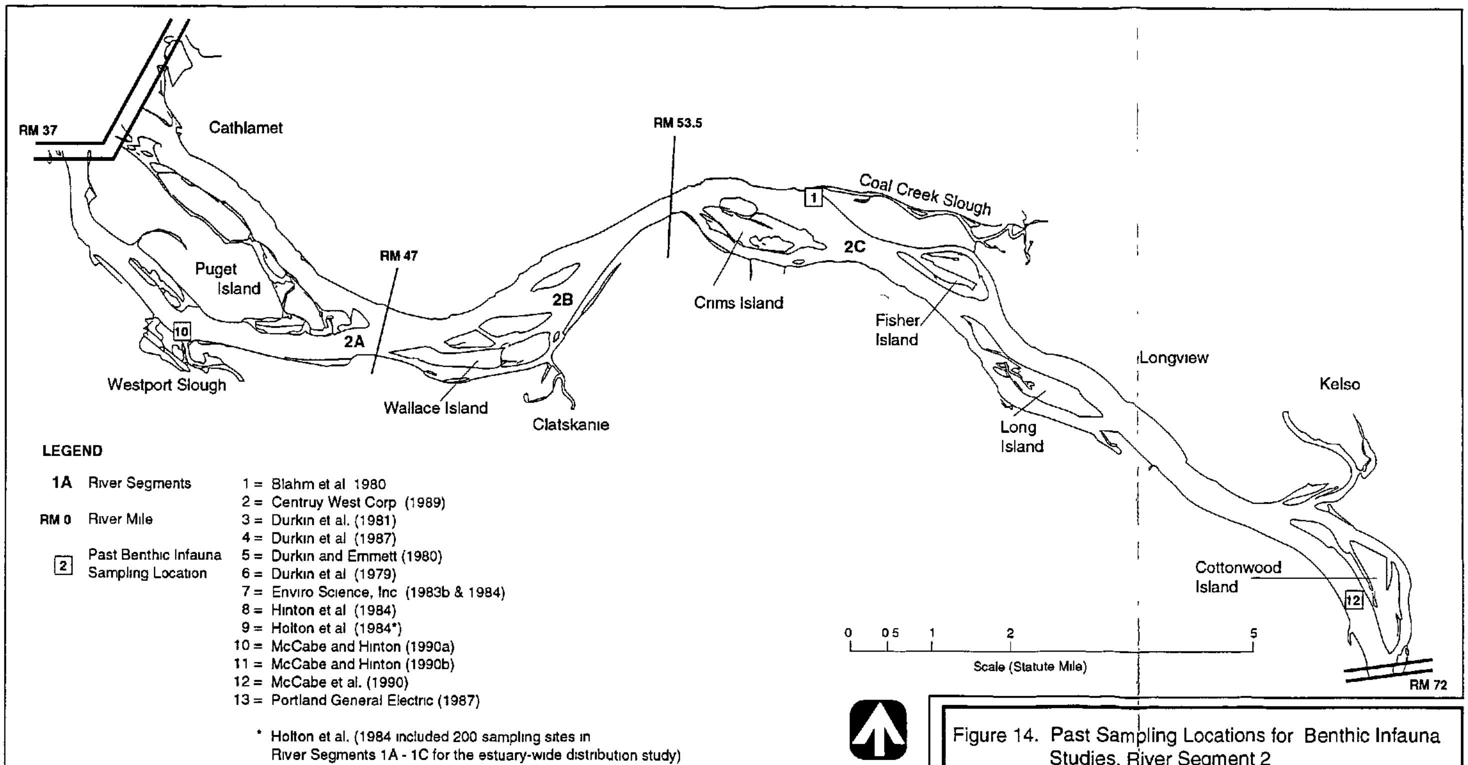


Figure 14. Past Sampling Locations for Benthic Infauna Studies, River Segment 2

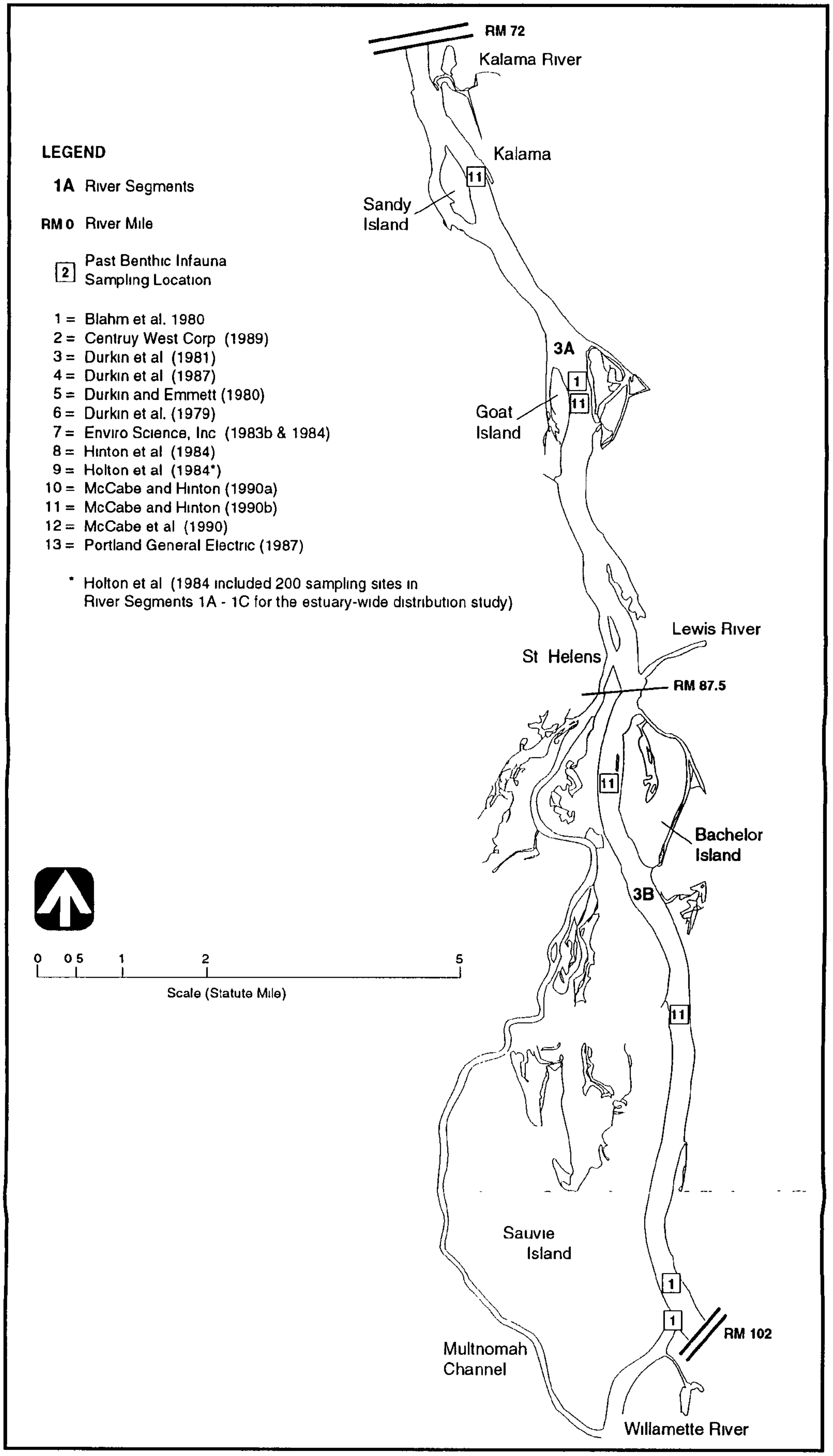
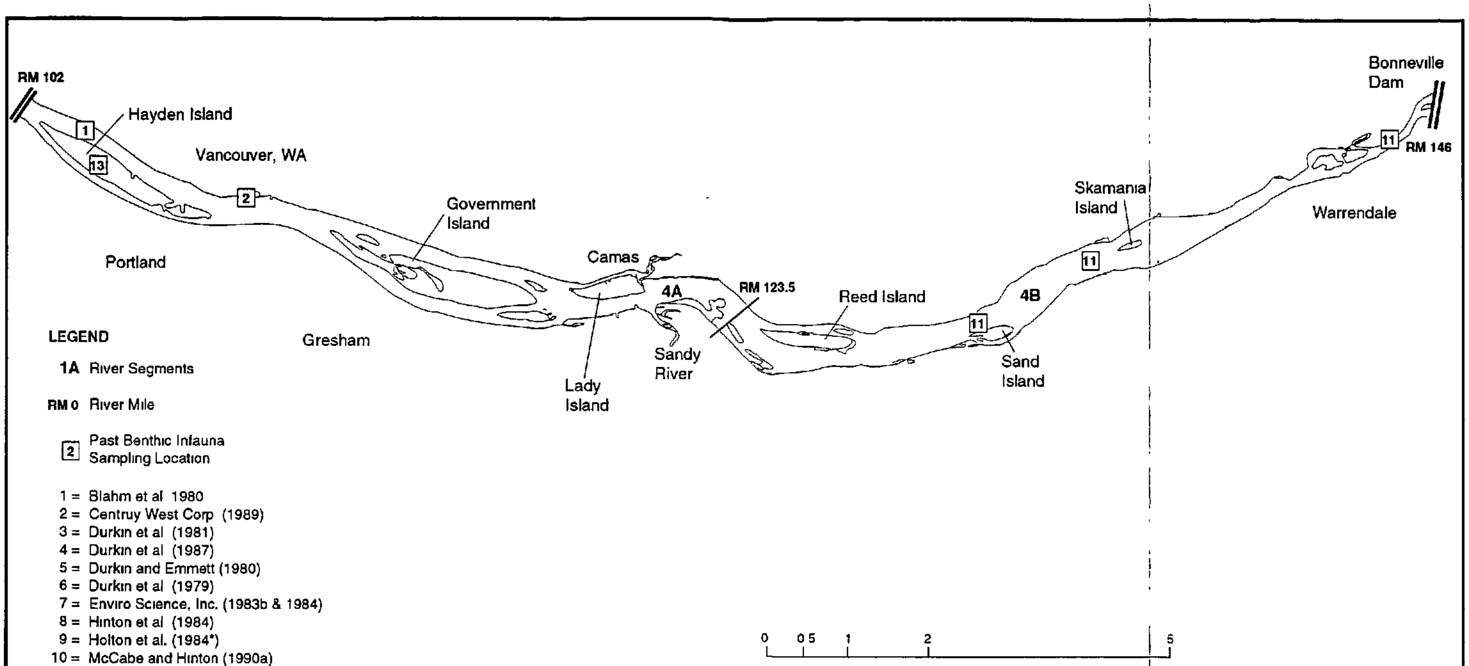


Figure 15. Past Sampling Locations for Benthic Infauna Studies, River Segment 3



LEGEND

1A River Segments

RM 0 River Mile

[2] Past Benthic Infauna Sampling Location

1 = Blahm et al 1980
2 = Centruy West Corp (1989)
3 = Durkin et al (1981)
4 = Durkin et al (1987)
5 = Durkin and Emmett (1980)
6 = Durkin et al (1979)
7 = Enviro Science, Inc. (1983b & 1984)
8 = Hinton et al (1984)
9 = Holton et al. (1984*)
10 = McCabe and Hinton (1990a)
11 = McCabe and Hinton (1990b)
12 = McCabe et al (1990)
13 = Portland General Electric (1987)

* Holton et al. (1984 included 200 sampling sites in River Segments 1A - 1C for the estuary-wide distribution study)

Figure 16. Past Sampling Locations for Benthic Infauna Studies, River Segment 4

terize infaunal assemblages rather than to identify impacted areas, and did not identify useful reference areas or conditions.

2.3.1.4 Elevation Above Reference Analysis. Because reference areas or conditions in the lower Columbia River are inadequately delineated and the studies lack consistent methods, rankings and EAR analyses were not conducted for benthic invertebrate populations. Instead, the general trends of macrofaunal densities and dominant taxa were described.

2.3.2 Review of Accepted Data

2.3.2.1 Data Summary: River Segment 1 (Columbia River Estuary). A large body of information on the distributions, life histories, and production ecology of benthic invertebrates in the lower 46 miles of the Columbia River was developed during 1980 and 1981 for the CREDDP (Holton et al. 1984). As a part of this program, the estuarywide relationships between benthic invertebrate populations and sediment properties were surveyed during September 1981 Although the results of this study are limited by lack of data from other seasons, the patterns of faunal distribution provide a framework for discussion.

Data were derived from a single survey of 206 stations on September 8-11, 1981. The authors divided the estuary into 16 geographic strata according to salinity (marine, transition, and freshwater) and substrate type/current strength (main channel center, main channel side, minor channel, unprotected flat, protected flat, and marsh channel). Marsh channels were delineated only in the freshwater zone. The 206 sampling sites were evenly distributed among the 16 strata. Precise sampling locations were chosen at random. One sediment sample was collected at each of 206 sites using a 0.05-m^2 Ponar dredge. Samples were rinsed over a 0.500-mm mesh screen before sorting and identification.

The objectives of the Holton study were to:

- Assess the accuracy with which the estuary was divided, *a priori*, into strata based on salinity and substrate type (i.e. are animal communities different between and yet homogeneous within strata?)
- Identify community types independent of the *a priori* stratum designation
- Evaluate the degree to which distributions of animals correspond with measured habitat properties (percent fine-grained sediments and percent organics).

The first objective was approached using discriminant analysis, a multivariate statistical technique. This analysis permitted the authors to determine the frequency with which samples collected from a salinity/substrate stratum could be classified, based on their species abundances, as belonging to that stratum. The results of this analysis suggested that community composition was most diverse in the marine zone of the estuary. Ninety-three percent of the samples from that stratum were correctly classified into their habitat of origin. Only 74 and 63 percent of the samples were correctly classified in the transition and freshwater zones, respectively. Thus, the original definition of habitats on the basis of physical characteristics provided a closer fit to the observed distributions of infauna in the marine zone than in the other two areas.

The second and third objectives were approached using the methods of ordination, a family of multivariate techniques used to analyze spatial trends in community structure and their relationship to environmental gradients. As a result of this analysis, samples fell into four distinct groups. Group 1 contained samples collected in the freshwater zone, characterized by the amphipod *Corophium salmonis*, the bivalve *Corbicula manilensis*, larval midges (Heleidae and Chironomidae), and oligochaetes. Group 2 included 16 samples from Baker Bay (a marine, protected flat habitat), 6 from Youngs Bay (a transition zone, protected flat), and other samples from the marine and transition zones. This group was characterized by species with fairly wide geographic distributions: the polychaetes *Hobsonia florida* and *Neanthes limnicola*, and the bivalve *Macoma balthica*. Group 3 was composed of samples from minor channel, channel side habitats, and unprotected flats within the transition zone. Dominant taxa were the amphipods *Eogammarus confervicolus* and *Eohaustorius estuarius*, *N. limnicola*, and Rhyncocoela. Group 4 samples represented a variety of strata within the marine and transition zone and were typified by high abundances of Rhyncocoela, the amphipod *Paraphoxus milleri*, the mysid *Archeomysis grebenitzkii*, and the polychaetes *Paraonella platybranchia*, and *Spio filicornis*. Groupings of infaunal assemblages were correlated with both the upriver salinity gradient and the presence of fine particles in sediment.

A variety of other authors have described the distributions and abundances of benthic macrofauna at specific sites within the Columbia River Estuary. These studies address a variety of objectives, including impacts of dredged-material disposal, oil spills, and the assessment of feeding habitat for white sturgeon. The results of these studies are discussed below. In the last paragraphs(s) in each section, results are summarized and compared with the model of species descriptions described by Holton et al. (1984).

River Segment 1A (Mouth of the Columbia River to Youngs Bay). A total of six studies were reviewed that described benthic infaunal assemblages in river segment 1A. Three of these contained data collected during the 1980s. Hinton et al. (1990) sampled a dredged-material disposal area at Desdemona Sands. In addition to the estuarywide distribution study discussed above, Holton et al. (1984) conducted intensive studies at both Baker Bay and Desdemona Sands. These studies described fluctuations in species densities (per square meter) over time and the production dynamics of the polychaetes, *Pseudopolydora kempi* and *Hobsonia florida*, a bivalve, *Macoma balthica*, and an amphipod, *Corophium salmonis*. The effects of in-water disposal of sediments dredged from deepwater berths at the Port of Astoria on benthos were assessed by Enviro Science (1983a,b and 1984).

Hinton et al. (1990) describe sediments and faunal assemblages at one intertidal and one subtidal site at Desdemona Sands. Samples were collected during October 1988 and May, July, and September 1989 (Table 11). Samples were collected using a 0.1-m^2 Van Veen grab and were washed over a 0.500-mm screen before sorting. Ten replicates were collected per sampling date. Sediments were predominately very fine or fine sands with a mean percent silt/clay of <2 percent. Mean Total Organic Carbon (TOC) ranged from 1.7 percent in September to 0.8 percent in July. The total number of taxa collected at Desdemona Sands varied from six during September 1988 to 10 in May 1989 and average total macrofaunal density ranged from 3,009 to 11,770/m^2 on the same dates, respectively. Numerically dominant species were the bivalve *Macoma balthica*, Turbellaria, and the amphipod *Eohaustorius estuarius*. Oligochaetes were abundant during all surveys.

The results of Hinton et al. (1990) were markedly different from those reported for an intertidal site (+0.3 m above MLLW) at Desdemona Sands by Holton et al. (1984). The latter authors collected samples monthly, from August 1980 to June 1981, and then twice monthly until August 1981. Samples were collected using a handheld 10.16-cm^2 coring device and were washed on a 0.500-mm mesh screen before sorting. The amphipod *Corophium salmonis* dominated the assemblage during May through September (peak density 72,149/m^2) but appeared to emigrate during winter to sites further up the estuary; the decline in *C. salmonis* at Desdemona Sands during September/October was mirrored by an increase in density (to 31,491/m^2) at Grays Bay (river segment 1C). Other dominant taxa at Desdemona Sands were oligochaetes, nematodes, the amphipod *Eohaustorius estuarius*, and the polychaete *Neanthes limnicola*. Differences in results between the Hinton et al. (1990) and Holton et al. (1984) studies at Desdemona Sands probably represent natural changes in the structure of macrofaunal assemblages over time. In addition, the smaller diameter, handheld corer used by Holton et al. (1984) could have resulted in underestimates of the densities of species with patchy distributions.

TABLE 11 METHODS USED IN HISTORICAL COLLECTIONS OF BENTHIC MACROFAUNAL INVERTEBRATES AT SITES LOCATED IN LOWER COLUMBIA RIVER, SEGMENT 1

Reference	Sampling Dates	Gear	Grab/Core Area	Sieve Size	No. Reps
Blahm et al. (1980)	June 1977 July 1978 February 1979	Ponar Dredge	0.1-m^2	0.595	not stated
Durkin et al. (1981)	October 1978 May 1979	Ponar Dredge	0.05-m^2	0.595	10
Durkin et al. (1979)	August 1977 November 1977 December 1977 January 1978	Ponar Dredge	0.05-m^2	not stated	not stated
Durkin et al. (1987)	September 1978 December 1978 March 1979 June 1979	Ponar Dredge	0.05-m^2	0.595	2
Durkin and Emmett (1980)	June 1977 September 1977 December 1977 March 1978	Ponar Dredge	0.05-m^2	0.595	2
Enviro Science, Inc. (1984)	October and December 1983 January and March 1984	Van Veen	0.1-m^2	0.500	4
Hinton et al. (1990)	September 1988 May 1989 July 1989 September 1989	Van Veen	0.1-m^2	0.500	10
Holton et al. (1984)	Monthly, August 1980-September 1981	hand-held core	10.16-cm^2	0.500	5
McCabe and Hinton (1990b)	April 1989 September 1989	Van Veen	0.1-m^2	0.500	5

Holton et al. (1984) also conducted an intensive study of benthic community structure in Baker Bay. Samples were collected monthly between August 1980 and September 1981 using the 10.16-cm^2 handheld coring device described above. Sediments in the mudflat at Baker Bay were composed of fine sands and silts (Holton et al. 1984). The macrofaunal assemblage was dominated by *Macoma balthica, Hobsonia florida, Pseudopolydora kempi,* and oligochaetes. Total macrofaunal density exceeded 30,000/m^2 during August–October 1980. The density of *M. balthica* remained fairly constant (approximately 5,000/m^2) throughout the year, with a slight decline during summer. *H. florida* demonstrated a peak in recruitment during June and July followed by a sharp decline in abundance. After peaking during August 1980, the abundance of *Pseudopolydora kempi* declined gradually until the next peak in recruitment during August 1981. Oligochaetes decreased in abundance from 18,000 to 5,000/m^2 over the study period. Deposit feeding, employed by *M. balthica* and oligochaetes, was the prevalent mode of feeding.

In studies by Enviro Science, Inc. (1983a,b and 1984) for the Port of Astoria, samples were collected during December 1982, January, February, March, October and December 1983 and January and March 1984 at sites 200 m east of Pier 1 and up to 500 m downstream. Samples were collected using a 0.1-m^2 van Veen grab. Species–area curves developed from preliminary sampling indicated that four replicates were required to adequately assess macrofaunal variability at each site. In samples collected between October 1983 and January 1984, *Macoma balthica* was the most common and abundant macrofaunal species (average density 962/m^2) in sediments downstream from the dredged-material outfall (Enviro Science 1984). Oligochaetes averaged 259/m^2. These two taxa plus the polychaete *Neanthes limnicola,* nemerteans, and the amphipod *Eogammarus confervicolus* comprised 99 percent of the individuals captured.

Three studies (Blahm et al. 1980, Durkin et al. 1981, and Durkin and Emmett 1980) contain data collected from sites in river segment 1A during the late 1970s (see Table 11). The Columbia River Oil Spill Study (Blahm et al. 1980) contains data collected at six stations between RM 4.5 and 11.4 during June 1977, July 1978, and February 1979. Results are presented as the densities of major taxa on each sampling date. Sediments varied from <1 percent silt/clay (at stations at the mouth of Youngs Bay) to 22 percent silt/clay (at a station in Baker Bay). Dominant taxa varied between stations and dates but included amphipods, oligochaetes, nematodes, and bivalves. Durkin et al. (1981) describe the abundances of major taxa at self-scouring sites within the Columbia River Estuary including Jetty A, Tansy Point, and under the Interstate Bridge. Sediments were clean [1–2 percent total volatile solids (TVS)], medium-grained sands. The macrofaunal assemblage in the navigation channel at Jetty A supported a low standing crop dominated by nematodes, mysids, and copepods. Abundances were higher at Tansy Point and the Interstate Bridge and included turbellarians, nemerteans, nematodes, amphipods, and copepods. Durkin and Emmett (1980) sampled fine sands in Baker and Youngs Bays during 1977–78. The macrofaunal assemblage in Baker Bay was dominated by *Macoma balthica*. The polychaete *Neanthes limnicola* and the amphipods *Eohaustorius estuarius* and *Corophium brevis* were also important. Sediments ranged in texture from fine sands along the northeast shoreline of Youngs Bay to very fine sand and silt at the mouths of the Youngs and Lewis and Clark Rivers. Deposit-feeding oligochaetes and the amphipods *Corophium salmonis* and *C. spinicorne* were abundant, especially in areas with fine-grained substrates.

In summary, river segment 1A encompasses the marine and lower transition zones of the Columbia River Estuary (delineated by Holton et al. 1984). Main channel center, main channel side, minor channel, unprotected flat, and protected flat habitats are located within these zones. Historical data exist for most of these habitat types. Samples collected from the main channel center and sides at Jetty A, Tansy Point, and under the Interstate Bridge contained relatively low standing crops (138 to 5,200/m^2) of macrofauna. Sediments collected along the main and side channel at the Port of Astoria contained an average of 1,300/m^2 and were dominated by *M. balthica* (Enviro Science 1984). The unprotected flats at Desdemona Sands supported large, unstable populations, fluctuating seasonally between 1,000 and 81,024/m^2 and dominated by *Corophium salmonis* at other sites. Populations fluctuated between 3,000 and 11,770/m^2 and were dominated by *Eohaustorius estuarius*. The protected mudflat at Baker Bay supported more stable macrofaunal densities of 10,000 to 30,000/m^2, dominated by oligochaetes and the polychaete *Neanthes limnicola*. Thus, as described by Holton et al. (1984), benthic macrofaunal assemblages in the marine and transition zones of the lower estuary are complex, varying with the degree of protection of the environment and over time.

River Segment 1B (Youngs Bay to Tongue Point). Only one of the studies reviewed contained data collected during the last ten years at a study site in river segment 1B. Hinton et al. (1990) described macrofaunal assemblages at subtidal stations near Taylor Sands during September 1988 and May 1989 (see Table 11). Taylor Sands comprises an area of unprotected flats within the transition zone of the estuary, as defined by Holton et al. (1984). Sediments at Taylor sands were primarily fine sands with low silt/clay and total organic carbon (<2 percent). The total number of macrofaunal taxa observed at Taylor Sands varied from four during September 1988 to seven during May 1989. Average densities ranged from 354/m^2 to 2,035/m^2, respectively. As on the unprotected flats of Desdemona Sands (river segment 1A), macrofaunal assemblages were dominated by the amphipods *Eohaustorius estuarius* and *Corophium salmonis*. Oligochaetes and the polychaete *Neanthes limnicola* were also abundant.

Studies were conducted during the late 1970s in river segment 1B by Blahm et al. (1980), Durkin et al (1981), and Durkin and Emmett (1980) (see Table 11). Blahm et al. (1980) sampled benthic assemblages in the Navigation Channel at Tongue Point (RM 17.8) during June 1977, July 1978, and February 1979. Sediments were medium sands with low organic content. Total macrofaunal densities ranged from $480/m^2$ during July 1978, two weeks after an oil spill at RM 102, to $3,600/m^2$ during February 1979. Macrofaunal assemblages were dominated by copepods, nematodes, and amphipods. Durkin et al. (1981) describe macrofaunal assemblages in the main navigation channel off Tongue Point and just inshore along the side of the channel during the same period. Similar results were observed. These sediments were also clean, medium-grained sands (<2 percent TVS). Total macrofaunal density ranged from $308/m^2$ during October 1978 to $6,716/m^2$ during May 1979. Copepods, nematodes, and amphipods were again the dominant species. Sampling by Durkin and Emmett (1980) included six sites along the Astoria waterfront and one site in the navigation channel off Tongue Point. Sediments at the Port of Astoria were generally fine sands with <5 percent TVS. Medium sands with <1 percent TVS predominated in the navigation channel. Macrofaunal assemblages at both locations were dominated by copepods, amphipods, and oligochaetes.

Summarized within the framework described by Holton et al. (1984), total macrofaunal densities in the transition zone of the estuary (Segment 1B) were distributed similarly to the densities observed in the marine zone. That is, densities averaged $<5,000/m^2$) in the main channel center, main channel side, and unprotected flats habitats. Dominant species were similar to those found in these habitats in river segment 1A: the amphipod *Eohaustorius estuarius*, the polychaete *Neanthes limnicola,* and oligochaetes. Missing from these sites were the marine-associated, protected-flats species *Macoma balthica, Psuedopolydora kempi,* and *Hobsonia florida.*

Protected flats occur within the bights just west of Grays Point on the Washington shoreline and just west of Tongue Point at Astoria. The only data available for these areas appear to be those collected at station 40, just west of Tongue Point, by Durkin and Emmett (1980) during 1977–78. Sediments collected at this station were fine sands dominated by amphipods. Thus, little is known of macrofaunal populations in what are potentially the most productive habitats, the minor channels and protected flats, in river segment 1B.

River Segment 1C (Tongue Point to Tenasillahe Island). Several authors have recently described benthic macrofaunal assemblages in river segment 1C. Holton et al. (1984) found that assemblages from protected flats in Grays Bay (at the boundary between the transition and freshwater zones) contained densities varying from $35,000/m^2$ during winter to $>10,000/m^2$ during summer and fall. Sediments were fine sands with 3–21 percent silt and clay. Popula–

tions at these sites were dominated by *Corophium salmonis*. The sharp increase in the abundance of *C. salmonis* in Grays Bay during November 1980 was attributed both to the recruitment of a fall cohort and immigration of members of this highly mobile species from areas such as Desdemona Sands, downstream. Juvenile specimens of the exotic Asian clam, *Corbicula manilensis*, occurred in samples from Grays Bay at densities of >600/m^2. These authors suggest that Grays Bay may be near the downstream end of the range of this species within the Columbia River.

As part of NOAA's study of sturgeon habitat in the lower Columbia River, McCabe and Hinton (1990b) collected benthic samples mid-channel and along the channel sides near Woody Island at RM 28 during 1989. Sediments were sands with low organic content. Samples collected mid-channel contained an average of 2,046/m^2 during April and 1,743/m^2 during September 1989 and were dominated by heleid larvae and *Corophium salmonis*, respectively. Macrofaunal densities in samples from the Washington side of the channel increased from 266 to 1,938/m^2 over the same period. Heleid larvae and *C. salmonis* were again the numerical dominants. On the Oregon side of the channel, closer to Woody Island, macrofaunal densities increased from 1,572 to 3,677/m^2, and assemblages were dominated by *C. salmonis* during the same period. Heleid larvae were not abundant at this location.

Hinton et al. (1990) describe macrofaunal invertebrates on the unprotected flats at Rice Island, Miller Sands, and Jim Crow Sands—three manmade islands created from dredged materials. Sediments at all three study areas were predominately fine sands with <2 percent total organic carbon. Percent silt/clay was <1 percent at Rice Island but ranged from 8–14 percent at Miller Sands and 6–10 percent at Jim Crow Sands. Species number was higher at Miller and Jim Crow Sands than at Rice Island, indicating an effect of smaller grain size and hydrologic regions. Macrofaunal densities were higher at all three study areas during September 1988 than July 1989, indicating a seasonal effect. Average densities for samples collected during September ranged from 5,162/m^2 for stations at Rice Island to 36,800/m^2 for stations at Miller Sands. One sample, collected from a subtidal station at Miller Sands during October 1988, contained the highest number of benthic invertebrates found during this study—90,751/m^2—of which 71,087/m^2 were *Corophium salmonis*.

Infaunal densities at Miller Sands during 1989 were higher than those measured during 1976. They were not significantly different than those measured during 1975 and 1977 (Hinton et al. 1990). The taxonomic composition of benthic assemblages was consistent between 1975–77 and 1989; dominant taxa were oligochaetes, *Corophium salmonis*, chironomids, *Corbicula manilensis*, and *Neanthes limnicola*. Although the benthic assemblage did not change significantly over the 12-year period, a change in sediment characteristics was observed. Median grain size increased from very fine sand to fine sand and percent silt/clay declined from 22 percent to 1977 to 4.4 percent in 1989. The authors suggested that the decline in percent silt/clay at Miller Sands may have resulted from dilution by coarse-grained material blown by strong winds from the unvegetated portions of the island into the intertidal area. However, no data on benthic invertebrates or sediments from a comparable control site are available with which to compare changes at Miller Sands over time (R. Emmett, 23 March 1992, personal communication).

Studies were conducted in river segment 1C in the late 1970s by Blahm et al. (1980), Durkin et al. (1981), and Durkin and Emmett (1980). Blahm et al. (1980) collected benthic samples at River Miles 19.4-29.4 during August 1977, July 1978 and February 1979. Sediments were mostly medium-grained sands with <1 percent total volatile solids. However, grabs at Station 21, in Mott Basin (southwest of Tongue Point), produced sediments with 63 percent silt/clay and 6.7 percent TVS. The density of oligochaetes at this station ranged from 5,700/m^2 during February 1979 to 23,180/m^2 during June 1977. Copepods were also extremely abundant. In contrast, sediments at Station 19, at Jim Crow Point, were coarse sands (<1 percent silt/clay) with little organic material. These sediments contained almost no oligochaetes. Copepods, however, reached 20,740/m^2 during February 1979. Three more stations at Jim Crow Point were characterized by medium sands and relatively diverse faunas including nematodes, oligochaetes, amphipods, cladocerans, and copepods.

Durkin and Emmett (1980) also collected benthic samples from Mott Basin. Sediments at two sites comprised very fine sands and silts with total volatile solids concentrations of 5-7 percent. Copepods, oligochaetes, and amphipods dominated the macrofauna at these stations with densities of 23,000-37,000/m^2.

Durkin et al. (1979) collected samples from stations located in the center and along the sides of the main navigation channel near Pillar Rock. Sediments ranged from medium to fine sands with 1 percent TVS. Densities of benthic invertebrates averaged approximately 140/m^2 at the disturbed dredge and dredged-materials disposal sites and 647/m^2 at a comparison site nearby. The most abundant species were *Corophium salmonis,* the mysid *Neomysis mercedis,* and the bivalve *Corbicula manilensis.*

Durkin et al. (1987) collected duplicate samples from 24 stations in Cathlamet Bay. Sampling was conducted seasonally, during September and December 1978 and during March and June 1979. Sediments were fine sands at most sites although medium sands dominated two samples from the Woody Island Channel and one from the John Day River. Fine-grained sediments were sampled at Minaker Island, Blind Slough, and off Aldrich Point. Average organic content (TVS) ranged from <3 percent in September 1978 to 4 percent in June 1979. Highest organic content levels (6-16 percent) were found at the mouth of Big Creek and in Blind Slough. Most sites which had low organics and a high percentage of fine sand also had large numbers of *Corophium salmonis*. Oligochaete densities were highest at stations with moderate amounts of very fine sand and high levels of organics. Tendipedidae were also abundant at sites high in organics. The abundance of *Corbicula manilensis,* another numerical dominant, appeared to be unrelated to grain size or organic content.

River segment 1C falls within the freshwater zone of the Columbia River estuary, as defined by Holton et al. (1984). Unprotected flats predominate although numerous, potentially productive minor channels connect freshwater marshes to the main channel. According to analyses by Holton et al. (1984), macrofaunal assemblages within the freshwater zone of the estuary are dominated by *Corophium salmonis, Corbicula manilensis,* larval heleids and chironomids, and oligochaetes. With few exceptions (e.g., the local abundance of copepods in fine-grained sediments at Mott Basin), this pattern was observed in all the studies reviewed. The structure of macrofaunal assemblages in the freshwater zone of the estuary, and further upstream, is highly predictable. Variation from the pattern described by Holton et al. (1984) may indicate physical disturbance or a localized accumulation of fine sediments and organic material.

As described by Holton et al. (1984), a transition in species composition is observed between the marine zone in river segment 1A and the freshwater zone in 1C. The bivalve *Macoma balthica* is seen only on the protected flats in the lower estuary, while the Asian clam, *Corbicula manilensis*, and chironomid, dipteran, and heleid larvae first appear in the freshwater zone (river segment 1C). Some species (the amphipods *Corophium salmonis* and *Eohaustorius estuarius* and the polychaete *Neanthes limnicola*) are relatively widely distributed.

Species richness (i.e., the number of species per samples) appears to be higher in the marine and freshwater zones than in the transition zone of the estuary. The position of the saltwater wedge and turbidity maximum moves up and down in the transition zone, depending on fluctuations in tidal strength and freshwater outflow. Many organisms may be unable to adapt to the relatively unpredictable nature of the salinity gradient in this zone. Alternately, the lower species richness observed in segment 1B may have reflected the relative homogeneity of the hydrologic environment in this zone. Segment 1B is dominated by unprotected flats and the main channel. Only a few minor channels and a small area of protected flats are in this area.

2.3.2.2 Data Summary: River Segment 2

River Segment 2A (Tenasillahe Island to Cathlamet Channel). Only one of the studies reviewed contained sampling stations in river segment 2A. McCabe and Hinton (1990a) sampled benthic assemblages near the route of the Cathlamet Ferry at RM 43.2 on August 31, 1989 The Cathlamet Ferry runs between docks on Puget Island, WA, and at Westport, OR. This study was done to describe the species composition of benthic assemblages in dredged areas.

In the Puget Island study (McCabe and Hinton 1990a), benthic assemblages at five stations were sampled with a 0.1-m^2 van Veen grab Samples were rinsed on a 0.500-mm screen before sorting. Five replicate samples for benthic invertebrates and one sample for sediment characterization were collected at each station. Sediments at the five stations varied from medium sands with 0.6 percent TVS to silt and clay with 2.6 percent TVS. A grab taken at a station located just off the ferry dock at Westport, OR, contained medium-grained sand with 3.3 percent TVS. The amphipod *Corophium salmonis* was the most abundant benthic invertebrate collected at all five stations, with densities ranging from 1,264/m^2 near the Westport ferry dock to 2,461/m^2 in the Columbia River at the mouth of Westport Slough (Table 12). Oligochaetes were also present, with densities of up to 374/m^2, near the mouth of Westport Slough. *Corbicula manilensis* densities were relatively low, less than 100/m^2.

River segment 2A may be classified in either the freshwater or transition zone of the Columbia River estuary. Estuarine taxa such as *Neanthes limnicola* and *Neomysis mercedis* were locally abundant although the dominant taxa (see Table 12) were those representative of the freshwater zone, as described by Holton et al. (1984). River segment 2A includes many large islands, shallow sloughs, and channels. Depositional areas occur at the Cathlamet Harbor entrance, the north end of Coffee Pot Island, the east end of Bernie Slough, and at the mouth of Westport Slough. A major point source occurs at the James River II mill at Wauna. To date, benthos have been sampled only at the mouth of Westport Slough. There are no ongoing studies in this river segment.

River Segment 2B (Cathlamet Channel to Beaver). None of the studies examined contained sampling sites within river segment 2B. Although segment 2B encompasses a relatively short (6.5 mi) stretch of the lower Columbia River, depositional areas are located at the mouth of Beaver Slough, east of the revetment at Wallace Slough, east of Copper Point,

TABLE 12. SUMMARY OF BENTHIC INFAUNA SAMPLING STATIONS AND COMMUNITY STRUCTURE IN COLUMBIA RIVER SEGMENT 2A[a]

McCabe & Hinton (1990a):

River Mile	Station No.	Station Location	Grain Size	Number Taxa[b]	Mean Density (±1SD)/m² of Numerically Dominant Macrofauna (N=5)					
					Total Macrofauna	Oligochaetes	*Corbicula manilensis*	*Neomysis mercedis*	*Corophium salmonis*	Heleid Larvae
43.2	Total	Puget Is -Total			2,152±659	240±137	40±34	2±2	1,818±589	13±21
	1	Westport Ferry Dock	Sand	9	1,529±732	216±141	19±19	4±6	1,264±805	13±17
	2	Mouth-Westport Channel	Silt/Clay	7	2,858±578	305±243	25±9	---	2,413±715	---
	3	Mouth-Westport Channel	Sand	8	2,871±568	374±326	11±7	4±6	2,461±847	---
	4	Mouth-Westport Channel	Sand	9	1,674±514	288±189	95±105	2±5	1,279±310	2±5
	5	Puget Is. Ferry Dock	Sand	7	1,829±642	17±18	48±26	---	1,672±578	50±41

[a] Sampled in August 1989

[b] Represents the total number of taxa found in 5 grabs.

and southeast of the groin at Beaver. None of these areas have been sampled. No major point sources are located within this river segment.

River Segment 2C (Beaver to Cowlitz River). Two of the studies reviewed contained sampling stations in river segment 2C. McCabe et al. (1990) sampled benthic assemblages along the shoreline of Cottonwood Island during 1987 and 1988. The U.S. COE constructed 15 pile dikes around the island between 1925 and 1969. By 1987, most of the dikes were in poor condition and needed reinforcement. The U S. COE proposed that seven of the pile dikes be replaced with rock groins (i.e., that rock be placed around the existing pile dikes). McCabe et al. (1990) conducted four surveys to assess short-term changes in benthic and demersal fish communities associated with rock groin construction between January and March 1988. Only the data from the July and September 1988 sampling dates, after rock groin construction, are analyzed in this report. In a second study, benthic assemblages at Jones Beach (RM 46.5 and 47.1) were sampled following a spill of 30,000 to 58,000 gallons of Bunker C (#6) fuel oil at RM 102.5 on June 27, 1978 (Blahm et al. 1980). Sediment samples were collected on July 12, 1978, at 28 sites downstream from the spill, including two sites in river segment 2C.

In the Cottonwood Island study, benthic assemblages at three shallow (1.8–4.9 m) and three deep (13.4–15.2 m) stations were sampled with a 0.1-mm van Veen grab (McCabe et al. 1990). Samples were rinsed on a 0.500-mm mesh screen before sorting. Six replicate grab samples were collected per station; five were used to characterize benthic assemblages. The sixth was analyzed for sediment grain size and percent organic carbon (TVS). The sediments at Cottonwood Island were coarse sands and gravels with 0.6 percent TVS.

The mean number of taxa per sample was higher during July than December at all six stations along the shoreline of Cottonwood Island (Table 13). The total number of macrofauna per station also decreased, from $4,011 \pm 1,091/m^2$ in July to $1,646 \pm 1,129/m^2$ in December. The amphipod *Corophium salmonis* was the dominant species in July samples, followed by oligochaetes and heleid larvae. All three taxa had decreased in abundance by December. The Asian clam, *Corbicula manilensis*, showed the opposite trend; *Corbicula* density increased between July and December. Some taxa were found only in July samples. These included the polychaete *Neanthes limnicola*, the mysid crustacean *Neomysis mercedis*, and an unidentified species of *Daphnia* (McCabe et al. 1990).

A 0.1-m^2 Ponar dredge was used to collect samples near Jones Beach (RM 46.5 and 47 1) for the Columbia River oil spill study (Blahm et al. 1980). Samples were rinsed on a 0.595-mm

TABLE 13 SUMMARY OF BENTHIC INFAUNA SAMPLING STATIONS AND COMMUNITY STRUCTURE IN COLUMBIA RIVER SEGMENT 2C

McCabe et al. (1990):

River Mile	Date	Station Number/ Location	Grain Size	Number Taxa*	Mean Density (±1SD)/m² of Numerically Dominant Macrofauna (N=5)				
					Total Macrofauna	Oligochaetes	*Corbicula manilensis*	*Corophium salmonis*	Heleid Larvae
69	July 88	Cottonwood Island - Overall Mean		16	4,911±1,091	498±515	127±82	3,011±785	918±146
	July 88	CW-11	Sand	19	5,450±2,495	225±118	71±39	3,912±1,831	903±505
	July 88	CW-21	Sand	14	5,569±2,618	67±51	128±99	3,387±1,401	867±292
	July 88	CW-12	Sand	17	6,506±1,978	1,504±1,044	61±32	3,805±1,221	985±202
	July 88	CW-22	Sand	15	3,780±1,372	473±283	281±151	2,113±891	802±323
	July 88	CW-13	Sand	14	3,980±1,844	445±479	80±26	2,480±1,115	777±506
	July 88	CW-23	Sand/Gravel	17	4,108±1,033	275±221	139±99	2,369±727	1,176±193
	Dec 88	Cottonwood Island - Overall Mean			1,646±1,129	244±244	535±896	616±773	157±105
	Dec 88	CW-11	Sand	14	2,407±3,052	105±78	92±120	2,079±2,850	61±76
	Dec 88	CW-21	Sand	9	817±377	36±18	464±339	132±86	137±86
	Dec. 88	CW-12	Sand	11	1,514±1,123	321±159	97±59	861±1,005	105±108
	Dec. 88	CW-22	Sand	11	3,545±4,213	683±581	2,337±4,358	27±44	336±436
	Dec. 88	CW-13	Sand	9	924±132	265±92	32±20	357±110	223±110
	Dec 88	CW-23	Gravel	12	666±600	53±94	187±165	242±232	80±114

* Represents the total number of taxa found in 5 grabs.

Blahm et al. (1980):

River Mile	Date	Station Number/ Location	Grain Size	Mean Density (±1SD)/m² of Numerically Dominant Macrofauna (N=5)					
				Total Macrofauna	Amphipods	Oligochaetes	Bivalves	Diptera	Cladocera
46 5	July 78	14/Jones Beach	Sand	2,000	1,830	5	95	60	10
47 1	July 78	13/Jones Beach	Sand	155	75	--	50	25	5

mesh screen before sorting. Sediments collected at these two locations were medium to coarse sands with approximately 0.7 percent TVS. Two weeks after the spill, on July 12, 1978, benthic assemblages at Jones Beach were dominated by amphipods, bivalves, and diptera (see Table 13).

Benthic assemblages at Cottonwood Island can be compared with those sampled ten years earlier at Jones Beach only at the level of major taxonomic groups. Amphipods, bivalves, and dipteran larvae dominated the assemblages sampled in both studies. Although samples collected for the oil-spill study were rinsed on a screen with a slightly larger mesh than those collected for the sturgeon habitat study, this difference in methods should not be sufficient to bias the dominance of the major taxa collected.

River segment 2C encompasses 18.5 mi of the freshwater zone of the river, from Beaver to the mouth of the Cowlitz River. Dominant species *Corophium salmonis*, *Corbicula manilensis*, oligochaetes, and heleid larvae were similar to those in river segment 2A. A number of estuarine taxa which were abundant in river segment 1C were absent or rare in 2C and further upstream. These include the polychaete *Neanthes limnicola*, the amphipod *Eohaustorius estuaries*, and the mysid *Neomysis mercedis*. In segment 2C, depositional areas occur at the west end of Bradbury Slough, the east end of Hump Island, north of Dibblee Point, near the pier in the vicinity of the Reynolds and Weyerhaeuser plants, the northwest corner of the anchorage area, and at the south end of Carroll Channel. Major point sources occur at the Cowlitz County Regional Sewer Treatment Plant, Weyerhaeuser Paper, and Reynolds Metals Company. Within this river segment, samples of benthic invertebrates have been collected only at Cottonwood Island and at Jones Beach.

2.3.2.3 Data Summary: River Segment 3

River Segment 3A (Cowlitz River to Lewis River). Two of the studies reviewed contained sampling stations in river segment 3A. The NOAA sturgeon habitat study (McCabe and Hinton 1990b) included two stations at RM 75, near Kalama, and three stations at River Mile 79, just downstream from Martin Island. Samples were collected during April and September, 1988 and 1989. Only the data collected during 1988 are summarized in this report. The Columbia River oil spill study (Blahm et al. 1980) described the effects of an accidental release of 30,000-58,000 gallons of Bunker C (#6) fuel oil at RM 102.5 on June 27, 1978. Samples were collected near Kalama, Washington, several weeks after the spill (July 12, 1978), at RM 76.4, 76.5, and 77.0.

The NOAA sturgeon study describes benthic assemblages sampled near the Washington and Oregon shorelines of the Lower Columbia River at RM 75 and near the Washington and Oregon shorelines and midchannel at RM 79 (McCabe and Hinton 1990b). Samples were collected with a 0.1-m^2 van Veen grab and rinsed over a 0.500-mm mesh screen. Sediments collected at both River Mile 75 and 79 were coarse sands with <1 percent silt/clay and up to 18 percent gravel. Concentrations of TVS were <1 percent at all sites sampled within this river segment.

At RM 75, on both sides of the river, *Corbicula manilensis* and *Corophium salmonis* appeared to increase in abundance between April and September 1989 (Table 14). Oligochaetes were abundant only in samples collected closer to the Washington side of the channel. A decline in the abundance of heleid larvae contributed to a decrease in the total number of macrofauna at sites sampled on the Washington side. Similar trends in macrofaunal abundance were observed at sites sampled on both sides of the river at RM 79. *Corbicula* and *Corophium* abundances increased over summer while heleid larvae declined. Oligochaetes were abundant only on the Washington side of the river. Samples collected mid-channel differed by a small increase in the abundance of heleid larvae between the April and September sampling periods.

Benthic assemblages were sampled near Kalama, Washington, for the Columbia River oil spill study using a 0.1-m^2 Ponar dredge (Blahm et al. 1980). Samples were rinsed over a 0.595-mm mesh screen before sorting. No description of replication of samples at dredge sites is given. Sediments at these sites were coarse sands with 0.6-1.3 percent TVS. Bunker C fuel oil was detected in sediments from all three stations. Amphipods dominated benthic assemblages at RM 76.5 and 77.0 (see Table 14). Bivalves and dipterans were also abundant at all three sampling sites.

Benthic assemblages sampled in the oil-spill study can be compared with those sampled 11 years later during NOAA's sturgeon habitat study only on the scale of major taxonomic groups. Amphipods dominated the samples collected during the oil spill study while bivalves were more important in samples taken in 1989. Although samples collected for the oil-spill study were rinsed on a slightly larger mesh screen than those collected for the sturgeon habitat study, this difference in methods should not be sufficient to bias the dominance of the major taxa collected.

River segment 3A encompasses 15.5 miles of the freshwater zone of the lower Columbia River, between the mouths of the Cowlitz and Lewis rivers. Dominant macrofauna were typical of those observed elsewhere in the freshwater zone (i.e., *Corophium salmonis, Corbicula manilensis,* oligochaetes, and heleid larvae). Total densities of macrofauna were typically an order

TABLE 14. SUMMARY OF BENTHIC INFAUNA SAMPLING STATIONS AND COMMUNITY STRUCTURE IN COLUMBIA RIVER SEGMENT 3A

McCabe & Hinton (1990b):

River Mile	Date	Station Number/ Location	Grain Size	Mean Density (±1SD)/m² of Numerically Dominant Macrofauna (N=10)				
				Total Macrofauna	Oligochaetes	*Corbicula manilensis*	*Corophium salmonis*	Heleid Larvae
75	April 89	75-1/WA Shoreline	Sand	663±342	56±61	48±44	2±4	489±312
	Sept 89	75-1/WA Shoreline	Sand	550±409	61±68	100±99	49±50	326±328
	April 89	75-2/OR Shoreline	Sand	148±118	---	21±37	7±10	99±92
	Sept. 89	75-2/OR Shoreline	Sand	760±414	---	303±292	40±62	401±246
79	April 89	79-1/WA Shoreline	Sand	902±837	238±471	18±15	2±4	546±658
	Sept. 89	79-1/WA Shoreline	Sand	1,295±775	464±386	392±461	79±141	322±188
	April 89	79-2/Mid-channel	Sand	262±216	---	26±29	1±3	219±198
	Sept. 89	79-2/Mid-channel	Sand	781±453	---	366±398	41±21	341±263
	April 89	79-3/OR Shoreline	Sand	68±38	---	6±7	1±3	49±38
	Sept 89	79-3/OR Shoreline	Sand	1,146±619	---	332±377	756±285	37±26

Blahm et al. (1980):

River Mile	Date	Station Number/ Location	Grain Size	Mean Density (±1SD)/m² of Numerically Dominant Macrofauna (N=5)				
				Total Macrofauna	Amphipods	Bivalves	Diptera	Polychaetes
77 0	July 78	10/WA Shoreline	Sand	2,795	2,295	175	305	20
76.5	July 78	11/Mid-channel	Sand	2,570	2,115	195	255	--
76.4	July 78	12/OR Shoreline	Sand	375	95	145	80	55

of magnitude lower than those observed in river segment 2C. In segment 3A, depositional areas are located at the downstream ends of Sandy, Goat, Martin, and Sauvie Islands and an unnamed island at RM 85. Major point sources occur at the City of St. Helens, Chevron Chemical Co., Kalama Chemical Co., and the Trojan Nuclear Power Plant. Downstream portions of the Ridgefield National Wildlife Refuge and the State of Oregon's Sauvie Island Wildlife Area lie within this area. To date, benthic assemblages have been sampled only between RM 75 and 79. No ongoing studies are being conducted in this area.

River Segment 3B (Lewis River to Willamette River). Two of the studies reviewed contained sampling stations in river segment 3B. The NOAA sturgeon habitat study (McCabe and Hinton 1990b) included two stations at RM 88, off the mouth of the Lewis River, and three stations at RM 95, adjacent to Sauvie Island. Samples were collected during April and September, 1988 and 1989. Samples were collected on May 15, 1978 six weeks before the Columbia River oil spill at an area just downstream (RM 102 to 99) in conjunction with a pre-dredge and disposal study for Portland Harbor. Post-spill samples were taken on July 12, 1978, at 11 sites in the same area.

The NOAA sturgeon study describes benthic assemblages sampled near the Washington and Oregon shorelines at RM 88 and near the Washington and Oregon shorelines and midchannel at RM 95 (McCabe and Hinton 1990b). Samples were collected with a 0.1-m^2 Van Veen grab and rinsed over a 0.500-mm mesh screen. Sediments collected at RM 88 were predominately sands with <1 percent silt/clay and 1 percent TVS. However, some of the samples collected near the Oregon shore of the river during September 1989 apparently contained large amounts of fine particles; these sediments were described as 10-99 percent sand and <1-90 percent silt/clay.

At RM 88, on the Washington side of the river, total numbers of macrofauna increased from 206/m^2 during April to 1,265/m^2 during September, 1989. Large numbers of *Corophium salmonis* were collected on the latter date (Table 15). A smaller increase in the abundance of *Corophium* in samples collected closer to the Oregon shoreline raised total macrofaunal abundance from 372/m^2 in April to 637/m^2 in September.

Sediments collected at RM 95 were sands with <1 percent silt/clay and 1 percent TVS. The authors' estimate of total macrofaunal abundance for samples collected near the Washington shoreline during April 1989 was inflated by the presence of an average of 7,359 eulachon eggs/m^2 (see Table 15). Subtracting the number of eulachon eggs from the estimate of mean macrofaunal density, total numbers of macrofauna fell from approximately 1,767/m^2 during April to 983/m^2 during September 1989. The abundances of *Corbicula* and heleid larvae

TABLE 15. SUMMARY OF BENTHIC INFAUNA SAMPLING STATIONS AND COMMUNITY STRUCTURE IN COLUMBIA RIVER SEGMENT 3B
(Page 1 of 2)

McCabe & Hinton (1990b):

River Mile	Date	Station Number/ Location	Grain Size	Mean Density (±1SD)/m² of Numerically Dominant Macrofauna (N=10)					
				Total Macrofauna	Oligochaetes	*Corbicula manilensis*	*Corophium salmonis*	Heleid Larvae	Eulachon Eggs
88	April 89	88-1/WA Shoreline	Sand	206±205	27±22	14±21	62±137	100±107	---
	Sept. 89	88-1/WA Shoreline	Sand	1,265±534	16±29	105±77	1,059±493	63±40	---
	April 89	88-2/OR Shoreline	Sand	372±367	---	72±69	5±7	275±338	---
	Sept 89	88-2/OR Shoreline	Sand	637±484		103±52	391±540	47±59	---
95	April 89	95-1/WA Shoreline	Sand	9,126±15,751	751±920	699±848	33±49	271±285	7,359±16,331
	Sept. 89	95-1/WA Shoreline	Sand	983±741	670±516	174±213	41±27	88±126	---
	April 89	95-2/Mid-channel	Sand	308±232	---	104±108	19±20	171±182	---
	Sept 89	95-2/Mid-channel	Sand	635±400	---	183±271	13±13	383±207	---
	April 89	95-3/OR Shoreline	Sand	600±330	22±18	98±81	134±112	337±310	---
	Sept. 89	95-3/OR Shoreline	Sand	1,518±709	12±13	116±126	1,177±930	180±228	---

TABLE 15 SUMMARY OF BENTHIC INFAUNA SAMPLING STATIONS
AND COMMUNITY STRUCTURE IN COLUMBIA RIVER SEGMENT 3B
(Page 2 of 2)

Blahm et al. (1980):[a]

River Mile	Date	Station Number/ Location	Grain Size	Mean Density (± 1SD)/m² of Numerically Dominant Macrofauna (N=5)					
				Total Macrofauna	Amphipods	Oligochaetes	Bivalves	Diptera	Polychaetes
99.6	July 78	9/Wash. side	Medium sand	2,720	2,620	---	100	---	---
100.2	July 78	8/Oregon side	Medium sand	630	520	---	70	40	---
100.9	July 78	7/Wash side	Fine sand	445	265	---	150	30	---
101 6	July 78	6/Wash side	Medium sand	525	470	5	15	5	30
101.9	July 78	5/Ore Kelly Pt	Medium sand	1,135	1,025	5	30	35	35
102 1	July 78	4/Ore. Kelly Pt.	Medium sand	200	125	---	10	---	65
102.3	July 78	3/Ore. Kelly Pt.	Very fine sand	380	25	15	10	325	5
105	July 78	2/Ore. side (ref)	Fine sand	208	175	---	20	3	10
105	July 78	1/Wash side (ref)	Medium sand	815	430	---	10	325	50

[a] A 0.595 mm sieve used.

declined over summer. This result contrasts with that observed at RM 88 where the abundance of *Corbicula* in samples collected near the Washington shore increased over the same period.

Samples collected mid-channel at RM 95 contained relatively low densities of macrofauna during April, although the abundances of *Corbicula manilensis* and heleid larvae increased by September (see Table 15). Closer to the Oregon shoreline, the abundances of *Corbicula* and *Corophium salmonis* increased between April and September. This result corresponds with changes observed in samples collected near the Oregon shoreline at RM 88.

Gut contents of white sturgeon collected at RM 95 during May–October 1988 were examined (McCabe and Hinton 1990b). Prey of size class I (350 mm FL) and size class II (351–725 mm FL) fish were primarily *Corophium salmonis*. Eulachon eggs were also important prey of size class II sturgeon collected during May and June.

A 0.1-m^2 Ponar dredge was used to collect samples for the Columbia River oil spill study (Blahm et al. 1980). Sediments ranged from very fine sand with 26.3 percent silt/clay and 3.5 percent TVS (just upstream from Kelly Point, above the mouth of the Willamette River) to medium sand with <1 percent silt/clay and TVS (just downstream from the mouth of the Willamette River) (unpubl. data, National Marine Fisheries Service, Hammond, OR). Bunker C fuel oil was found in sediments from all nine stations. However, the authors report that levels of Bunker C were low and may represent the residue of minor spills that frequently occur throughout the area (Blahm et al. 1980). Benthic assemblages sampled 2.5 wk before the oil spill were dominated by bivalves, dipterans, and amphipods (Table 16). Although the mean estimate of amphipod abundance increased 20 times between the pre- and post-spill sampling dates, high coefficients of variation calculated for the post-spill data rendered detection of effects of the spill unlikely. Examining the post-spill data alone, elevated levels of silt/clay (26.3 percent) and TVS (3.5 percent) at Station 3 were associated with lower numbers of amphipods and higher numbers of oligochaetes.

Benthic assemblages sampled in the oil-spill study during 1978 can be compared with those sampled in NOAA's sturgeon habitat study only on the scale of major taxonomic groups. Amphipods, bivalves, dipteran larvae, and oligochaetes dominated both taxonomic lists. Although samples collected for the oil-spill study were rinsed on a screen with a slightly larger mesh than those collected for the sturgeon habitat study, this difference in methods is not sufficient to bias a comparison of the dominance of the major taxa collected.

TABLE 16 COMPARISON OF BENTHIC INVERTEBRATE NUMBERS TAKEN WITH A 0 1 m^2 PONAR DREDGE AT PORTLAND HARBOR, CRM 99 TO 105, MAY 1978 AND JULY 1978, PRIOR TO AND FOLLOWING THE TOYOTA MARU #10 OIL SPILL[a]				
	<u>May 15, 1978</u> Average per m^2 20 sample sites	<u>July 12, 1978</u> Average per m^2 9 sample sites	SD	CV
Nematoda	1.4	--	--	--
Polychaeta	--	21.7	±24 4	110%
Oligochaeta	16 3	2 8	±5.1	180%
Bivalvia	164.9	46.1	±50.1	110%
Gastropoda	1.1	--	--	--
Amphipoda	32.3	628.3	±802 7	130%
Cladocera	15 3	0.6	±1 7	280%
Copepoda	24.2	--	--	--
Diptera	73.2	85.0	±137 1	160%
Arachnida	0.3	0.6	--	--
Other	0.3	--	--	--
TOTAL	329.7	784.5		

[a] Blahm et al. 1980.

Amphipods, bivalves, oligochaetes, and heleid larvae dominated benthic infaunal assemblages at all sites in river segment 3B, as in Segments 2C and 3A. These taxa are representative of the freshwater zone of the lower Columbia River estuary (Holton et al. 1984). Total macrofaunal densities typically were <1,000/m^2 in river segment 3B and thus were comparable to those in 3A. Higher abundances (>1,000/m^2) were typically associated with local concentrations of *Corophium salmonis*.

River segment 3B is topographically and hydrodynamically complex, with a myriad of quiescent shallow-water areas. Depositional areas for sediments include the downstream ends of Bachelor Island Slough and Multnomah Channel, Fishtrap Shoal, and Hewlett Point. Particularly near the Ridgefield National Wildlife Area and the State of Oregon's Sauvie Island Wildlife Area, shallow-water areas provide feeding habitat for fishes, waterfowl, and shorebirds. Despite the concentration of industrial activity just upstream in river segment 4A, and the presence of a major point source at the Salmon Creek Sewage Treatment Plant, few data on benthic assemblages in these depositional areas are available. No ongoing studies are being conducted in this segment of the lower Columbia River.

2.3.2.4 Data Summary: River Segment 4

River Segment 4A (Willamette River to Sandy River). Three of the studies reviewed contained sampling stations in river segment 4A (Tables 17 and 18). The NOAA sturgeon habitat study (McCabe and Hinton 1990b) included two stations at RM 114, adjacent to Government Island. Samples were collected during April and September 1988 and 1989. Only data collected during 1989 are included in this analysis. The Columbia River Impact Investigation (Century West Engineering Corporation 1989) described samples collected along a gradient from a bulk cargo loading facility at the Port of Vancouver. This study was to evaluate the impact of a copper concentrate spill on the benthic community. Samples were taken during December 1988. Benthic assemblages at five sampling sites within the area of affected sediments were compared to those at a reference site 2.7 km (1.7 mi) upstream. The third study was an EIS prepared by Portland General Electric for the West Hayden Island Industrial Park (PGE 1987). Samples were collected at six stations, three along the north and three along the south shore of Hayden Island, during April, May, and July 1984.

The NOAA sturgeon habitat study describes benthic samples collected near the Washington and Oregon shorelines at RM 114 (McCabe and Hinton 1990b). Samples were collected with a 0.1-m^2 van Veen grab and rinsed over a 0.500-mm mesh screen. Sediments collected closer to the Washington shore were composed of sand and gravel with <1 percent TVS. Total macrofaunal numbers remained approximately the same between April and December 1989 (see Table

TABLE 17. SUMMARY OF BENTHIC INFAUNA STATIONS AND COMMUNITY STRUCTURE IN COLUMBIA RIVER SEGMENT 4A
(Page 1 of 2)

McCabe & Hinton (1990b) Mean Densities ($\pm$1SD)/m^2 of Numerically Dominant Macrofauna (n = 10)

River Mile	Date	Station Location	Grain Size	Total Macrofauna	Oligochaetes	Corbicula manilensis	Corophium salmonis	Heleid larvae
114	April 89	114-1/WA Shoreline	Sand & Gravel	501±257	2±4	156±169	3±7	275±155
	September 89	114-1/WA Shoreline	Sand & Gravel	401±190	15±20	102±128	14±28	256±139
	April 89	114-2/OR Shoreline	Sand	219±170	--	48±34	--	155±158
	September 89	114-2/OR Shoreline	Sand	470±280	--	36±23	--	408±269

Century West Engineering Corp. (1989a) Mean Densities ($\pm$1SD)/m^2 of Major Taxa (n = 3)

River Mile	Date	Station Location (rel. to bulk loading facility)	Grain Size	Total Macrofauna	Oligochaetes	Bivalues	Amphipods	Vol. of Organic Debris (mL)
108	December 88	640 m Downstream	Fine Sand	1,631±159	1,309±303	30±28	200±63	117±31
	December 88	520 m Downstream	Fine Sand	6,176±430	4,855±649	503±323	139±121	192±38
	December 88	370 m Downstream	Fine Sand	5,878±1,212	4,970±1,241	485±353	97±38	83±47
	December 88	80 m Downstream	Fine Sand	1,091±520	727±495	18±1	121±64	55±28
	December 88	28 m Upstream	Medium Sand	1,169±1,092	879±1,163	91±83	67±38	18±13
	December 88	2.7 km Upstream	Fine Sand	1,073±608	346±395	333±290	42±28	27±12

TABLE 17. SUMMARY OF BENTHIC INFAUNA STATIONS AND COMMUNITY STRUCTURE IN COLUMBIA RIVER SEGMENT 4A
(Page 2 of 2)

PGE (1987)

River Mile	Date	Station No./ Location	Depth (m)	Grain Size	Total Macrofauna per m^2 (n = 3)
105	Apr - Jan 84	South Shore-1	3.1	Coarse Sand	1,133±737
			16.1	Coarse Sand	1,312±764
			12.2	Silt & Sand	109[c]
	Apr - Jan 84	South Shore-2	3.1	Coarse Sand	1,559±598
			6.1	Silt & Detritus	2,513±1,045
			12.2	Coarse Sand	326
	Apr - Jan 84	South Shore-3	3.1	Silt & Detritus	2,080±587
			6.1	Silt & Detritus	1,855±743
			12.2	Coarse Sand	1,737±1,039
	Apr - Jan 84	North Shore-4	3.1	Coarse Sand	1,280
			6.1	Silt & Detritus	1,655
			12.2	Coarse Sand	1,060
	Apr - Jan 84	North Shore-5	3.1	Fine Sand	1,263±942
			6.1	Fine Sand	913±1,053
			12.2	Silt & Sand	617±760
	Apr - Jan 84	North Shore-6	3.1	Silt & Sand	597±463
			6.1	Coarse Sand	567±396
			12.2	Sand & Cobbles	143±132

[a] A 0.055 m^2 ponar grab and 0.297 μm sieve was used

[b] A 0.023 m^2 petite ponar grab and 0.6 μm sieve was used.

[c] Based on replicate samples but no estimate of variance reported

TABLE 18. MEAN ABUNDANCES OF BENTHIC INFAUNA BY LOCATION AND WATER DEPTH NEAR HAYDEN ISLAND (RM 105)[a]		
Depth (m)	Location Hayden Island	Total No /m^2 (n = 18)
3 1	South Shore	1,591±693
	North Shore	1,018±685
6.1	South Shore	1,893±910
	North Shore	969±760
12.2	South Shore	869±1,015
	North Shore	550±595

[a] PGE 1987.

17). Dominant species included heleid larvae and the Asian clam, *Corbicula manilensis*. Sediments collected closer to the Oregon shore were sands with <1 percent TVS. Total macrofauna increased from 219/m^2 during April to 470/m^2 during September. As at stations sampled closer to the Washington shore, heleid larvae and *Corbicula* dominated the macrofauna at stations on the Oregon side of the channel.

Sediments collected near the Port of Vancouver's bulk cargo loading facility and at the upstream reference stations were primarily fine sands (Century West Engineering Corporation 1989). Samples were collected with a 0.055-m^2 Ponar grab and were rinsed on a 0.297-mm screen. Total macrofaunal numbers averaged 2,900 ± 2,906/m^2 across the five stations within the area affected by the copper concentrate spill (see Table 17). Total numbers of macrofauna were higher at stations 370–640 m downstream from the bulk loading facility than at stations in the immediate vicinity of the facility or at the reference station 2.7 km (1.7 mi) upstream. Higher numbers of macrofauna were associated with higher numbers of oligochaetes and higher volumes of "organic debris". Oligochaetes, with short life cycles and high fecundity (number of eggs per female), are rapid colonizers and typically dominate macrofaunal communities in soft, unstable substrates. Whether the abundance of oligochaetes at stations downstream from the bulk loading facility is related to the copper concentrate spill, to other activities at the bulk loading facility, or to unrelated factors, is unclear from the data presented. Unidentified clams, amphipods, and chironomids were also abundant in samples collected within the region of affected sediments and upstream at the reference station.

Sediments collected in the vicinity of Hayden Island (PGE 1987) varied in texture from sand mixed with pebbles and cobbles to silt with large amounts of detritus. Samples were collected with a 0.023-m^2 "petite ponar grab." Estimates of macrofaunal density for samples obtained with a petite ponar grab do not differ significantly from estimates for samples collected with a regular Ponar grab sampler, sampling area = 0.055 m^2 (Steve Bullock, 14 August 1991, personal communication). Sediments collected during this study were rinsed on a 0.600-mm screen. Averaged across all three sampling months, total numbers of macrofauna at the six stations ranged from 597 to 2,080/m^2 at 3.1 m, 567 to 2,513/m^2 at 6.1 m, and 179 to 1,737/m^2 at 12.2 m (see Table 17). Densities appeared to be higher at stations characterized by "silt and detritus" than in coarser sediments. In general, macrofauna were more abundant at 3.1 and 6.1 m than at the deeper stations and, at a given depth, were more abundant on the south shore than on the north side of Hayden Island (Table 18).

Benthic populations in river segment 4A are not well characterized. Macrofauna were identified to species only in the NOAA sturgeon habitat study. The Asian clam, *Corbicula manilensis*, and heleid larvae dominated assemblages at RM 114. *Corophium salmonis*, a numerical dominant in samples from river segments 1C–3B, was present at low densities ($<15/m^2$) at this location. Macrofauna were not identified to species in the Columbia River Impact Investigation. Only total numbers of macrofauna were reported in the Hayden Island EIS. Thus, it is difficult to compare results from river segment 4A with those from other segments of the study area

Depositional areas for sediments in river segment 4A are located at the west end of Hayden Island, in North Portland Harbor, north of Tomahawk Island (on Tomahawk Bar), north of the Portland Airport (in the Tidewater Barge area), at the west ends of Lemon and Lady Islands, east of Lady Island, and east–southeast of Government Island. Major point sources occur at Portland and Gresham, OR, Vancouver, WA, ALCOA in Vancouver, and at the James River II mill in Camas, WA. Aside from the copper concentrate impact study at the Port of Vancouver, little is known of the affects of human activity on benthic communities in this industrialized section of the river. At present, ongoing studies in river segment 4A are being conducted by Young in the vicinity of the James River, Inc. mill at Camas, WA. These data are not yet available.

River Segment 4B (Sandy River to Bonneville Dam). The only data on benthic communities available for the segment of the Columbia River between Sandy River and the Bonneville Dam is that presented in NOAA's white sturgeon habitat study (McCabe and Hinton 1990b). Samples were collected mid–channel and closer to the Oregon shore at RM 127 and mid–channel and closer to both the Washington and Oregon shores at RM 131. Samples were taken with a $0.1\text{-}m^2$ Van Veen grab and were rinsed on a 0.500–mm mesh screen. Ten replicate samples were taken per site per sampling date.

Samples were collected closer to the Washington shore only at RM 131. Sediments collected during April were well sorted sand whereas some of the samples collected during September contained more gravel. Macrofaunal numbers, predominantly oligochaetes, *Corbicula manilensis*, *Corophium salmonis*, and heleid larvae increased from $194/m^2$ in April to $974/m^2$ in September (see Table 19).

Sediments collected mid–channel were well–sorted sands with <1 percent TVS. Total numbers of macrofauna appeared to increase from 59 to $434/m^2$ at RM 127 but remained approximately constant at River Mile 131 (see Table 19). The increase at RM 127 was primarily due to an increase in the number of heleid larvae. *Corophium salmonis* increased in abundance at RM 131.

TABLE 19. SUMMARY OF BENTHIC INFAUNA SAMPLING STATIONS AND COMMUNITY STRUCTURE IN COLUMBIA RIVER SEGMENT 4B

McCabe & Hinton (1990b):

River Mile	Date	Station Number/ Location	Grain Size	Mean Density ($\pm$1SD)/m^2 of Numerically Dominant Macrofauna (N=10)				
				Total Macrofauna	Oligochaetes	*Corbicula manilensis*	*Corophium salmonis*	Heleid Larvae
127	April 89	127-2/Mid-channel	Sand	59$\pm$37	---	---	20$\pm$19	24$\pm$17
	Sept. 89	127-2/Mid-channel	Sand	434$\pm$235	---	---	10$\pm$9	315$\pm$175
	April 89	127-3/OR Shoreline	Sand/gravel	682$\pm$720	290$\pm$433	35$\pm$56	---	343$\pm$341
	Sept. 89	127-3/OR Shoreline	Sand/gravel	1,638$\pm$1,365	443$\pm$644	648$\pm$998	---	506$\pm$278
131	April 89	131-1/WA Shoreline	Sand	194$\pm$79	6$\pm$11	68$\pm$55	5$\pm$7	105$\pm$67
	Sept. 89	131-1/WA Shoreline	Sand/gravel	974$\pm$398	168$\pm$111	302$\pm$233	80$\pm$93	392$\pm$216
	April 89	131-2/Mid-channel	Sand	252$\pm$153	15$\pm$17	52$\pm$44	54$\pm$30	108$\pm$107
	Sept. 89	131-2/Mid-channel	Sand	374$\pm$150	19$\pm$33	26$\pm$22	198$\pm$185	88$\pm$110
	April 89	131-3/OR Shoreline	Sand	2,137$\pm$1,090	1,078$\pm$1,081	120$\pm$53	766$\pm$270	---
	Sept. 89	131-3/Or Shoreline	Sand	643$\pm$253	261$\pm$124	34$\pm$56	205$\pm$188	---

Samples collected closer to the Oregon shore were poorly sorted sand and gravel at RM 127 and well sorted sand at RM 131. At RM 127, the total number of macrofauna increased from $682/m^2$ during April to $1,638/m^2$ during September (see Table 19). The increase in numbers was dominated by the Asian clam, *Corbicula manilensis*. In contrast, total macrofauna at RM 131 declined from $2,137/m^2$ to $643/m^2$ at RM 131. The largest decreases were recorded for oligochaetes and *Corophium salmonis*.

Gut contents of white sturgeon collected during 1988 at RM 131 were examined. The prey of size class I sturgeon (<350 mm fork length) were primarily *Corophium salmonis* (McCabe and Hinton 1990b). However, the eggs of eulachon were consumed in large numbers during May and June and the mysid shrimp *Neomysis mercedis* was important during July and August. The guts of size class II sturgeon (351–725 mm FL) contained eulachon eggs and *Corophium* during May and June, *Corbicula* during May through August, and *Corophium* and chironomid larvae during September and October.

As for river segment 4A, macrofaunal populations in this portion of the lower Columbia River are not well described. Taxa that dominated samples from the sturgeon habitat study, however, are typical of those observed in other freshwater segments of the river (2A–3B).

Depositional areas for sediments in this portion of the study area are located north of the west end of Reed Island, east-southeast of Phoca Rock, east of Onion Rock, and northwest of Pierce Island in the Pierce Island National Wildlife Refuge. At present, no data for invertebrate assemblages in any of these areas are available. No ongoing studies are known for this river segment nor are major point sources located within it. However, much of the land draining into the river is used for agriculture, a potential pollutant source.

2.3.3 Data Synthesis and Conclusions

The model of macrofaunal distributions described by Holton et al. (1984) for the Columbia River estuary is supported by the data reviewed in this report. Faunal assemblages within the study area appear to be structured by salinity and the degree to which a particular habitat is protected from wind stress and current speed. A fauna typical of freshwater environments was observed in river segments 1C–4B (Table 20). The list of dominant species remained relatively constant over this 127.5 mile stretch of the study area. River segments 1A and 1B were dominated by marine and euryhaline transition zone species, respectively.

Relatively few samples have been taken in depositional habitats in the freshwater zone of the study area. Where data from depositional environments are available, high densities of oligochaetes appear to be associated with fine-grained sediments and concentrations of organic

TABLE 20. SUMMARY OF RESULTS FROM PREVIOUS BENTHOS STUDIES IN THE LOWER COLUMBIA RIVER

Salinity Zone	River Segment	Habitat	Dominant Species	Total Macrofaunal Abundance
Marine	1A, 1B	Main Channel	Tubellaria Nematodes Oligochates Amphipods Copepods	<5,000/m^2
		Unprotected flats	Nematodes Oligochates *Corophuim sallmonis* *Eohaustorius estuarius*	<5,000/m^2
		Protected flats	Oligochates *Hobsonia florida* *Pseudopolydora kempi* *Macoma balthica*	10,000-30,000/m^2[a]
Transition	1C, 2A	Channel	Oligochates *Corophium salmonis* Heleid larvae	<5,000/m^2
		Unprotected flats	Oligochates *Corophium salmonis* *Corbicula manilensis* *Neanthes limnicola* Ostracods Chironomid larvae	500-12,000/m^2[b]
		Protected flats	Nematodes Oligochates *Corophium salmonis*	>10,000-35,000/m^2
Freshwater	2C		Oligochates *Corophium salmonis* *Corbicula manilensis* Heleid larvae	<5,000/m^2
	3A-4B		Oligochates *Corophium salmonis* *Corbicula manilensis* Heleid larvae	<1,000/m^2

[a] Local concentrations of *C. salmonis* up to 80,000/m^2

[b] Local concentrations of *C. salmonis* up to 90,000/m^2

matter. This phenomenon has been described by other authors. For example, oligochaetes are abundant around a petroleum seep near Santa Barbara, California (Davis and Spies 1980) and in sewage-polluted rivers in India (Rao and Rao 1980) and Poland (Kaniewska-Prus 1983). Like polychaetes, however, the oligochaetes are a diverse taxonomic group that includes species with life histories that adapt them to rapid colonization and production in disturbed and organically enriched sediments. However, as seen in this review, these species respond to concentrations of natural organic materials as well as anthropogenic inputs. Thus, a high density of oligochaetes at a site is not necessarily an indicator of organic pollution.

The taxonomic composition of an oligochaete assemblage may be equally important in interpreting the significance of high abundances of this group. Assemblages in disturbed and organically enriched sediments may be characterized by low species richness compared to those at reference sites. An example is seen in the results of a study by Giani (1984) in the Riou Mort, a small French stream heavily polluted by industrial and domestic discharges. Unfortunately, the taxonomy of the Class Oligochaeta is incompletely described. None are identified to genus or species in any of the studies in this review. For this reason, and given the concerns expressed in the preceding paragraph, use of the presence of high densities of oligochaetes as an indicator of pollution must be approached with caution.

Based on the availability of data for this review, future data collection efforts in the Lower Columbia River should be concentrated in river segments 2B, 4A, and 4B, where little or no information has previously been obtained. More effort should be made to sample depositional environments in Segments 3B and 4A, just downstream from and including the heavily industrialized cities of Portland, Oregon, and Vancouver, Washington. Ideally, the stratified sampling design and multivariate analytical techniques used by Holton et al. (1984) can be employed to describe the Lower Columbia River study area as a whole, providing a powerful tool for describing the relationships between community composition and environmental parameters.

2.4 FISH COMMUNITIES

2.4.1 Data Selection and Review Methods

A diverse number of estuarine, euryhaline, anadromous, and resident freshwater fish species reside in the lower Columbia River. However, despite its size and importance as a major fisheries habitat, there is relatively little published information on fish assemblages and their ecological relationships. Many of these studies have been limited to the Columbia River estuary between the mouth and RM 45. The first comprehensive study of fish communities in the lower Columbia River estuary was conducted by Haertel and Osterberg (1967) who described the distribution of plankton, macroinvertebrates and demersal fish. The largest biological database on fish communities and their ecological relationships was produced under CREDDP. Ten studies were produced as part of this program which collected and analyzed biological, physical, and chemical data in 1980 and 1981. Of these studies, Bottom et al. (1984) and Frey et al. (1984) examined fish communities, larval fishes and zooplankton in the estuary between RM 0 and 45. Further analyses of the data collected under CREDDP were published by Simenstad et al. (1990a,b) and Bottom et al. (1990). McCabe et al. (1983) examined ecological relationship between salmonid and non-salmonid fish in the estuary. Jones et al. (1990) examined epibenthic communities in the estuary. A number of other studies examining specific areas or species, usually for dredging projects, have been conducted by Clairain et al. (1978), Durkin et al. (1981), and Hinton et al. (1990).

Fewer studies were found that examine fish communities in the freshwater riverine habitats between RM 45 and the Bonneville Dam. Dawley et al. (1986) studied the migrational characteristics and survival of juvenile salmonids in the lower Columbia River. An on-going study of the status and habitat requirements of white sturgeon below the McNary Dam is being conducted by state and federal agencies (Nigro 1990). NOAA's Estuarine Living Resources Project presents tables of relative abundance, along with spatial and temporal distribution for 30 species of fish and invertebrates in the lower Columbia River (Monaco et al. 1990). Demersal fishes and benthic invertebrates were examined between RM 46.5 and 78 (river segment 2) as part of a rock groin construction project (McCabe et al. 1990) and dredging project (Blahm et al. 1979). Limited sampling of fish also occurred after an oil spill in 1978 at RM 102 (river segment 3) (Blahm et al. 1980). Commercial fishery statistics are kept for the major commercial and recreational species (primarily salmonids and sturgeon) in the lower Columbia River below the McNary Dam by the Oregon Department of Fish and Wildlife, and the Washington Department of Fisheries (ODF&W and WDF 1989).

The diversity and abundance of fish in the lower Columbia River are enhanced by the presence of several habitat zones which include near ocean conditions at the mouth, tidal estuarine conditions prominent to about RM 15, a euryhaline transition zone, and freshwater riverine conditions. Within these habitat zones, the composition and distribution of fish communities are also affected by seasonal cycles in the migration and life history of the fishes and seasonal changes in river flow conditions and salinity patterns. The discussion of lower Columbia River fish communities is presented below and follows the four major habitat zones assembled for the study area. However, when appropriate, these zones are further divided into sub-zones to accommodate specific habitats utilized by fish communities in the river.

2.4.2 Review of Accepted Data

2.4.2.1 Data Summary: River Segment 1. The most diverse fish community assemblages are present in river segment 1, the estuarine zone of the lower Columbia River. This diversity is due to a larger number of sub-habitats within the estuary. Bottom et al. (1984, 1990) and Simenstad et al. (1990a) generally divide the estuary into three estuarine zones: Marine, Estuarine Mixing, and Tidal Fluvial. The Marine sub-zone begins at the mouth of the river and extends to RM 7. The Estuarine Mixing sub-zone extends from RM 8 to about RM 20 and the Tidal Fluvial sub-zone extends from RM 21 to RM 45.

In an extensive analysis of fisheries data collected throughout the Columbia estuary, Bottom et al. (1984) lists 75 species of anadromous, estuarine, and resident freshwater species in river segment 1 (Table 21). Although the maximum intrusion of ocean conditions occur only to RM 12, 46 of the 75 species observed are estuarine. Thirteen anadromous species and 16 freshwater resident species were also observed. Thirty-nine species were considered common (greater than 10 individuals per species collected over 3 sampling periods) (Table 22). The largest number of species and the greatest densities of fish were observed in the Estuarine Mixing sub-zone, followed by the Marine sub-zone, and lastly the Tidal Fluvial sub-zone. Anadromous and freshwater species dominated in the Tidal Fluvial sub-zone.

The most abundant species of fish in river segment 1 (greater than 5,000 individuals per species collected over 3 sampling periods) share either estuarine resident or anadromous life histories. The most abundant anadromous species are American shad, chinook salmon and longfin smelt. Abundant estuarine species are northern anchovy, Pacific herring, Pacific staghorn sculpin, Pacific tomcod, shiner perch, starry flounder, surf smelt, and three spine stickleback. All of the anadromous species and five of the eight estuarine species were observed in the Marine, Estuarine Mixing, and Tidal Fluvial Zones. Pacific herring, northern anchovy, and Pacific tomcod were not observed in the Tidal Fluvial sub-zone which is dominated by freshwater. All species were observed during all seasons of the year.

Seven other species of fish were of secondary abundance (between 1,000 and 3,000 individuals per species collected over 3 sampling periods), representing estuarine, anadromous and freshwater life histories. Coho salmon and eulachon are the anadromous species and were observed in all three estuarine sub-zones. English sole, Pacific sand lance, and whitebait smelt are estuarine; each of these species were observed throughout the Marine and Estuarine Mixing sub-zones. Prickly sculpin and peamouth are the two freshwater resident species and were observed in the Estuarine Mixing and Tidal Fluvial sub-zones. These were the two most common freshwater resident species observed in river segment 1 (Bottom et al. 1990). Both are

TABLE 21. SPECIES OF FISH TAKEN IN THE COLUMBIA RIVER ESTUARY BETWEEN FEBRUARY 1979 AND JULY 1981 (BOTTEM ET AL 1984)[a]
(Page 1 of 3)

Common Name	Scientific Name
Pacific lamprey	*Lampetra tridentata*
River lamprey	*Lampetra ayresi*
Spiny dogfish	*Squalus acanthias*
Big skate	*Raja binoculata*
Green sturgeon	*Acipenser medirostris*
White sturgeon	*Acipenser transmontanus*
American shad	*Alosa sapidissima*
Pacific herring	*Clupea harengus pallasi*
Northern anchovy	*Engraulis mordax*
Chum salmon	*Oncorhynchus keta*
Coho salmon	*Oncorhynchus kisutch*
Sockeye salmon	*Oncorhynchus nerka*
Chinook salmon	*Oncorhynchus tshawytscha*
Mountain whitefish	*Prosopium wlliamsoni*
Cutthroat trout	*Salmo clarki*
Steelhead	*Salmo gairdneri*
Whitebait smelt	*Allosmerus elongatus*
Surf smelt	*Hypomesus pretiosus*
Night smelt	*Spirinchus starksi*
Longfin smelt	*Spirinchus thaleichthys*
Eulachon	*Thaleichthys pacificus*
Common carp	*Cyprinus carpio*
Peamouth	*Mylocheilus caurinus*
Northern squawfish	*Ptychocheilus oregonensis*
Largescale sucker	*Catostomus macrocheilus*
Yellow bullhead	*Icxtalurus natalis*
Brown bullhead	*Ictalurus nebulosus*
Pacific hake	*Merluccius productus*

TABLE 21. SPECIES OF FISH TAKEN IN THE COLUMBIA RIVER ESTUARY BETWEEN FEBRUARY 1979 AND JULY 1981 (BOTTEM ET AL. 1984)[a] (Page 2 of 3)

Common Name	Scientific Name
Pacific tomcod	*Microgadus proximus*
Walleye pollock	*Theragra chalcogramma*
Threespine stickleback	*Gasterosteus aculeatus*
Bay pipefish	*Syntnathus leptorhynchus*
Pumpkinseed	*Lepomis gibbosus*
Warmouth	*Lepomis gulosus*
Bluegill	*Lepomis macrochirus*
Largemouth bass	*Micropterus salmoides*
White crappie	*Pomoxis annularis*
Black crappie	*Pomoxis nigromaculatus*
Yellow perch	*Perca flavescens*
Redtail surfperch	*Amphistichus rhodoterus*
Shiner perch	*Cymatogaster aggregata*
Striped seaperch	*Embiotoca lateralis*
Spotfin surfperch	*Hyperprosopon anale*
Walleye surfperch	*Hyperprosopon argenteum*
Silver surfperch	*Hyperprosopon ellipticum*
White seaperch	*Phanerodon furcatus*
Pile perch	*Rhacochilus vacca*
Pacific sandfish	*Trichodon trichodon*
Snake prickleback	*Lumpenus sagitta*
Saddleback gunnel	*Pholis ornata*
Pacific sand lance	*Ammodytes hexapterus*
Bay goby	*Lepidogobius lepidus*
Black rockfish	*Sebastes melanops*
Kelp greenling	*Hexagrammos decagrammus*
Lingcod	*Ophiodon elongatus*
Padded sculpin	*Artedius fenestralis*

TABLE 21. SPECIES OF FISH TAKEN IN THE COLUMBIA RIVER ESTUARY BETWEEN FEBRUARY 1979 AND JULY 1981 (BOTTEM ET AL 1984)[a]
(Page 3 of 3)

Common Name	Scientific Name
Coastrange sculpin	*Cottus aleuticus*
Prickly sculpin	*Cottus asper*
Buffalo sculpin	*Enophyrs bison*
Red Irish lord	*Hemilepidotus hemileptidotus*
Pacific staghorn sculpin	*Leptocottus armatus*
Cabezon	*Scorpaenichthys marmoratus*
Warty poacher	*Ocella verrucosa*
Tubenose poacher	*Pallasina barbata*
Pricklebreast poacher	*Stellerina xyosterna*
Slipskin snailfish	*Liparis fucensis*
Showy snailfish	*Liparis pulchellus*
Ringtail snailfish	*Liparis rutteri*
Pacific sanddab	*Citharichthys sordidus*
Speckled sanddab	*Citharichthys stigmaeus*
Butter sole	*Isopsetta isolepis*
English sole	*Parophrys vetulus*
Starry flounder	*Platichthys stellatus*
C-O sole	*Pleuronichthys coenosus*
Sand sole	*Psettichthys melanostictus*

[a] Species list includes results of 14 trapnet surveys in tributaries, coves, and sloughs of the estuary (NMFS 1981). Trapnet counts are not included among analyses for this report.

TABLE 22. ABUNDANT SPECIES OF FISH IN HABITAT ZONE 1 AND DISTRIBUTION WITHIN THE ESTUARY (BOTTOM ET AL. 1984)			
	Habitat Zones		
Species	Marine	Estuarine Mixing	Fluvial
Anadromous			
American shad	X	X	X
Chinook salmon	X	X	X
Chum salmon	X	X	X
Coho salmon	X	X	X
Sockeye salmon	X	X	X
Cutthroat trout	X	X	X
Steelhead	X	X	X
Longfin smelt	X	X	X
Eulachon	X	X	X
White sturgeon		X	X
Pacific lamprey		X	X
River lamprey	X	X	
Estuarine			
Big skate	X		
Butter sole	X	X	
English sole	X	X	
Starry flounder	X	X	X
Speckled sanddab	X	X	
Ling cod		X	
Northern anchovy	X	X	
Pacific herring	X	X	
Pacific sand lance	X	X	
Pacific staghorn sculpin	X	X	X
Pacific tomcod	X	X	
Redtail surfperch	X	X	
Spotfin surfperch	X	X	
Shiner perch	X	X	X
Saddleback gunnel	X	X	
Sand sole	X	X	
Showy snailfish	X	X	
Snake prickleback	X	X	
Spiny dogfish	X	X	
Surf smelt	X	X	X
Whitbait smelt	X	X	
Threespone stickleback	X	X	X
Resident/Freshwater			
Largescale sucker			X
Northern squawfish			X
Peamouth		X	X
Prickly sculpin		X	X
Carp	X	X	X

known to be tolerant of brackish conditions for at least limited periods (Scott and Crossman 1973).

Another important species, white sturgeon was observed primarily in the Estuarine Mixing and Tidal Fluvial sub-zones. Bottom et al. (1984, 1990) reported only 74 sturgeon, but Nigro (1990), in a study investigating sturgeon below Bonneville Dam captured 2,154 between RM 5 and 34.

The Columbia estuary also appears to be a very important nursery area for several species. This is illustrated by the observation that fish abundance was greatest during the summer months when assemblages were dominated by young-of-the-year fish. Sub-yearling starry flounder, shiner perch, Pacific herring, longfin smelt, English sole, and chinook salmon were observed in large numbers during the summer (Bottom et al. 1990).

Within the estuarine sub-zones, fish appear to be distributed in specific areas. In the Marine sub-zone, higher densities of fish were observed in the water column between the surface and approximately one meter above the estuary bottom as opposed to the channel bottom. In the broad Estuarine Mixing sub-zone, most species were observed in the shallower, quiet embayments of Baker Bay, Trestle Bay, and Youngs Bay. Mean density in bay habitats of the Estuarine Mixing sub-zone were over 1.5 times the density of areas outside of the bays. Similarly, mean densities in embayments within the Tidal Fluvial sub-zone were over twice the density of main channel areas. Seasonal flow and salinity data indicate that the distribution of fish is also correlated with salinity.

Bottom et al. (1984, 1990) found that the distribution of fish abundance within habitats or broad salinity zones in the Columbia estuary is influenced by prey density. Further, the predominant food items of demersal fish assemblages are epibenthic zooplankton. *Corophium salmonis, C. spinicorne,* and calanoid and harpacticoid copepods were the major prey of most species including juvenile anadromous salmonids, American shad, starry flounder, staghorn sculpin, longfin smelt, surf smelt, and Pacific herring. *Eogammarus affinis* and *Archaeomysis grebnitzkii* were other important epibenthic prey items. Pelagic *Daphnia* sp. were also important to the pelagic assemblages of juvenile salmonids, American shad, and surf smelt (Jones et al. 1990). *C. salmonis* and eulachon eggs were predominant food of juvenile white sturgeon in the estuary (Nigro 1990).

2.4.2.2 Data Summary: River Segment 2. Unlike the numerous comprehensive studies conducted in river segment 1, only two studies were found examining fish communities in river segment 2. McCabe et al. (1990) examined demersal fish communities between RM 68 and 71, while Blahm et al. (1980) examined primarily juvenile salmonids at RM 46.5 and 78. These studies observed eight species of fish, most of which were freshwater resident species. Freshwater residents were prickly sculpin, sand roller, peamouth, northern squawfish, and largescale sucker. Anadromous species were the white sturgeon and chinook salmon, and the euryhaline species was the starry flounder

Observations of habitat type, flow, and salinity were not made during these studies, but given the sampling locations, habitats were likely similar to those of the main channel of the Tidal Fluvial sub-zone in the upper reaches of river segment 1. The species assemblage was similar to the freshwater and anadromous component observed in the Tidal Fluvial sub-zone and reflected a freshwater habitat with limited saltwater intrusion. The one euryhaline species, starry flounder was observed during one sampling episode in November at RM 78. Starry flounder are known to tolerate very low salinities (6 to 10 parts per thousand) and travel substantial distances up large rivers (Hart 1973).

Although ecological observations were not made, McCabe et al. (1990) examined benthic and epibenthic communities in river segment 2. This study found that the amphipod *Corophium salmonis* dominated epibenthic assemblages in river segment 2 between RM 68 and 71. *C. salmonis* was the primary prey species of several estuarine, anadromous, and freshwater species present in river segment 1.

2.4.2.3 Data Summary: River Segments 3 and 4. Blahm et al. (1979) is the only study found that examined fish communities and ecological relationships in river segment 3. No studies were located for river segment 4. Blahm et al. (1979) looked primarily at juvenile salmonids between RM 98 and 107, but also listed the other species observed in association with salmon. The species assemblage found in river segment 3 was similar to that observed in river segment 2, dominated by freshwater resident and anadromous species. The same species were found with the addition of the freshwater residents carp, coastrange sculpin, fivescale sucker, and speckled dace, and the anadromous species of sockeye salmon, coho salmon, steelhead, and Pacific lamprey.

Ecological observations of habitat were not made, but Blahm et al. (1979) examined the feeding habits of juvenile salmonids and sturgeon in river segment 3. This study again illustrated the importance of epibenthic organisms in the rearing of anadromous fishes in the lower Columbia River. Juvenile salmonids preyed primarily on epibenthic insects and amphipods with some cladocerans and copepods. This overlapped with prey species observed in the extensive studies conducted in river segment 1, but juvenile salmon in river segment 3 had a higher proportion of insects in their diet while those in the lower estuary fed primarily on amphipods. Similarly, sturgeon in river segment 3 fed primarily on amphipods and insects while sturgeon in Zone 1 fed on amphipods and eulachon eggs. This difference in diets between river segments 1 and 3 likely reflect prey availability.

Considering the similarities of river segments 3 and 4 it is expected that similar fish assemblages inhabit Zone 4. River segment 4 is likely dominated by demersal resident fresh-water species and anadromous salmonids, white sturgeon, and American shad. The incidence of euryhaline species likely diminishes with distance from the estuary. Recreational catch, tribal harvest, and hatchery statistics confirm the use of Zone 4 by adult and juvenile chinook, coho, chum, and sockeye salmon, steelhead trout, and American shad. Adults of the species spawn upstream of river segment 4, and within the major and minor drainages within the zone. Subsequent use by subyearling and yearling juveniles as foraging and nursery habitats likely occur as the fish migrate out to the ocean.

Nigro (1990) in an on-going study examining the habitat requirements of white sturgeon reports that areas in river segment 4 are important spawning grounds for the economically important white sturgeon. Analysis of white sturgeon eggs and larvae showed that the primary spawning ground in the lower Columbia River for this species is the Ives Island area 2.5 miles below Bonneville Dam. This study found that eggs and larvae at sites above Ives Island were younger and fewer in number. Below Ives Island, catches of larvae were greater and eggs were in later developmental stages presumably because of downriver drift from the Ives Island area. Peak catches of eggs and larvae were observed in late May indicating a peak spawning period.

Investigations of juvenile white sturgeon below Bonneville Dam indicate that their distribution may be patchy throughout the river. Juvenile sturgeon were observed in higher numbers at RM 95 in river segment 3 and RM 131 in river segment 4, indicating that these areas may be important for juvenile rearing. Feeding studies in these areas indicate that juvenile sturgeon preyed primarily on *Corophium salmonis*, the freshwater bivalve *Corbicula manilensis*, and eulachon eggs. Benthic and epibenthic studies showed a dominance of *C. salmonis*, and *C. manilensis* (Nigro 1990).

2.4.3 Data Synthesis and Conclusions

Approximately 20 studies on fish communities or aspects of fish life history were reviewed for this indicator. As with the benthic infauna, most of the data are from the estuarine portion of the study area and were conducted in conjunction with CREDDP in the early 1980's. None of the studies utilized fish communities to assess impacts. Many of the studies focused on salmonids, while several others examined non-salmonid species. Fewer studies were found that examined fish communities in the freshwater riverine habitats.

The diversity and abundance of fish in the lower Columbia River are enhanced by the presence of several habitat zones which include near-ocean conditions at the mouth, tidal euryhaline conditions prominent to about river mile 15, a euryhaline transition zone, and freshwater riverine conditions. Within these habitat zones, the composition and distribution of fish species are also affected by seasonal cycles in the migration and life history of the fishes and seasonal changes in river flow conditions and salinity patterns.

The most diverse fish communities are present in the estuarine zone and are due mainly to the large number of subhabitats within the estuary. Over 75 species of anadromous, estuarine, and resident freshwater species have been identified in river segment 1. In river segments 2 and 3, in more limited studies, less than 10 species were identified. In general, similar species were collected in segments 2 and 3. No studies were conducted in segment 4 but considering the similarities of river segments 3 and 4, it is expected that similar fish assemblages inhabit segment 4. However, the lack of information from this segment identifies it as a data gap, suitable to recommend for sampling in the future.

The existing fish community data are not very useful for identifying potential problem areas in the lower Columbia River. This is based on the limited data available and the qualitative/descriptive nature of the fish community data. There are virtually no site specific studies where an assessment of a potential problem area could occur. Therefore, no attempt was made to rank the fish community data in terms of problem areas. However, this lack of information will be treated as a data gap, but given a fairly low priority because of the difficulty in using fish communities as quantitative indicators of impacts. This descriptive fish community data may be useful for establishing a within system "reference condition" if fish communities are identified as potential biological indicators as part of TASK 4: Biological Indicators.

2.5 BIOACCUMULATION

2.5.1 Data Selection and Review Methods

The purpose of this section is to summarize existing bioaccumulation data from the lower Columbia River fish and wildlife species. Types of information to be summarized include the sampling location, species, and variables measured. Table 23 presents summary information on the fish bioaccumulation studies collected as part of Task 1.

TABLE 23. SUMMARY OF EXISTING BIOACCUMULATION STUDIES ON THE LOWER COLUMBIA RIVER
(Page 1 of 2)

Study Reference	Sampling Location Name	River Mile	River Segment	Species	Variables Measured	Comments
Beak Consultants (1989)	C.R. Estuary Below Bonneville Dam Cascade Locks	2 to 45 139 to 146 146 to 151	1A to 2A 4B --	Coco salmon Chinook salmon Steelhead White sturgeon Carp Largescale sucker	Dioxins/furans	4 other sites upstream of Bonneville
Lowe et al. (1985)	Cascade Locks	149	--	Largescale sucker Northern squawfish	Metals	NCBP 1978-80
U.S. F&W (1991)	Cathlamet Longview St Helens Camas Portland		2A 3A 3A 4A 4A	Carp Northern squawfish Western gulls (Cathlamet only) Cormorants (Cathlamet only) Caspian terns (Cathlamet only) River otters (Camas only)	Dioxins/furans	No data available yet
U S. F&W (1991)	Youngs Bay Baker Bay Lewis/Clark Cathlamet Bay Julia Butler Longview Ridgefield Camas	12 5 12 18 34	1A 1A 1A 1B 1C 3A 3A 4A	Carp Largescale sucker Peamouth Western gulls (Cathlamet & Baker Bay) Cormorants (Cathlamet & Baker Bay) Caspian terns (Cathlamet only)	PCBs Pesticides Dioxins/furans	No data available yet
May and McKinney (1981)	Cascade Locks	149	--	Largescale sucker Northern squawfish	Metals	NPMP 1976-77
Schmitt et al. (1990)	Cascade Locks	149	--	Largescale sucker Northern squawfish	Organochlorines	NCBP 1976-84

TABLE 23. SUMMARY OF EXISTING BIOACCUMULATION STUDIES ON THE LOWER COLUMBIA RIVER (Page 2 of 2)						
Document Number	Sampling Location Name	River Mile	River Segment	Species	Variables Measured	Comments
Schmitt et al. (1981)	Cascade Locks	149	--	Largescale sucker Northern squawfish Carp	Organochlorines	NPMP 1970-74
Schmitt et al. (1983)	Cascade Locks	149	--	Largescale sucker Northern squawfish	Organochlorines	NPMP 1976-79
Schmitt et al. (1985)	Cascade Locks	149	--	Largescale sucker Northern squawfish	Organochlorines	NCBP 1976-84
Schmitt and Brumbaugh (1990)	Cascade Locks	149	--	Largescale sucker Northern squawfish	Metals	NCBP 1976-84
PGE (1990)	Trojan	72	2C	Largescale sucker Northern squawfish Carp Chinook salmon Steelhead Tui chub Black crappie Yellow bullhead Yellow perch	Radionuclides	3 stations small number of fish
ODEQ (1990a)	Tenasillahe Is. Longview St. Helens Hayden Is. to Lemon Is. Columbia Slough	36 107 to 112 105	1C 3A 3A 4A 4A	Northern squawfish Carp Crayfish	PCBs Pesticides Dioxins/furans	No data available yet
U.S. EPA (1991c)	Portland St. Helens Longview Wauna Camas		4A 3A 2C 2A 4A	Carp Northern squawfish Largescale sucker Bridgelip sucker	PCBs Pesticides Dioxins/furans	NBS
	Woody Island Kalama Deer Island		1C 3A 3A	Sturgeon	Dioxins/furans	NBS

The two classes of compounds that have received the most attention in previous bioaccumulation studies on the lower Columbia River are organochlorines and metals. Organochlorine compounds include PCBs, pesticides, dioxins, and furans. Other priority pollutants have been measured infrequently in fish from the lower Columbia River. Most previous studies have reported analyses from edible tissue (muscle) only. In general, bioaccumulation studies that focus on human health risk measure edible fish tissue (fillets), while those studies that are concerned with the larger ecological ramifications of bioconcentrated pollutants measure whole fish.

Two studies provided the majority of the fish bioaccumulation data for the lower Columbia River. These were the U.S. EPA's National Bioaccumulation Study (U.S. EPA 1991c) and the pulp and paper industry sponsored Columbia River Fish Study (Beak Consultants 1989). Whereas both studies have some data limitations, their results do provide useful information on fish bioaccumulation along the lower Columbia River. Therefore, data from both studies were equally used to evaluate existing knowledge of bioaccumulation in the river.

The National Bioaccumulation Study is a nationwide investigation of bioaccumulation by 60 contaminants in 119 species of fish. In general, whole-body samples were analyzed from bottom-feeding fish and filets were analyzed from game fish. Each sample was composited from three to five adult fish of the same species and comparable size. Eight of the 319 National Bioaccumulation Study sites were located within the lower Columbia River, and, therefore, used in this discussion. Data were collected from sturgeon, carp, and sucker for whole-body analysis at these sites. In addition, squawfish filets were also analyzed. Laboratory duplicates were analyzed in some cases, but field duplicates were not collected.

The Columbia River Fish Study (Beak Consultants 1989) was sponsored by pulp and paper mills along the River to measure dioxin levels in fish for human health risk assessment and ambient water criteria determination. This study analyzed 120 fish-filet composite samples from six study areas along the Columbia River. Only two of these areas are below the Bonneville Dam. Species collected were coho salmon, chinook salmon, steelhead, sturgeon, carp, and sucker. Anadromous fish (e.g. salmon, steelhead, and sturgeon) were sampled because of their high consumption rates by humans. Although anadromous strains believed to spend the most time in the river were chosen, interpretation of bioaccumulation results from the river are limited.

Although only a limited number of bioaccumulation studies have been undertaken, the results of these studies have a significant impact on regulatory decisions. Based on the results obtained as part of the National Bioaccumulation Survey (U.S. EPA 1991c), the Columbia River has been classified as "water quality limited" for dioxins.

In only one of the studies discussed in this section was an attempt made to collect fish from a reference site. In this study (Beak Consultants 1989), the Columbia River estuary (Site 1) was designed as a control for collection of anadromous salmonids on their return from the Pacific Ocean.

A narrative description of the bioaccumulation study results is presented below for each river segment. When appropriate, data tables report the results of these bioaccumulation studies. Sampling locations for past and ongoing bioaccumulation studies are shown in Figures 17-20. An assessment will be made regarding the comparability of bioaccumulation data from each segment.

2.5.2 Review of Accepted Data

2.5.2.1 Data Summary: River Segment 1. There are only limited bioaccumulation data available for river segment 1. Table 24 gives some of the results of a study sponsored by the Northwest Pulp & Paper Association to measure dioxins and furans in a variety of fish at six Columbia River stations (Beak Consultants 1989). The species collected included coho salmon, chinook salmon (two different races), steelhead, white sturgeon, carp, and largescale sucker. Site 1 of this study was considered to be the entire Columbia River estuary [i.e., all of segment 1 (see Figure 17)]. Each species, however, was caught at specific locations within the estuary. Five composite samples, ranging from 4 to 8 fish per composite, were analyzed for each species. Each composite was analyzed for TCDF (2,3,7,8-Tetrachlorodibenzofuran) and TCDD (2,3,7,8-Tetrachlorodibenzodioxin). The lipid content of each composite was also determined. Age structures (fin rays for sturgeon, scales for all other fish) were collected from virtually every fish. The age of each fish was determined by counting annuli on the age structures.

TCDF concentrations ranged from non-detected levels (less than 0.5 pg/g) from two steelhead composites, to 11 pg/g for a Tule Chinook composite. The majority of the composite samples contained undetectable levels of TCDD (less than 0.2 pg/g), but one carp composite contained 1.7 pg/g of TCDD. The correlation between TCDF and TCDD concentrations and percent lipids was generally not significant, with the exception of the five carp composites, for which the tissue concentrations of each compound was significantly correlated with percent lipids at $p = 0.01$.

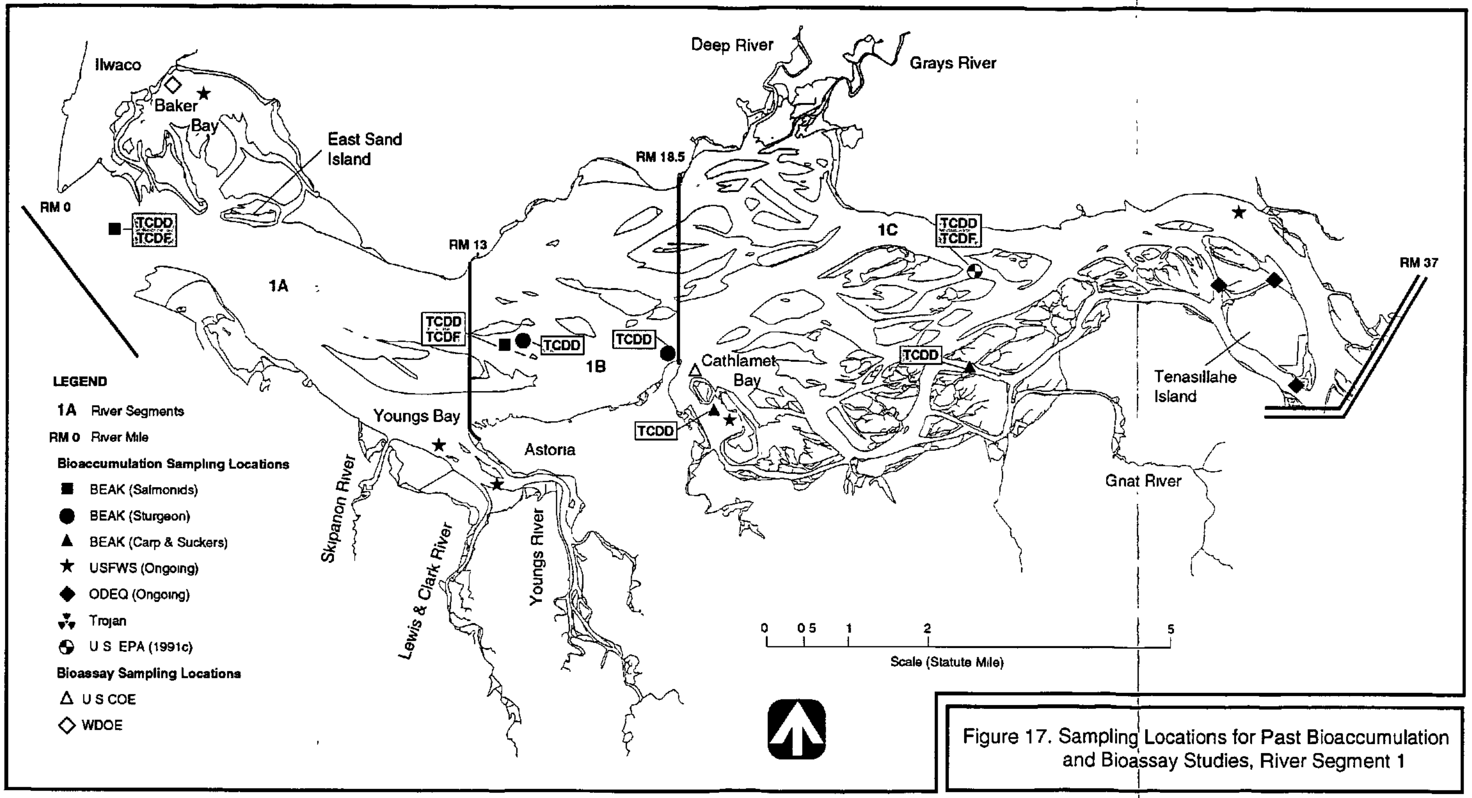


Figure 17. Sampling Locations for Past Bioaccumulation and Bioassay Studies, River Segment 1

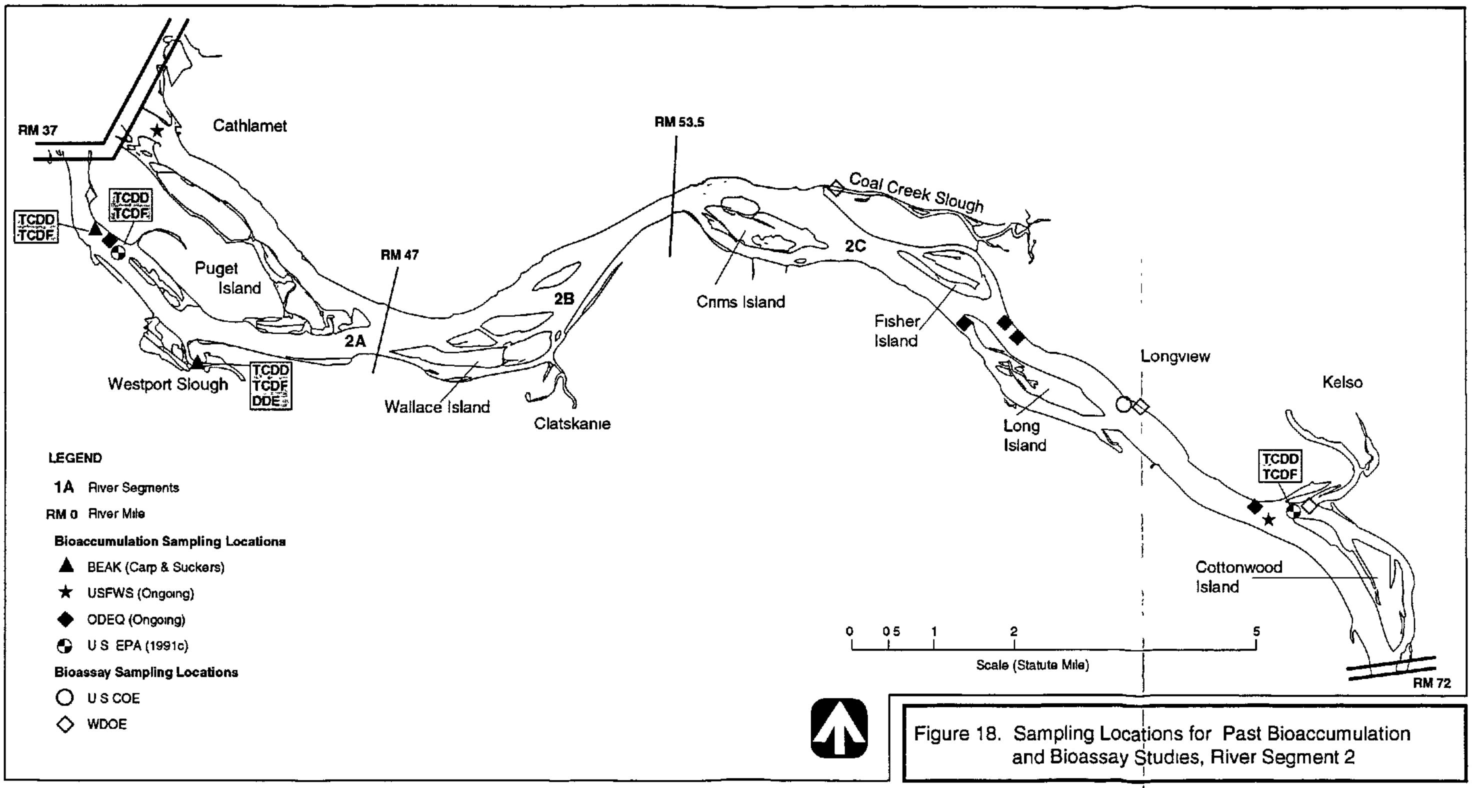


Figure 18. Sampling Locations for Past Bioaccumulation and Bioassay Studies, River Segment 2

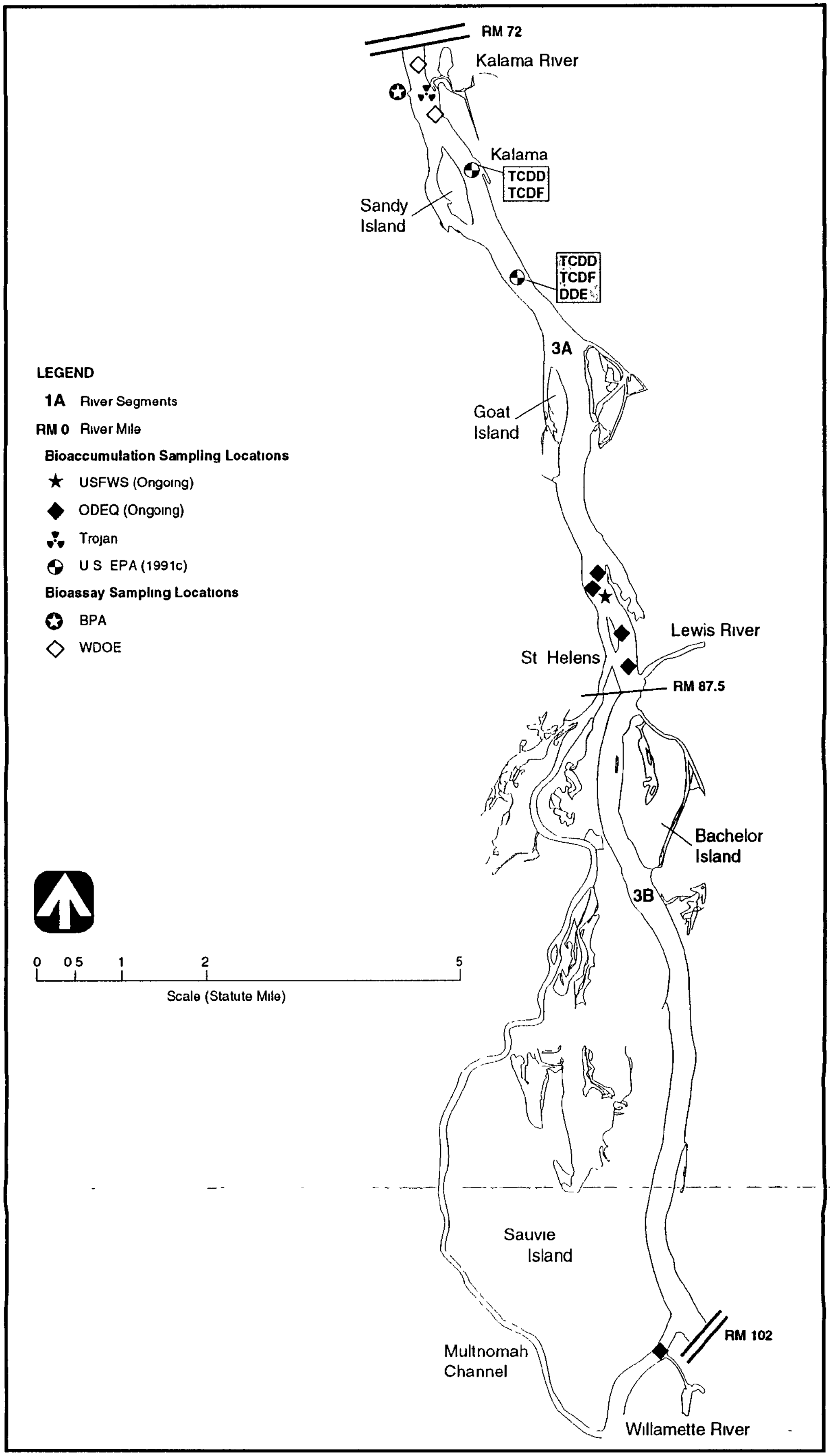


Figure 19. Sampling Locations for Past Bioaccumlation and Bioassay Studies, River Segment 3

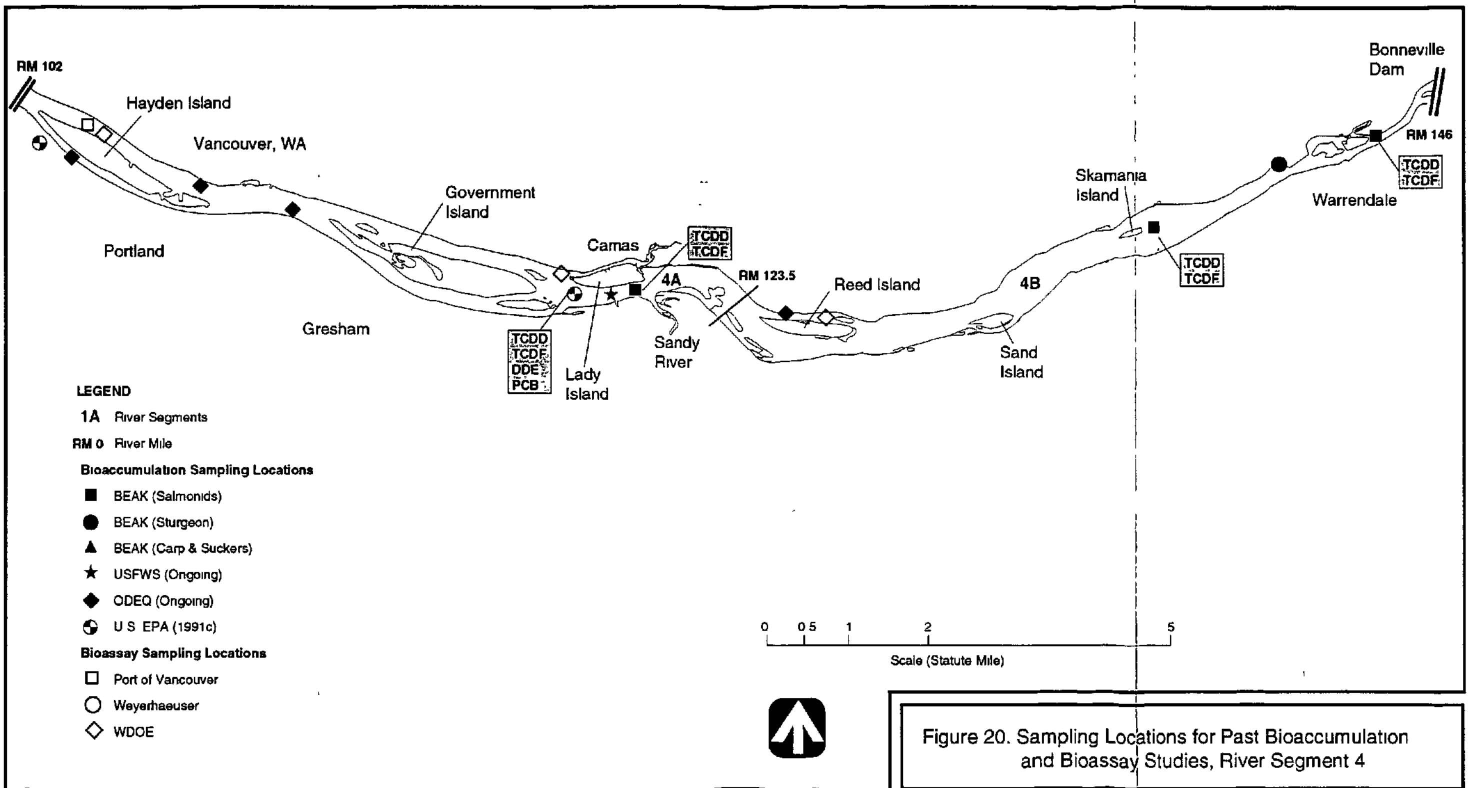


Figure 20. Sampling Locations for Past Bioaccumulation and Bioassay Studies, River Segment 4

TABLE 24. SUMMARY OF DIOXIN/FURAN BIOACCUMULATION DATA COLLECTED FROM THE LOWER COLUMBIA RIVER
(Page 1 of 2)

Site	Species	Comp. No.	TCDF pg/g	DL	Mean	R	TCDD pg/g	DL	Mean	R	% Lipids
Estuary	Coho	1	0.54	--	0.476	0.041	ND	0.17	--		1.85
		2	0.5	--			ND	0.14			1
		3	0.53	--			ND	0.15			1.55
		4	0.43	--			ND	0.17			1.15
		5	0.38	--			ND	0.23			1.76
	Chinook (upriver)	1	3.8	--	1.708	0.176	ND	0.22	--		9.05
		2	1.1	--			ND	0.13			11.1
		3	1.3	--			ND	0.17			9.4
		4	1.6	--			ND	0.16			8.3
		5	0.74	--			ND	0.11			6.1
	Chinook (Tule race)	1	11	--	7.058	0.885	0.33	--	0.316	0.835	3.9
		2	10	--			0.29	--			3
		3	7.3	--			0.36	--			3.5
		4	6.5	--			0.34	--			3.2
		5	ND	0.49			0.26	--			1.65
	Steelhead	1	0.44	--	0.69		ND	0.14	--		5.4
		2	ND	0.44			ND	0.21			4.95
		3	0.45	--			ND	0.08			9.35
		4	ND	0.62			ND	0.07			8.75
		5	1.5	--			ND	0.22			9.05
	Sturgeon	1	2.7	--	2.7	-0.04	ND	0.13	--		0.8
		2	2.2	--			ND	0.16			0.75
		3	3.1	--			ND	0.16			0.4
		4	2.7	--			ND	0.12			1.05
		5	2.8	--			0.24	--			1.85
	Carp	1	1.8	--	2.19	0.984	0.64	--	0.866	0.986	0.9
		2	1.6	--			0.53	--			0.8
		3	4.6	--			1.7	--			3
		4	0.95	--			0.69	--			0.7
		5	2	--			0.77	--			1
	Sucker	1	2.5	--	1.45	0.377	0.57	--	--		1.75
		2	1.1	--			0.32	--			1.05
		3	1.6	--			ND	0.45			1.3
		4	0.85	--			0.27	--			1.75
		5	1.2	--			0.32	--			1.2
Below Dam	Coho	1	0.55	--	0.542	0.249	ND	0.23	--		2.4
		2	0.38	--			ND	0.22			1.45
		3	0.5	--			ND	0.14			1.2
		4	0.65	--			ND	0.14			1.7
		5	0.63	--			ND	0.34			1.5
	Chinook (upriver)	1	2.5	--	3.44	-0.18	ND	0.33	--		8.3
		2	5.5	--			ND	0.2			9.3
		3	1.9	--			ND	0.1			9.35
		4	5.8	--			0.21	--			9.4
		5	1.5	--			ND	0.08			10.45

TABLE 24. SUMMARY OF DIOXIN/FURAN BIOACCUMULATION DATA COLLECTED FROM THE LOWER COLUMBIA RIVER
(Page 2 of 2)

Site	Species	Comp. No.	TCDF pg/g	DL	Mean	R	TCDD pg/g	DL	Mean	R	% Lipids
Below Dam	Chinook (Tule race)	1	3 7	--	4 54	-0.06	0.25	--	0 27		1.65
		2	5.9	--			0 26	--			2
		3	3.4	--			ND	0.28			2.3
		4	5.6	--			ND	0.34			1.9
		5	4 1	--			ND	0.22			1.8
	Steelhead	1	ND	0 54	--		ND	0.15	--		5 25
		2	ND	0.45			ND	0.13			5 7
		3	ND	0 55			ND	0.13			8.05
		4	ND	0 45			ND	0 18			6 05
		5	ND	0.48			ND	0.13			5
	Sturgeon	1	3.7	--	3 2	0.972	ND	0.28	--		1.95
		2	2.6	--			ND	0.24			0 65
		3	3	--			ND	0.24			1.3
		4	3 5	--			ND	0.22			1 55
		5	3.2	--			ND	0.25			1 35
Above Dam	Sturgeon	1	38	--	39.6	-0.46	1.3	--	1.366		3 7
		2	60	--			2.1	--			4.85
		3	19	--			ND	0.63			9
		4	28	--			1	--			3 6
		5	53	--			1.8	--			4.8
	Carp	1	10	--	10.88	0 832	1.1	--	1.164	0 739	1 4
		2	13	--			1.6	--			7
		3	11	--			1.3	--			3
		4	17	--			1 4	--			7 8
		5	3.4	--			0.42	--			1 5
	Sucker	1	7 2	--	5.78	0.819	0.51	--	0.542		2 45
		2	3.2	--			ND	0.4			1 7
		3	6.6	--			0.45	--			2 6
		4	3 1	--			ND	0.38			1 65
		5	8.8	--			0.97	--			2 25

Source: Beak Consultants (1989)

One segment 1 site at Woody Island was sampled for sturgeon as part of the National Bioaccumulation Study (U.S. EPA 1991c). A composite of five fish was created and analyzed for fifteen different dioxins and furans. The results of these analyses are reported in Table 25. All laboratory analyses were duplicated. Most of the compounds were not detected, with the exception of 1,2,3,4,6,7,8-HpCDD (average of 0.78 pg/g) and 2,3,7,8-TCDF (average of 21 pg/g).

Two ongoing studies, one sponsored by the U.S. Fish and Wildlife Service and the other by Oregon Department of Environmental Quality, will be collecting data from fish and crayfish in river segment 1. The U.S. Fish and Wildlife (1991) study will collect carp, largescale sucker, peamouth, and crayfish at five stations in Segment 1. Composite samples will be analyzed for PCBs, pesticides, and dioxins/furans. A similar suite of compounds will be measured in the ODEQ (1990) study at a Segment 1 station near Tenasillahe Island. The target species include northern squawfish, carp, and crayfish. Several species of waterfowl (Western gulls, cormorants, and Caspian terns) will also be collected as part of the USFWS studies and analyzed for PCBs, pesticides, and dioxins/furans. No data are yet available from either of these studies.

2.5.2.2 Data Summary: River Segment 2. There are only limited bioaccumulation data available for river segment 2 (see Figure 18). Some of the carp and largescale suckers analyzed in the Columbia River estuary for the dioxin/furan study described above (Beak Consultants 1989), were actually collected in river segment 2A. Unfortunately, due to the wide boundaries of Site 1, the fish captured in segment 2 for the above study can not be differentiated from those fish collected in segment 1. Some of the results given in Table 24 for carp and sucker are applicable to segment 2.

The Portland General Electric Company (1990) sponsored a bioaccumulation study at the Trojan Nuclear Power Plant. Nine different fish species (see Table 23) and crayfish were collected at three stations in the vicinity of the nuclear plant and analyzed for gamma emitting radionuclides. All samples analyzed contained undetectable levels (detection limit of 0.10 pCi/g nuclide, wet weight) of gamma emitters. It should be pointed out that for all fish species except tui chub, yellow bullhead, and yellow perch, no more than two specimens of any given species were analyzed at one time.

As part of the National Bioaccumulation Survey, squawfish and suckers were collected from two sites, one at Wauna and the other at Longview (see Figure 18). At the Wauna site, five suckers (whole body) were composited and analyzed for mercury, dioxins/furans and chlorinated hydrocarbons. Five squawfish fillets were composited and analyzed for mercury, furans,

TABLE 25. DIOXIN AND FURAN CONCENTRATIONS IN FISH COLLECTED FOR THE NATIONAL BIOACCUMULATION STUDY
(all concentrations in pg/g wet weight)
(Page 1 of 2)

Site	Woody Island	Woody Island	Kalama	Deer Island	Portland	St. Helens	St Helens	St. Helens
River Segment	1C	1C	3A	3A	4A	3A	3A	3A
Species	Sturgeon	Sturgeon	Sturgeon	Sturgeon	Carp	Squawfish	Sucker	Sucker
Sample Type	Whole Body	Lab. Dup.	Whole Body	Whole Body	Whole Body	Fillet	Whole Body	Lab. Dup.
2,3,7,8-TCDD	ND	0.88	1.06	ND	2 86	1.28	2 57	2.01
1,2,3,7,8-PeCDD	ND	ND	ND	ND	3 33	0 95	0 68	0 55
1,2,3,4,7,8-HxCDD	ND	ND	ND	ND	ND	ND	ND	ND
1,2,3,6,7,8-HxCDD	ND	ND	ND	ND	8 68	0.8	0 9	0.77
1,2,3,7,8,9-HxCDD	ND	ND	ND	ND	1 09	ND	0 18	0 19
1,2,3,4,6,7,8-HpCDD	0 72	0 84	ND	0 62	13 27	0 9	5 86	4.66
2,3,7,8-TCDF	22 05	20 94	17 75	22.15	4 1	9 03	11 38	10 27
1,2,3,7,8-PeCDF	ND	0.52	ND	ND	0 57	0.51	0.28	ND
2,3,4,7,8-PeCDF	ND	ND	ND	ND	2 19	0 59	0.44	0 43
1,2,3,4,7,8-HxCDF	ND	ND	ND	ND	2.88	ND	ND	ND
1,2,3,6,7,8-HxCDF	ND	NDN	ND	ND	0.91	ND	ND	ND
1,2,3,7,8,9-HxCDF	ND	ND	ND	ND	ND	ND	ND	ND
2,3,4,6,7,8-HxCDF	ND	ND	ND	ND	1.85	ND	ND	ND
1,2,3,4,6,7,8-HpCDF	ND	ND	ND	ND	2.88	ND	0.76	0.65
1,2,3,4,7,8,9-HpCDF	ND	ND	ND	ND	ND	ND	ND	ND
Percent Lipids	2.9	2 6	3 2	4	4.3	2	9.6	NA

TABLE 25. DIOXIN AND FURAN CONCENTRATIONS IN FISH COLLECTED FOR THE NATIONAL BIOACCUMULATION STUDY
(all concentrations in pg/g wet weight)
(Page 2 of 2)

Site	Wauna	Wauna	Longview	Longview	Longview	Camas	Camas
River Segment	2A	2A	2C	2C	2C	4A	4A
Species	Squawfish	Sucker	Squawfish	Squawfish	Sucker	Squawfish	Sucker
Sample Type	Fillet	Whole Body	Fillet	Lab. Dup.	Whole Body	Fillet	Whole Body
2,3,7,8-TCDD	1.73	2.78	1.48	1.75	5.23	1.14	2.28
1,2,3,7,8-PeCDD	0.78	ND	0.49	ND	0.68	ND	0.32
1,2,3,4,7,8-HxCDD	ND	ND	ND	ND	ND	ND	ND
1,2,3,6,7,8-HxCDD	0.77	0.66	0.56	ND	ND	0 2	0.45
1,2,3,7,8,9-HxCDD	ND	ND	ND	ND	ND	ND	ND
1,2,3,4,6,7,8-HpCDD	2	ND	1.16	ND	2.2	ND	1 65
2,3,7,8-TCDF	21.63	16.39	20 12	20 73	28.34	11.95	15.95
1,2,3,7,8-PeCDF	0.29	ND	0.21	ND	0.3	ND	ND
2,3,4,7,8-PeCDF	0 36	ND	ND	0.26	0.67	0.21	0.25
1,2,3,4,7,8-HxCDF	ND	0 6	ND	ND	ND	ND	ND
1,2,3,6,7,8-HxCDF	ND	ND	ND	ND	ND	ND	ND
1,2,3,7,8,9-HxCDF	ND	ND	ND	ND	ND	ND	ND
2,3,4,6,7,8-HxCDF	ND	ND	ND	ND	ND	ND	ND
1,2,3,4,6,7,8-HpCDF	ND	0.28	ND	ND	ND	ND	0.24
1,2,3,4,7,8,9-HpCDF	ND	ND	ND	ND	ND	ND	ND
Percent Lipids	2 9	7	3	3	11.4	1.3	9.2

Source. U S EPA 1991c

pesticides, and PCBs. The results of these analyses are given in Tables 25 and 26 for dioxins/furans and priority pollutants, respectively. Five and six dioxins/furans, respectively, were detected for suckers and squawfish. Six of the thirty-one pesticides and PCBs analyzed were found above the quantification limit in the squawfish composite, while none of chlorinated hydrocarbons analyzed for the sucker composite were found above the quantification limit.

At the Longview site, five squawfish fillets were composited and analyzed for mercury and dioxins/furans. These analyses were repeated twice in the laboratory. Six of the fifteen dioxins/furans measured were detected above the detection limit. Four Bridgelip suckers from the Longview site were composited and analyzed for dioxins/furans, mercury, chlorinated hydrocarbons, pesticides, and PCBs. Six of the fifteen dioxins/furans and seven of the forty-five additional organic compounds were detected above the method detection limit.

Additional data are due to be collected in river segment 2 in a study sponsored by the U.S. Fish and Wildlife Service (1991). Carp and northern squawfish are to be collected at Cathlamet and analyzed for dioxins and furans. No data are yet available from this study.

2.5.2.3 Data Summary: River Segment 3. The only bioaccumulation data available for river segment 3 are from the National Bioaccumulation Study (U.S. EPA 1991c). Sturgeon composites from Kalama and Deer Island were analyzed for dioxins and furans (see Figure 19). Two of the fifteen compounds analyzed were detected above the detection limit. In addition, squawfish and suckers were collected at St. Helens and analyzed for dioxins/furans, mercury, chlorinated hydrocarbons, pesticides, and PCBs.

The sucker composite was analyzed in duplicate. The results of these analyses are given in Table 25 and 26 for dioxins/furans and priority pollutants, respectively. Seven dioxins/furans and four priority pollutants, were found above the detection limits for squawfish, while nine dioxins/furans and five priority pollutants were found above the detection limit for suckers.

The ongoing studies described in above sections (U.S. Fish and Wildlife Services 1990, 1991; Oregon Department of Environmental Quality 1990a) will collect data from fish and invertebrates from Segment 3 sites. Sampling locations will include Longview (three stations), St. Helens (two stations), and Ridgefield (see Figure 19). The samples (carp, northern squawfish, largescale sucker, peamouth, and crayfish) will be analyzed for PCBs, pesticides, and dioxins/furans. No data are yet available from these studies.

TABLE 26. PRIORITY POLLUTANT CONCENTRATIONS IN FISH COLLECTED FOR THE NATIONAL BIOACCUMULATION STUDY
(all concentrations in ng/g wet weight)
(Page 1 of 6)

Site	Portland	St. Helens	St. Helens	St Helens	Wauna	Wauna
River Segment	4A	3A	3A	3A	2A	2A
Species	Carp	Squawfish	Sucker	Sucker	Squawfish	Sucker
Sample Type	Whole Body	Fillet	Whole Body	Lab. Dup.	Fillet	Whole Body
Mercury (in µg/g)	0.1	0.33	0.05	NA	0.09	0.36
1,2,3-Trichlorbenzene	ND	ND	0.24D	ND	--	ND
1,2,4-Trichlorbenzene	0.72D	ND	ND	0.48D	--	ND
1,3,5-Trichlorbenzene	ND	ND	ND	ND	--	ND
1,2,3,4-Tetrachlorobenzene	ND	ND	ND	ND	--	ND
1,2,3,5-Tetrachlorobenzene	ND	ND	ND	ND	--	ND
1,2,4,5-Tetrachlorobenzene	ND	ND	ND	ND	--	ND
Octachlorostyrene	ND	ND	ND	ND	--	ND
Pentachlorobenzene	0.54D	ND	ND	ND	--	ND
Pentrachloronitrobenzene	ND	ND	ND	ND	--	ND
Hexachlorobenzene	2.12D	ND	ND	ND	--	ND
Alpha BHC	1.11D	ND	2 74	5.48	--	ND
Gamma BHC	ND	ND	ND	ND	--	ND
Cis chlordane	9.68	0.17D	ND	ND	--	0.73D
Trans chlordane	6.7	ND	ND	ND	--	ND
Oxychlordane	ND	ND	ND	ND	ND	--
Cis nonachlor	5 41	ND	ND	ND	ND	--
Trans nonachlor	14.4	1 58D	ND	ND	2.67	--
Heptachlor	ND	ND	ND	ND	ND	--

TABLE 26. PRIORITY POLLUTANT CONCENTRATIONS IN FISH COLLECTED FOR THE NATIONAL BIOACCUMULATION STUDY
(all concentrations in ng/g wet weight)
(Page 2 of 6)

Site	Portland	St Helens	St. Helens	St. Helens	Wauna	Wauna
River Segment	4A	3A	3A	3A	2A	2A
Species	Carp	Squawfish	Sucker	Sucker	Squawfish	Sucker
Sample Type	Whole Body	Fillet	Whole Body	Lab. Dup.	Fillet	Whole Body
Heptachlor expoxide	ND	ND	ND	ND	ND	--
p,p'-DDE	333E	34.3	80.9	89 8	52	--
Dieldrin	12.4	ND	ND	ND	ND	--
Endrin	ND	ND	ND	ND	ND	--
Dicofol	ND	ND	ND	ND	ND	--
Methoxychlor	ND	0 39D	ND	ND	ND	--
Perthane	ND	ND	ND	ND	ND	--
Mirex	0.94D	0 26D	ND	ND	ND	--
Nitrofen	ND	ND	ND	ND	ND	--
Chlorpyrifost	ND	ND	ND	ND	ND	--
Isopropalin	ND	ND	ND	ND	ND	--
Trifluralin	ND	ND	ND	ND	ND	--
Pentachloroanisole	2 13D	ND	0.92D	1.32D	ND	--
Biphenyl	3.41	0 06D	0.73D	1.09D	0.06D	--
Total PCBs	2043 1	37.1	127 9	173	55 6	--
Total Monochlorobiphenyls	1.32D	ND	ND	ND	ND	--
Total Dichlorobiphenyls	ND	ND	ND	ND	ND	--
Total Trichlorobiphenyls	14.5	ND	ND	ND	ND	--
Total Tetrachlorobiphenyls	208E	ND	15	21 7	ND	--

TABLE 26. PRIORITY POLLUTANT CONCENTRATIONS IN FISH COLLECTED FOR THE NATIONAL BIOACCUMULATION STUDY
(all concentrations in ng/g wet weight)
(Page 3 of 6)

Site	Portland	St. Helens	St. Helens	St. Helens	Wauna	Wauna
River Segment	4A	3A	3A	3A	2A	2A
Species	Carp	Squawfish	Sucker	Sucker	Squawfish	Sucker
Sample Type	Whole Body	Fillet	Whole Body	Lab. Dup.	Fillet	Whole Body
Total Pentachlorobiphenyls	890E	12.4	55.1	71	20 8	--
Total Hexachlorobiphenyls	713E	19.8	57.8	68.6	29.7	--
Total Hectachlorobiphenyls	186E	4.9	ND	11.7	5 1	--
Total Octachlorobiphenyls	30.3	ND	ND	ND	ND	--
Total Nonachlorobiphenyls	ND	ND	ND	ND	ND	--
Total Decachlorobiphenyls	ND	ND	ND	ND	ND	--
Diphenyl Disulfide	ND	ND	ND	ND	ND	--
Hexachlorobutadiene	ND	ND	ND	ND	ND	--
Percent Lipids	8.9	1.4	7.8	7 7	2 8	NA
qualifier codes: D = value below limit of quantitation E = value exceeds calibration standard						

TABLE 26 PRIORITY POLLUTANT CONCENTRATIONS IN FISH COLLECTED FOR THE NATIONAL BIOACCUMULATION STUDY (all concentrations in ng/g wet weight) (Page 4 of 6)				
Site	Longview	Longview	Camas	Camas
River Segment	2C	2C	4A	4A
Species	Squawfish	Sucker	Squawfish	Sucker
Sample Type	Fillet	Whole Body	Fillet	Whole Body
Mercury (in $\mu g/g$)	0.23	0.05	0.74	ND
1,2,3-Trichlorbenzene	--	ND	--	ND
1,2,4-Trichlorbenzene	--	ND	--	ND
1,3,5-Trichlorbenzene	--	ND	--	ND
1,2,3,4-Tetrachlorobenzene	--	ND	--	ND
1,2,3,5-Tetrachlorobenzene	--	ND	--	ND
1,2,4,5-Tetrachlorobenzene	--	ND	--	ND
Octachlorostyrene	--	ND	--	ND
Pentachlorobenzene	--	ND	--	ND
Pentrachlornitrobenzene	--	ND	--	ND
Hexachlorobenzene	--	ND	--	1.49D
Alpha BHC	--	ND	--	ND
Gamma BHC	--	ND	--	ND
Cis chlordane	--	ND	--	ND
Trans chlordane	--	ND	--	ND
Oxychlordane	--	ND	--	ND
Cis nonachlor	--	ND	--	ND
Trans nonachlor	--	ND	--	4.5
Heptachlor	--	ND	--	ND

TABLE 26 PRIORITY POLLUTANT CONCENTRATIONS IN FISH COLLECTED FOR THE NATIONAL BIOACCUMULATION STUDY
(all concentrations in ng/g wet weight)
(Page 5 of 6)

Site	Longview	Longview	Camas	Camas
River Segment	2C	2C	4A	4A
Species	Squawfish	Sucker	Squawfish	Sucker
Sample Type	Fillet	Whole Body	Fillet	Whole Body
Heptachlor expoxide	--	ND	--	ND
p,p'-DDE	--	107	--	89.2E
Dieldrin	--	ND	--	ND
Endrin	--	ND	--	ND
Dicofol	--	ND	--	ND
Methoxychlor	--	ND	--	ND
Perthane	--	ND	--	ND
Mirex	--	ND	--	ND
Nitrofen	--	ND	--	ND
Chlorpyrifost	--	ND	--	ND
Isopropalin	--	ND	--	ND
Trifluralin	--	ND	--	ND
Pentachloroanisole	--	6.74	--	0 68D
Biphenyl	--	ND	--	0 2D
Total PCBs	--	174.72	--	92 36
Total Monochlorobiphenyls	--	ND	--	ND
Total Dichlorobiphenyls	--	ND	--	ND
Total Trichlorobiphenyls	--	0.72D	--	0 63D
Total Tetrachlorobiphenyls	--	41 3	--	24.9

TABLE 26. PRIORITY POLLUTANT CONCENTRATIONS IN FISH COLLECTED FOR THE NATIONAL BIOACCUMULATION STUDY
(all concentrations in ng/g wet weight)
(Page 6 of 6)

Site	Longview	Longview	Camas	Camas
River Segment	2C	2C	4A	4A
Species	Squawfish	Sucker	Squawfish	Sucker
Sample Type	Fillet	Whole Body	Fillet	Whole Body
Total Pentachlorobiphenyls	--	67.1	--	37.5
Total Hexachlorobiphenyls	--	55.1	--	25 3
Total Hectachlorobiphenyls	--	10.5	--	4.03
Total Octachlorobiphenyls	--	ND	--	ND
Total Nonachlorobiphenyls	--	ND	--	ND
Total Decachlorobiphenyls	--	ND	--	ND
Diphenyl Disulfide	--	ND	--	ND
Hexachlorobutadiene	--	ND	--	ND
Percent Lipids	NA	15 9	NA	20.06
qualifier codes: D = value below limit of quantitation E = value exceeds calibration standard				

Source. U.S. EPA 1991c

2.5.2.4 Data Summary: River Segment 4. There are only limited bioaccumulation data available for river segment 4. Anadromous fish (salmon and steelhead) and sturgeon were collected at a site encompassing a seven mile reach just below the Bonneville Dam (see Figure 20). In this study, described above in the segment 1 section (Beak Consultants 1989), tissue samples were analyzed for TCDF and TCDD. Tissue levels of TCDD for all samples were largely undetectable (detection limit ranging from 0.13 to 0.34 pg/g) with the exception of three composites for chinook salmon, for which the TCDD concentrations were barely above the detection limit (see Table 24). TCDF tissue concentrations were all above the detection limit, with the exception of all the composites from steelhead, and ranged from 0 38 pg/g for a coho composite, to 5.9 pg/g for a chinook composite. The mean and range of TCDD and TCDF concentrations were similar between the Columbia River estuary site and the Bonneville Dam site. Carp and largescale sucker were not collected at the Bonneville site, although they were collected from the estuary site (segment 1). The correlation between TCDF and TCDD concentrations and percent lipids was generally not significant, with the exception of the sturgeon composites, for which the tissue concentration of each compound was significantly correlated with percent lipids at $p = 0.025$.

As part of the National Bioaccumulation Study, carp were collected at Portland and squawfish and suckers were collected from Camas. The carp composite from Portland (three fish) and the sucker composite from Camas (five fish) were analyzed for dioxins/furans, mercury, chlorinated hydrocarbons, pesticides, and PCBs. A squawfish composite (five fillets) from Camas was analyzed for dioxins/furans and mercury. The results of these analyses are given in Tables 25 and 26 for dioxins/furans and priority pollutants, respectively. Twelve, seven, and four dioxins/furans, respectively, were detected above the detection limits for the carp, squawfish, and sucker composites. Eleven and seven priority pollutants, respectively, were found above the detection limit for the carp and sucker composites. The concentration of total PCBs was over 2,000 ppb for the carp composite, which is more than one order of magnitude greater than any other organic concentration for Columbia River fish collected as part of the National Bioaccumulation Survey.

Three ongoing studies described in above sections (U.S. Fish and Wildlife Services 1990, 1991; Oregon Department of Environmental Quality 1990a) will collect data from fish and invertebrates from Segment 4 sites. Sampling locations will include Camas (two studies), Portland, Columbia Slough, and the reach from Hayden Island to Lemon Island (see Figure 20). The samples (carp, northern squawfish, largescale sucker, peamouth, and crayfish) will be analyzed for PCBs, pesticides, and dioxins/furans. No data are yet available from these studies.

A large body of bioaccumulation data exists for the region just upstream of Bonneville Dam (Cascade Locks). Although technically outside the lower Columbia River study area, the data from this sampling location can serve as a valuable reference for data collected downstream of the Bonneville Dam. For the Columbia River fish study described above (Beak Consultants 1989), sturgeon, carp, and largescale sucker were collected from a five mile section around Cascade Locks (River Mile 149) and analyzed for TCDF and TCDD. The tissue concentrations of TCDF and TCDD were as much as one order of magnitude greater for the Cascade Locks fish compared to the estuary fish (see Table 24). No anadromous fish were collected from the Cascade Locks site.

As part of the National Contaminant Biomonitoring Program (NCBP; formerly called the National Pesticide Monitoring Program), largescale sucker and Northern squawfish have been collected from Cascade Locks since 1970 and analyzed for organochlorine pesticides and metals. The results of these studies have been described in seven different reports (Lowe et al 1985; May and McKinney 1985; Schmitt et al. 1981, 1983, 1985, 1990; Schmitt and Brumbaugh 1990) The organochlorine data are summarized in Table 27, while the metals data are reported in Table 28. The detection limits for all analyses reported in Tables 25 and 26 were not available. There are no comparable data from the lower Columbia River for these species. In the near future, the ongoing Fish and Wildlife and ODEQ studies (U.S. Fish and Wildlife Service 1990, 1991; Oregon Department of Environmental Quality 1990a), will provide data with which the NCBP data can be compared.

*2.5.2.5 **Wildlife.*** Wildlife species which forage along the lower Columbia River are potentially exposed to dangerous levels of contaminants from the prey items they consume. As described in the above sections, fish and invertebrates have been shown to bioaccumulate organochlorine compounds and metals. When animals which have accumulated these toxic substances are consumed by predatory birds or mammals, the health of the predator can be adversely affected from further bioaccumulation. A limited number of wildlife surveys have been performed on the lower Columbia River. These studies have focused on predatory birds (e.g., bald eagles and ospreys) and mammals (e.g., mink, river otter, and harbor seals). Table 29 gives the results of several of these studies. The concentration of DDE and PCBs in the eggs of bald eagles and ospreys have been measured as high as 16.0 ppm and 26.7 ppm, respectively (Garrett et al. 1988; Henny and Anthony 1989). Studies of mink and river otters from the lower Columbia River conducted in 1978–1979 detected mean PCB concentrations of 9.3 ppm in livers of river otters and 1.09 ppm in livers of mink (Henry et al. 1981).

Limited data on reproductive impairment or mortality correlated with PCB concentrations in livers of mink exist. One study on experimental mink found reproductive failure after feeding

TABLE 27. SUMMARY OF ORGANOCHLORINE BIOACCUMULATION DATA FROM THE NATIONAL CONTAMINANT BIOMONITORING PROGRAM STATION 46 AT CASCADE LOCKS (RIVER MILE 149)
(all values are in mg/kg wet weight)
(Page 1 of 6)

Species	Year	p,p'-DDE	p,p'-DDD	p,p'-DDT	PCBs Aroclors 1242	1248	1254	1260	Dieldrin
Largescale sucker	1970	0.22	0.12	0.08	NA	NA	0.44	NA	0.01
Northern squawfish	1970	1.41	0.51	0.23	NA	NA	20.8	NA	0.01
Northern squawfish	1970	0.93	0.34	0.18	NA	NA	1.41	NA	0.01
Carp	1971	0.11	0.03	0.02	NA	NA	0.13	NA	0.02
Carp	1971	0.25	0.1	0.03	NA	NA	0.25	NA	0.01
Largescale sucker	1971	0.32	0.22	0.2	NA	NA	0.29	NA	0.01
Largescale sucker	1971	0.47	0.37	0.27	NA	NA	0.95	NA	0.01
Northern squawfish	1971	0.94	0.24	0.08	NA	NA	0.98	NA	0.01
Northern squawfish	1971	0.85	0.19	0.06	NA	NA	0.83	NA	0.01
Carp	1972	0.5	0.18	ND	NA	NA	0.1	NA	ND
Largescale sucker	1972	0.47	0.38	0.24	NA	NA	1.4	NA	ND
Carp	1973	0.23	ND	ND	ND	NA	ND	ND	ND
Largescale sucker	1973	0.28	0.11	ND	ND	NA	0.8	ND	ND
Largescale sucker	1973	0.22	0.17	ND	ND	NA	0.93	ND	ND
Northern squawfish	1973	0.24	ND	ND	ND	NA	0.5	ND	ND
Carp	1974	0.32	0.12	ND	ND	NA	0.18	ND	ND
Largescale sucker	1974	2	ND	ND	ND	NA	ND	ND	ND
Largescale sucker	1974	0.02	ND	ND	ND	NA	ND	ND	ND
Northern squawfish	1974	1.2	0.28	ND	ND	NA	2.6	ND	ND
Largescale sucker	1976	0.18	0.04	0.01	ND	0.01	0.3	0.2	0.01

TABLE 27. SUMMARY OF ORGANOCHLORINE BIOACCUMULATION DATA FROM THE NATIONAL CONTAMINANT BIOMONITORING PROGRAM STATION 46 AT CASCADE LOCKS (RIVER MILE 149)
(all values are in mg/kg wet weight)
(Page 2 of 6)

Species	Year	p,p'-DDE	p,p'-DDD	p,p'-DDT	PCBs Aroclors 1242	1248	1254	1260	Dieldrin
Largescale sucker	1976	0.09	0.07	0.03	ND	ND	2.1	0.7	0.01
Northern squawfish	1976	0.27	0.12	0.02	ND	ND	1.6	0.4	0.02
Largescale sucker	1978	0.23	0.14	0.03	ND	ND	0.24	ND	0.01
Largescale sucker	1978	0.35	0.21	0.04	ND	ND	0.2	0.2	0.01
Northern squawfish	1978	0.36	0.03	ND	ND	0.01	0.4	0.3	ND
Largescale sucker	1980	0.47	0.22	0.07	NA	ND	0.1	0.1	0.01
Largescale sucker	1980	0.61	0.2	0.03	NA	ND	0.2	0.2	0.01
Northern squawfish	1980	0.64	0.14	ND	NA	ND	0.1	0.4	0.01
Largescale sucker	1984	0.73	0.23	0.05	NA	ND	0.4	0.1	0.01
Northern squawfish	1984	0.56	0.12	ND	NA	ND	0.5	0.1	0.01

TABLE 27. SUMMARY OF ORGANOCHLORINE BIOACCUMULATION DATA FROM THE NATIONAL CONTAMINANT BIOMONITORING PROGRAM STATION 46 AT CASCADE LOCKS (RIVER MILE 149)
(all values are in mg/kg wet weight)
(Page 3 of 6)

Species	Year	Endrin	Heptachlor	cis Chlordane	trans Chlordane	cis Nonachlor	trans Nonachlor	Oxy-chlordane	Toxaphene
Largescale sucker	1970	ND	ND	NA	NA	NA	NA	NA	NA
Northern squawfish	1970	ND	ND	NA	NA	NA	NA	NA	NA
Northern squawfish	1970	ND	ND	NA	NA	NA	NA	NA	NA
Carp	1971	ND	ND	NA	NA	NA	NA	NA	ND
Carp	1971	0.01	ND	NA	NA	NA	NA	NA	ND
Largescale sucker	1971	ND	ND	NA	NA	NA	NA	NA	ND
Largescale sucker	1971	ND	ND	NA	NA	NA	NA	NA	ND
Northern squawfish	1971	ND	ND	NA	NA	NA	NA	NA	ND
Northern squawfish	1971	0 01	NA	NA	NA	NA	NA	NA	ND
Carp	1972	ND	ND	NA	NA	NA	NA	NA	ND
Largescale sucker	1972	ND	ND	NA	NA	NA	NA	NA	ND
Carp	1973	ND	ND	NA	NA	NA	NA	NA	ND
Largescale sucker	1973	ND	ND	NA	NA	NA	NA	NA	ND
Largescale sucker	1973	ND	ND	NA	NA	NA	NA	NA	ND
Northern squawfish	1973	ND	ND	NA	NA	NA	NA	NA	ND
Carp	1974	ND	ND	NA	NA	NA	NA	NA	ND
Largescale sucker	1974	ND	ND	NA	NA	NA	NA	NA	ND
Largescale sucker	1974	ND	ND	NA	NA	NA	NA	NA	ND
Northern squawfish	1974	ND	ND	NA	NA	NA	NA	NA	ND
Largescale sucker	1976	ND	ND	0 02	0.01	0 01	0 02	NA	ND
Largescale sucker	1976	ND	ND	0 05	0 01	ND	ND	NA	ND
Northern squawfish	1976	0 01	ND	0 32	0 19	ND	ND	NA	0 1

TABLE 27. SUMMARY OF ORGANOCHLORINE BIOACCUMULATION DATA FROM THE NATIONAL CONTAMINANT BIOMONITORING PROGRAM STATION 46 AT CASCADE LOCKS (RIVER MILE 149)
(all values are in mg/kg wet weight)
(Page 4 of 6)

Species	Year	Endrin	Heptachlor	cis Chlordane	trans Chlordane	cis Nonachlor	trans Nonachlor	Oxy-chlordane	Toxaphene
Largescale sucker	1978	0.01	ND	0.02	ND	ND	0.01	ND	ND
Largescale sucker	1978	ND	ND	0 03	0.01	0.01	0.02	ND	0.1
Northern squawfish	1978	ND	ND	0.01	ND	0.01	0 02	ND	0.1
Largescale sucker	1980	ND	ND	0.02	ND	ND	0.02	ND	0.1
Largescale sucker	1980	ND	ND	0.01	ND	ND	0 01	ND	0 2
Northern squawfish	1980	ND	ND	0.01	0 02	0 01	0.03	ND	0 1
Largescale sucker	1984	ND	ND	0 01	0 01	0 01	0 02	0.01	0.1
Northern squawfish	1984	ND	ND	0.01	0.01	0 01	0.01	ND	0.1

TABLE 27. SUMMARY OF ORGANOCHLORINE BIOACCUMULATION DATA FROM THE NATIONAL CONTAMINANT BIOMONITORING PROGRAM STATION 46 AT CASCADE LOCKS (RIVER MILE 149)
(all values are in mg/kg wet weight)
(Page 5 of 6)

Species	Year	alpha-BHC	gamma-BHC	HCB	methoxy-chlor	Mirex	Dacthal	PCA	Lipids (%)
Largescale sucker	1970	0.01	NA	NA	NA	NA	NA	NA	6 4
Northern squawfish	1970	0.01	NA	NA	NA	NA	NA	NA	5.6
Northern squawfish	1970	0.01	NA	NA	NA	NA	NA	NA	5 6
Carp	1971	NA	NA	NA	NA	NA	NA	NA	4.5
Carp	1971	NA	NA	NA	NA	NA	NA	NA	1 7
Largescale sucker	1971	NA	NA	NA	NA	NA	NA	NA	3.2
Largescale sucker	1971	NA	NA	NA	NA	NA	NA	NA	5 4
Northern squawfish	1971	NA	NA	NA	NA	NA	NA	NA	4.8
Northern squawfish	1971	NA	NA	NA	NA	NA	NA	NA	4 3
Carp	1972	NA	NA	NA	NA	NA	NA	NA	5
Largescale sucker	1972	NA	NA	NA	NA	NA	NA	NA	4 7
Carp	1973	NA	NA	NA	NA	NA	NA	NA	7 4
Largescale sucker	1973	NA	NA	NA	NA	NA	NA	NA	3.6
Largescale sucker	1973	NA	NA	NA	NA	NA	NA	NA	6
Northern squawfish	1973	NA	NA	NA	NA	NA	NA	NA	3 6
Carp	1974	NA	NA	NA	NA	NA	NA	NA	6.4
Largescale sucker	1974	NA	NA	NA	NA	NA	NA	NA	3
Largescale sucker	1974	NA	NA	NA	NA	NA	NA	NA	2 5
Northern squawfish	1974	NA	NA	NA	NA	NA	NA	NA	6.8
Largescale sucker	1976	0 07	0.01	0 01	NA	NA	NA	NA	6
Largescale sucker	1976	0 07	0 02	0 01	NA	NA	NA	NA	9 9
Northern squawfish	1976	0 01	ND	ND	NA	NA	NA	NA	7 9

TABLE 27. SUMMARY OF ORGANOCHLORINE BIOACCUMULATION DATA FROM THE NATIONAL CONTAMINANT BIOMONITORING PROGRAM STATION 46 AT CASCADE LOCKS (RIVER MILE 149)
(all values are in mg/kg wet weight)
(Page 6 of 6)

Species	Year	alpha-BHC	gamma-BHC	HCB	methoxy-chlor	Mirex	Dacthal	PCA	Lipids (%)
Largescale sucker	1978	ND	ND	ND	NA	NA	ND	NA	11.1
Largescale sucker	1978	0.01	ND	ND	NA	NA	ND	NA	8.5
Northern squawfish	1978	ND	ND	ND	NA	NA	ND	NA	12.3
Largescale sucker	1980	ND	ND	0.01	ND	ND	0.01	ND	12.7
Largescale sucker	1980	0.01	ND	0.01	ND	ND	0.01	ND	13.3
Northern squawfish	1980	ND	ND	ND	ND	ND	0.01	ND	6.5
Largescale sucker	1984	0.01	ND	0.01	NA	ND	ND	0.01	9.1
Northern squawfish	1984	ND	ND	ND	NA	ND	0.05	0.01	9.1

TABLE 28. SUMMARY OF HEAVY METALS BIOACCUMULATION DATA FROM THE NATIONAL CONTAMINANT BIOMONITORING PROGRAM STATION 46 AT CASCADE LOCKS (RIVER MILE 149)

[All values are in mg/kg (wet weight)]

Species	Year	Cadmium	Lead	Mercury	Arsenic	Selenium	Copper	Zinc	Lipids (%)
Largescale sucker	1976	0.15	ND[a]	0.05	0.87	NA	NA	NA	--
Largescale sucker	1976	NA	NA	NA	NA	NA	NA	NA	--
Northern squawfish	1976	ND	ND	0.23	ND	NA	NA	NA	--
Largescale sucker	1978	0.06	0.23	0 05	0.42	0 43	1.3	21.4	11 1
Largescale sucker	1978	0 05	0 27	0.11	0 25	0.41	1 1	23 6	8.5
Northern squawfish	1978	ND	ND	1.09	0 11	0 49	0 7	18 5	12 3
Largescale sucker	1980	0 03	ND	0.05	0.47	0.29	0 8	17 4	12 7
Largescale sucker	1980	0 03	ND	0 1	0 4	0 23	1	19.4	13.3
Northern squawfish	1980	0 02	ND	0.37	0 1	0 17	0 8	14.2	6 5
Largescale sucker	1984	0.04	0 09	0.1	0.22	0 24	1.01	20.79	--
Northern squawfish	1984	0.05	0 04	0.07	0.32	0.35	0.97	21 17	--

[a]ND = not detected, NA = not analyzed

TABLE 29. BIOACCUMUATION OF CONTAMINANTS BY WILDLIFE FROM THE LOWER COLUMBIA RIVER (Page 1 of 3)											
Study Reference	Species	Tissue	Location	River Mile	Segment	DDE (ppm)	DDD (ppm)	PCBs (ppm)	Lead (ppm)	Mercury (ppm)	Cadmium (ppm)
Garrett et al (1988)	Bald Eagle	Egg	Megler	15	1B	4	1.3	5.6	0.2	0.36	0.098
			Megler	15	1B	5.8	1.2	8.6	0.2	0.33	0.099
			Cliff Point	16	1B	15.2	2.4	17.3	0.2	0.16	0.099
			Cliff Point	16	1B	8.5	1.5	12.6	0.19	0.26	0.095
			Rocky Point West	22	1C	11.4	1	19.5	0.19	0.13	0.095
			Rocky Point West	22	1C	14.9	1.4	26.7	0.2	0.15	0.099
			Altoona	24	1C	16	1	19	--	--	--
			Jim Crow Pt	29	1C	10.7	2.1	11.8	0.28	0.2	0.1
			Jim Crow Pt	29	1C	7	1.4	8.8	0.22	0.13	0.098
			Tenasillahe Island	38	1C	4	1	4.8	0.2	0.2	0.099
			Tenasillahe Island	38	1C	6.6	1.5	6.9	0.2	0.25	0.098
			Abernathy	54	2C	12.5	2.6	17.6	0.2	0.17	0.098
			Abernathy	54	2C	8.8	1.9	13.3	0.2	0.16	0.098
			Abernathy	54	2C	5.3	1	7.8	0.22	0.13	0.099
		Blood	Fort Canby	2	1A	0.06	--	0.11	0.25	0.52	--
			Fort Canby	2	1A	0.04	--	ND	0.04	0.3	--
			Fort Columbia	7	1A	0.09	--	0.12	0.25	0.52	--
			Chinook	7	1A	0.02	--	ND	0.5	0.19	--
			Youngs River	14	1B	0.02	--	ND	0.03	1.4	--
			Mill Creek	17	1B	0.03	--	ND	0.2	0.51	--
			John Day Point	18	1B	0.15	--	0.19	0.27	3.1	--
			Rocky Point West	22	1C	0.024	--	ND	0.2	0.6	--
			W F Grays River	23	1C	0.03	--	0.13	0.05	0.24	--

TABLE 29. BIOACCUMUATION OF CONTAMINANTS BY WILDLIFE FROM THE LOWER COLUMBIA RIVER (Page 2 of 3)											
Study Reference	Species	Tissue	Location	River Mile	Segment	DDE (ppm)	DDD (ppm)	PCBs (ppm)	Lead (ppm)	Mercury (ppm)	Cadmium (ppm)
Garret et al. (1988) (Cont.)	Bald Eagle (Cont.)	Blood (Cont.)	W.F. Grays River	23	1C	0.03	--	ND	0.06	1.3	--
			Rocky Point East	23	1C	0.03	--	ND	0.6	0.25	--
			Miller Sands	24	1C	0.23	--	0.28	0.22	1.3	--
			Miller Sands	24	1C	0.7	--	1.5	0.2	1.6	--
			Miller Sands	24	1C	0.17	--	0.14	ND	ND	--
			Aldrich Point	32	1C	0.01	--	0.06	0.24	0.25	--
			Aldrich Point	32	1C	3.2	--	3.5	0.05	1.3	--
			Clifton Channel	36	1C	0.03	--	0.11	0.04	0.13	--
			Clifton Channel	36	1C	0.03	--	ND	0.7	0.2	--
			Clifton Channel	36	1C	1	--	1.4	0.24	3.8	--
			Maygar	60	2C	0.03	--	0.1	0.04	0.21	--
			Maygar	60	2C	0.03	--	ND	0.3	0.43	--
Henny and Anthony (1989)	Osprey	Eggs	Washougal	125	4B	3.3	0.26	5.6	--	--	--
			Multnomah Falls	136	4B	8.4	0.93	5.1	--	--	--
Henny et al. (1981)	River Otter	Liver (Males)	LCR nr. Portland		3B	4.8	0.15	17			
					3B	0.8	--	4.8			
					3B	2.1	--	5.0			
					3B	4.3	0.21	2.3			
					3B	2.5	--	7.3			

TABLE 29. BIOACCUMUATION OF CONTAMINANTS BY WILDLIFE FROM THE LOWER COLUMBIA RIVER (Page 3 of 3)											
Study Reference	Species	Tissue	Location	River Mile	Segment	DDE (ppm)	DDD (ppm)	PCBs (ppm)	Lead (ppm)	Mercury (ppm)	Cadmium (ppm)
Henny et al (1981) (Cont.)	River Otter (Cont.)	Muscle (Males)	LCR nr. Portland (Cont.)		3B	1.3		5 0			
					3B	0 8		4.8			
					3B	0.6		1 1			
					3B	1.5		8 3			
					3B	0 48		3.0			
		Liver (Females)			3B	0.88		7.0			
					3B	0 43		1 7			
		Muscle (Females)			3B	0.78		4 5			
					3B	0.53		1 6			
	Mink	Liver (Males)			3B	--		1.1			
					3B	--		1 2			
					3B	--		0 55			
					3B	0 45		0.1			
					3B	0 17		0.92			
		Liver (Females)			3B	--		0 95			
		Muscle (Males)			3B	--		0.90			
					3B	0.14		1.6			
					3B	--		--			
					3B	--		0 55			
					3B	0 18		0.82			
					3B	0 11		0 63			
	Juvenile Salmon	Muscle			3B	4 9 (3 9-5 7)		99 (88-115)			

them a diet containing 0.64 ppm PCB for 160 days (Platnow and Karstad 1973). Liver values associated with this diet ranged between 0.87–1.33 ppm wet weight. These values are similar to those reported in lower Columbia River mink, and indicate a contamination concern for mink. No equivalent information for other species was available. It should be noted, however, that species sensitivity to pollutants is known to be highly variable, so comparison of otter contamination to mink is inappropriate without additional information.

Two ongoing studies described in above sections (U.S. Fish and Wildlife Service 1990, 1991) will collect data from birds and river otters from river segment 1 (birds) and river segment 4 (otters). The samples will be analyzed for PCBs, pesticides, and dioxins/furans. No data are yet available from these studies.

2.5.3 Data Synthesis and Conclusions

Limited data characterizing bioaccumulation in fish tissue and other wildlife exist for the lower Columbia River. For fish tissue, only two studies provided the majority of the data. These studies were the U.S. EPA's Bioaccumulation of Selected Pollutants in Fish (U.S. EPA 1991c, also known as the National Bioaccumulation Study), and the Northwest Pulp and Paper Association's study assessing dioxins and furans in fish tissue (Beak Consultants 1989). In addition, the Portland General Electric Company sponsored a small survey of radionuclides in fish tissue at three sites near the Trojan Nuclear Power Plant (PGE 1990). Data from two other ongoing studies in the lower Columbia River (by U.S. the Fish and Wildlife Service and the Oregon Department of Environmental Quality, respectively) were not available and were not used in the analysis and summary.

A total of twenty sampling stations with tissue bioaccumulation data were utilized in the accepted studies. These locations are illustrated in Figures 17–20. In general, analyses for metals, pesticides, dioxins, furans, PCBs, and other organic compounds were conducted on the tissue. The most commonly collected species were coho salmon, chinook, steelhead, sturgeon, carp, suckers, and squawfish.

Table 30 presents the levels of most frequently detected pollutants in these fish species by river segment. The most commonly detected pollutants were ascertained by analysis of the raw data and determined to be:

- TCDF
- TCDD
- Mercury
- DDE
- PCBs.

TABLE 30. BIOACCUMULATION OF SELECTED POLLUTANTS IN LOWER COLUMBIA RIVER FISH TISSUE								
River Segment	Species	TCDF (mean) pg/g	TCDD (mean) pg/g	Other Dioxins/ Furans Detected	Hg (mean) µg/kg	DDE (mean) µg/kg	PCB (mean µg/kg	Other Organic Compounds Detected
1	Coho	0 476	ND (0.14-0.23)					
	Chinook (upstream)	1.708	ND (0 11-0.22)					
	Chinook (Tule)	7.058 (max 11)	0.316					
	Steelhead	0.69	ND (0.07-0.22)					
	Sturgeon	2 7	0 24 (4 NDs:0 12-0 16)					
	Carp	2 19	0.866 (max. 1.7)					
	Sucker	1 45	0.342 (+ 1 ND)					
1C	Sturgeon	21.50	0 88 (+ 1 ND)					
2	Squawfish (Wauna)	21 63	1 73	5	0 09	52	55 6	5
	Sucker (Wauna)	16.39	2.78	3	0 36			
	Squawfish (Longview)	20 43	1.615	5	0 23			
	Sucker (Longview)	28 34	5 23	4	0 05	107	174 72	5
3	Sturgeon (Kalama)	17 75	1.06					
	Sturgeon (Deer Is)	22.15	ND	1				
	Squawfish (St Helens)	9 03	1.28	5	0 33	34.3	37 1	3
	Sucker (St Helens)	10 83	2 29	7	0 05	85 4	150.5	5
4	Coho	0.542	ND (0 14-0.34)					
	Chinook (upstream)	3 44	0.21 (4 NDs 0.08-0.33)					
	Chinook (Tule)	4.54	0.27					
	Steelhead	ND (0.45-0 55)	ND (0.13-0 18)					
	Sturgeon	3 2	ND (0.22-0 28)					
	Squawfish	11.95	1 14	2	0.74			
	Sucker	15.95	2.28	5	ND	89 2E	92 36	4
	Carp	13.27	2 86	10	0 1	333 E	2043 1	12
Screening Levels[a]		2.97	0.19		170	54	209	

[a] Screening levels were generated from observed median tissue concentrations of fish nationwide (National Bioaccumulation Study) or tissue levels corresponding to EPA chronic water criteria, whichever were lower.

E = Estimated value

In addition to observed levels of these selected contaminants in tissues, Table 30 also presents the values that are used as contaminant screening levels for ranking of problem areas. These screening levels were obtained from using the lowest value among two sources:

- The reported median value of individual contaminant concentrations observed nationwide in the National Bioaccumulation Study (U.S. EPA 1991c), or

- The tissue level corresponding to the U.S. EPA chronic freshwater criteria (calculated using the Bioconcentration Factor, or BCF).

Pollutant levels were prioritized for fish species within each river segment by comparison of data from previous studies to the screening levels (Table 31). High, medium, and low priorities were assigned based on the following criteria:

- High priority was assigned to any detected level or detection limit of a contaminant that was above the screening level for that contaminant.

- Medium priority was assigned to any detected contaminant in a fish that was below the appropriate screening level.

- Low priority was assigned to any non-detected contaminant in a fish species with a detection limit below the appropriate screening level.

This prioritization of pollutants allowed for the comparison of problem pollutants between species and river segments. As shown in Table 31, dioxins and furans consistently appear as high priority pollutants in all non-anadromous species in all river segments. These compounds were also assigned a high ranking for the anadromous chinook salmon, but not for the coho or steelhead. The DDT pesticide degradation product, DDE, ranked as a high priority in suckers from river segments 2 through 4 (it was not analyzed in segment 1). DDE and PCBs also ranked as high priorities for carp in river segment 4.

Of the twenty bioaccumulation stations, seven were located in river segment 1. TCDF was detected in all species; TCDD was detected in chinook, sturgeon, carp, and suckers. Other contaminants were not analyzed. Four stations were located in river segment 2. Only squawfish and suckers were collected at these stations, and they all had detectable levels of TCDF, TCDD, and mercury. In addition, DDE and PCBs were detected in squawfish from Wauna,

TABLE 31. PRIORITIZATION OF PROBLEM POLLUTANTS IN LOWER COLUMBIA RIVER FISH TISSUES BASED ON SCREENING LEVELS[a]			
Species	High[b]	Medium[c]	Low[d]
River Segment 1			
Coho		TCDF	TCDD
Chinook	TCDF, TCDD		
Steelhead		TCDF	TCDD
Sturgeon	TCDF, TCDD		
Carp	TCDD	TCDF	
Sucker	TCDD	TCDF	
River Segment 2			
Squawfish	TCDF, TCDD	Hg, DDE, PCB	
Sucker	TCDF, TCDD, DDE	Hg, PCB	
River Segment 3			
Sturgeon	TCDF, TCDD		
Squawfish	TCDF, TCDD	Hg, DDE, PCB	
Sucker	TCDF, TCDD, DDE	Hg, PCB	
River Segment 4			
Coho	TCDD[e]	TCDF	TCDD
Chinook	TCDF, TCDD	TCDD	
Steelhead			TCDF, TCDD
Sturgeon	TCDD[e]	TCDF	
Squawfish	TCDF, TCDD	Hg	
Sucker	TCDF, TCDD, DDE	PCB	Hg
Carp	TCDF, TCDD, DDE, PCB	Hg	

[a] Chemical screening levels were generated from observed median tissue concentrations nationwide (U.S. EPA 1991c) or tissue levels corresponding to EPA chronic water criteria, whichever were lower.
[b] High priority: any detected level or detection limit above the screening level.
[c] Medium priority: any detected level below the screening limit.
[d] Low priority: any non-detected compound, whose detection limit is below the screening level
[e] High priority is based upon the mean detection limit; not a detected value.

OR and suckers from Longview, WA. Of the three stations located in river segment 3, one strictly analyzed radionuclides near the Trojan Nuclear Power Plant. For the six species analyzed, no detectable levels of radionuclides were found. Among the two other stations located in river segment 3, sturgeon, squawfish, and suckers revealed detectable levels of TCDF and TCDD. Squawfish and suckers from the St. Helens site also revealed detectable quantities of mercury, DDE, and PCBs. At the six stations in river segment 4, all species analyzed except steelhead contained TCDF. Chinook, squawfish, suckers, and carp all revealed detectable levels of TCDD. DDE and PCBs were detected in carp and suckers; mercury was found in squawfish and carp.

Based on the limited data available on pollutant bioaccumulation in fish and the inconsistencies in contaminants screened, it is difficult to ascertain problem areas within the river. However, the data suggested that dioxins and furans may be detectable in most areas of the river. These compounds were also detected in adult anadromous steelhead and salmon. However, because of their anadromous life history, attributing the contaminant levels solely to the Columbia River cannot be done.

Wildlife species which forage along the lower Columbia River are potentially exposed to levels of contaminants from the prey items they consume. A limited number of wildlife studies that emphasize tissue contaminant concentration have been performed on the river. These studies have focused on predatory birds (e.g., bald eagles, ospreys) and mammals (e.g., mink, river otters). Results of these studies have detected concentrations of DDE and PCBs in bald eagle and osprey eggs as high as 16.0 ppm and 26.7 ppm, respectively (Garrett et al. 1988; Henry and Anthony 1989). Studies of mink and river otters from the lower Columbia River conducted in 1978-1979 detected mean PCB concentrations of 9.3 ppm in livers of river otter and 1.09 ppm in livers of mink (Henry et al. 1981). The levels detected in mink were similar to levels in experimental mink that experienced total reproductive failure. Thus, although limited, the wildlife tissue data indicate that contamination has occurred in the past and at levels that may cause an impact.

2.6 BIOASSAY

2.6.1 Data Selection and Review Methods

The purpose of this section is to summarize existing bioassay data from the lower Columbia River. Types of information to be summarized include the sampling location, species, and types of bioassays performed. Table 32 presents summary information on the bioassay studies reviewed.

TABLE 32 SUMMARY OF EXISTING BIOASSAY DATA ON THE LOWER COLUMBIA RIVER
(Page 1 of 2)

Study Reference	Sampling Location	Bioassay Conditions					
		River Mile	River Segment	Medium	Species	Duration	Endpoint
Weyerhaeuser (1990)	Weyerhaeuser (Longview)	63	2C	Sediment	*Phytobacterium*	5, 15 min	Luminescence
				Sediment	*Hyalella* (amphipod)	10 day	Mortality
Johnson and Norton (1988)	Reed Island	124	4B	Sediment	*Daphnia*/*Hyalella* (amphipod)	48 h/96 h	Mortality
	Camas Slough	118	4A	Sediment	*Daphnia*/*Hyalella* (amphipod)	48 h/96 h	Mortality
	Vancouver (two stns.)	102-10	3B-4A	Sediment	*Daphnia*/*Hyalella* (amphipod)	48 h/96 h	Mortality
	Kalama	75	3A	Sediment	*Daphnia*/*Hyalella* (amphipod)	48 h/96 h	Mortality
	Longview (four stns.)	56-67	2C	Sediment	*Daphnia*/*Hyalella* (amphipod)	48 h/96 h	Mortality
	Ilwaco	3	1A	Sediment	*Daphnia*/*Hyalella* (amphipod)	48 h/96 h	Mortality
Young et al. (1988)	Tongue Point	18	1B	Sediment	*Macoma*	10, 20 day	Mortality
				Sediment	*Nephtys*	10 day	Mortality
	Offshore of river mouth	Reference station		Sediment	*Rhepoxynius*	10 day	Mortality
	West Beach (Whidbey)	Reference station		Sediment	*Grandidierella*	10 day	Mortality
Century West Engineering (1990)	Port of Vancouver (Bulk loading facility)	104	4A	Sediment (copper concentrate)	Rainbow trout	96 h	Mortality

TABLE 32. SUMMARY OF EXISTING BIOASSAY DATA ON THE LOWER COLUMBIA RIVER
(Page 2 of 2)

Study Reference	Sampling Location	Bioassay Conditions					
		River Mile	River Segment	Medium	Species	Duration	Endpoint
Dawley et al. (1975)	Prescott	72	3A	Water	Rainbow trout	49-59 day	Mortality
					Salmon	55 day	Mortality
					Smelt	12 day	Mortality
					Crappie	20 day	Mortality
					Squawfish	35 day	Mortality
					Suckers	46 day	Mortality
					Largemouth bass	--	Mortality
					Whitefish	--	Mortality
					Squawfish	12 day	Feeding response

Only five bioassay studies have been performed on the lower Columbia River. Of these, most used mortality as an endpoint for both acute and chronic studies. A variety of test organisms have been used, including amphipods, other invertebrate species, and fish. Although effluent bioassays are routinely performed by some of the industrial dischargers on the river (e.g., Weyerhaeuser in Longview) as part of their NPDES monitoring requirements, it is the bioassay studies utilizing river sediments that are of most interest for the reconnaissance survey.

A summary of the bioassay study results for each river segment is provided below. When appropriate, data tables will be presented which report the results of the bioassay studies. An assessment will be made regarding the comparability of bioassay data from each section.

2.6.2 Review of Accepted Data

2.6.2.1 Data Summary: River Segment 1. Two studies have reported bioassay results using sediments collected from river segment 1. The results of these studies are summarized in Table 33. Sediments from the Ilwaco Boat Basin were collected as part of a reconnaissance survey of sediment toxicity at five lower Columbia River ports (Johnson and Norton 1988). Acute bioassays were performed for the amphipod *Hyalella azteca* and the cladoceran *Daphnia pulex*. Both species showed zero percent mortality in duplicate bioassays. The second study was designed to assess the toxicity of sediments from Tongue Point, Oregon, located in the Columbia River estuary (Young et al. 1988). The sediments were collected from a former ship supply and storage site. The development of this site for commercial shipping required dredging and eventual disposal of these sediments. Chronic bioassays using Tongue Point sediments were performed using two amphipod species (*Rhepoxynius abronius* and *Grandidierella japonica*), a clam (*Macoma nasuta*), and a polychaete (*Nephtys caecoides*). A low level of mortality (1-8 percent) was observed in assays using the amphipod species. In general, although some mortality was observed with the clam *Macoma* and the polychaete *Nephtys*, these invertebrates seemed less sensitive than the amphipods to sediment contaminants.

2.6.2.2 Data Summary: River Segment 2. Two studies have reported bioassay results from sediments collected from river segment 2 (see Table 32). The results of these studies are reported in Table 33. The lower Columbia River Port study described above (Johnson and Norton 1988) reported sediment bioassay results from four stations in the Longview vicinity (see Figure 18). These sediments did not cause much mortality in tests using the amphipod *Hyalella*. In contrast, higher mortalities ranging from 8.8 to 22.5 percent were observed with the test species *Daphnia*. The second study reported results from the annual NPDES permit class II inspection of the Weyerhaeuser facility in Longview. Sediments were collected from

TABLE 33 SUMMARY OF MEAN PERCENT MORTALITIES FROM ACUTE BIOASSAYS CONDUCTED ON SEDIMENTS FROM THE LOWER COLUMBIA RIVER
(Page 1 of 2)

Study Reference	Sampling Location	*Grandidierella*		*Rhepoxynius*	*Macoma*		*Nephtys*
		Flow Through	Static	Flow Through	10-Day	20-Day	10-Day
Young et al. (1988)	Tongue Point (C1)	6	8	10	0	2.4	4
	Tongue Point (C2)	6	8	13	0	0	3
	Disposal Site F (C.R. Mouth)	4	4	7	0	3.2	5
	West Beach (Whidbey Island)	1	5	4	--	--	--
Study Reference	Sampling Location	*Hyalella*	*Daphnia*				
Johnson and Norton (1988)	Laboratory control	6.5	0				
	Reed Island (Reference area)	7	27 5				
	Camas Slough	3.3	6.3				
	Van. Lower Turning Basin	0	10				
	Vancouver below VANALCO	3 3	7 5				
	Kalama Chemical Pier	7	15				
	Below Longview Fibre	0	22.5				
	Longview below Weyco	1.7	8.8				
	Longview below Reynolds	0	22.5				
	Coal Creek Slough	0	12.5				
	Ilwaco Boat Basin	0	0				
Study Reference	Sampling Location	*Hyalella*					
Weyerhaeuser (1990)	Weyco (Longview) outfall	30					
	Downstream Dilution Zone	7					
	Upstream of Weyco (Longview)	0					

TABLE 33. SUMMARY OF MEAN PERCENT MORTALITIES FROM ACUTE BIOASSAYS CONDUCTED ON SEDIMENTS FROM THE LOWER COLUMBIA RIVER
(Page 2 of 2)

Study Reference	Sampling Location	*Salmo*					
		100 mg/L	1,000 mg/L	100 mg/L (Am Test)			
Century West Engineering (1990)	Port of Vancouver (Zone 1)	0	--	0			
	Port of Vancouver (Zone 2)	0	--	--			
	Port of Vancouver (Zone 3)	0	--	0			
	Port of Vancouver (Zone 4)	0	--	--			
	Port of Vancouver (Zone 5)	0	0	10			
	Port of Vancouver (Zone 6)	0	90	--			
	Background	0	--	--			
	Control	0	0	0			

upstream of the outfall (background), at the edge of the dilution zone, and at the outfall. Bioassay tests using *Hyalella* resulted in 30 percent mortality for the outfall sand, 7 percent for the edge of dilution zone sand, and 0 percent for the background sand. No toxicity was indicated for any of the sediments using the Microtox bioassay (Weyerhaeuser 1990).

Bioassays were also performed on both the Weyerhaeuser final effluent and the final centrifuged effluent sludge. No toxicity was indicated for any of the final effluent bioassays. The sludge did not cause mortality in the rainbow trout, but was toxic to the bacteria used in the Microtox bioassay (EC50 equaled 7.1 percent).

2.6.2.3 Data Summary: River Segment 3. There have been two bioassay studies performed for sites in river segment 3. The results of these studies are reported in Table 33. The lower Columbia River Port study described above (Johnson and Norton 1988) reported sediment bioassay results from sediments collected near the Kalama Chemical Pier. The mean percent mortality of two replicates was 7 percent for *Hyalella* and 15 percent for *Daphnia*. The second study was designed to study the effects of supersaturation of dissolved gases on fish (Dawley et al. 1975). In this study, conducted at the NMFS Prescott Field Station near Longview, several fish species were exposed to supersaturated (> 100% N_2) Columbia River water for a period of 12–59 days. The supersaturated water caused mortality to all species, particularly smelt and the salmonids.

2.6.2.4 Data Summary: River Segment 4. Two studies have reported bioassay results from sediments collected from river segment 4 (see Table 33). The lower Columbia River Port study described above (Johnson and Norton 1988) reported sediment bioassay results from Reed Island, Camas Slough, and two stations in the Vancouver vicinity. Mortality of *Hyalella* was generally low, ranging from 0 to 7 percent, while mortality of *Daphnia* was slightly higher, ranging from 6.3 percent at Camas Slough to 27.5 percent at Reed Island.

The second study reported sediment bioassay results from the Port of Vancouver's bulk loading facility. This facility handles a copper concentrate which has been classified as an extremely hazardous waste (EHW). Results of a series of acute lethal bioassays with rainbow trout indicate that the sediments in the vicinity of the bulk loading facility caused fish mortality only at the site nearest the facility at a concentration of 1,000 mg/L.

2.6.3 Data Synthesis and Conclusions

Of the five identified studies containing bioassay data using lower Columbia River media, four studies used sediments and one study used water as the test medium. Sediments from 24 locations (see Table 33) along the lower river were tested for lethal toxicity (measured by mortality) to a few invertebrate and fish species. The sediments assayed were collected mostly from around a few industrialized areas or point sources. Although several studies used amphipods as test species, the data are only marginally comparable because different species and different assay methods were used. Inferences on sub-lethal toxicities of the sediments tested are also not possible because mortality was the primary end-point used in the bioassays.

The patchy and limited distribution of test sediments used in bioassays, the inconsistency in species and methods used, and the generally high variability in bioassay results does not allow an overall assessment of the toxicities of lower Columbia River sediments to resident biota.

Only one study (Dawley et al. 1975) used lower Columbia River water as a bioassay test medium. This study tested the effects of supersaturation of dissolved gases on several fish species. We did not identify any bioassay studies testing the effects of river water contaminants on biota health.

3.0 IDENTIFICATION OF POTENTIAL PROBLEM AREAS AND DATA GAPS

3.1 INRODUCTION

The availability of data and an asessment of data gaps has been reviewed and detailed for each media in the previous chapter. This chapter summarizes that information and attempts to provide an overall assessment of data availabilty, data gaps, and potential problem areas The identification of potential problem areas is limited by the amount of available data for the lower Columbia River. Large gaps in data coverage exist for all media evaluated, on both spatial and temporal scales.

Many studies have been conducted on the lower Columbia River since approximately 1980. Most of those studies were done in association with CREDDP to investigate and characterize conditions in the estuary. Other studies focus on the maintenance and dredging of the main navigational channel or harbor areas and involve sediment contaminants. The USGS has provided long-term water quality monitoring data from two site in the lower river measuring conventionals, nutrients, and metals. Other agencies, firms, and educational institutions have done site-specific studies ranging from sediment bioassays to fish tissue bioaccumulation to National Pollutant Discharge Elimination System (NPDES) permit monitoring studies. However, there is a general lack of studies that survey the entire lower Columbia River. Some segments of the river are completely unstudied for some media. In addition, very little data exist from depostional areas where contaminants would be expected to accumulate.

Data on contaminant concentrations in wildlife, fish, and invertebrate tissues are also generally lacking. Bioaccumulation data are currently being collected by several state and federal agencies, and these studies will contribute greatly to the bioaccumulation database. However, systemwide ecological data on tissue levels do not exist for benthic infauna, for fish assemblages, or wildlife.

Further compounding the major problem of lack of data, nearly all the data collection and analysis efforts to date have been inconsistent. Such a lack of consistency greatly limits the comparisons and conclusions tha can be made from the existing data.

Because of the general lack of data, this section focuses on the data gaps for each media (Table 34). These will be discussed in the following sections. Potential problem areas based

TABLE 34. DATA GAPS IDENTIFIED IN THE LOWER COLUMBIA RIVER	
Media	Segment
Water Quality	General Data Gap
Sediment	
Dioxins and Furans Resin Acids	1A
Dioxins and Furans Resin Acids	1C
Resin Acids	2A
Metals Pesticides PAHs PCBs Dioxins and Furans Resin Acids	2B
Resin Acids	3A
Metals Pesticides PAHs PCBs	3B
Benthic Infauna	General Data Gap
Fish Communities	General Data Gap
Bioaccumulation	Limited Data Gap
Bioassays	General Data Gap

on the available data exceeding screening levels are also identified in this section (Table 35 and Figures 21–24).

3.2 WATER COLUMN

Historical water quality data for the lower Columbia River are not widely available. Many of the stations sampled were meant to characterize a potential point source of pollution. The data from these sampling events are not generally useful for assessing the water quality of the lower Columbia River as a whole, because of the limited areal and temporal coverage of the sampling stations. The available data represent a patchwork of sampling points, both in space and time. No reconnaissance survey of the lower Columbia River has been performed in the past.

A primary objective of this report was to identify problem areas based on the available data. The informal criteria used here to prioritize problem areas was the presence of detectable levels of pollutants and their relationship to the freshwater water quality criteria (see Table 3). Because many of the metals and organic compounds for which analyses have been performed are not typically detected in lower Columbia River water samples, the detected values take on increased importance. A ranking of problem areas based on these criteria is given in Table 4. A more complete discussion of the methods used to create Table 4 are given in Section 2.1.3. By discounting the contaminated metals data from the two USGS stations at Warrendale and Beaver Army Terminal, the limited data collected in the last three years lead to the conclusion that there are no water quality problem areas with respect to toxic substances on the lower Columbia River.

Given the limitations of the sampling design of most of the water quality surveys described herein, the entire lower Columbia River can be considered a data gap with respect to water quality (see Table 34). A considerable amount of conventional and nutrient data have been collected, but the ecological and public health ramifications of these data are still largely unknown.

The limited nature of the historical lower Columbia River data emphasizes the importance of performing a reconnaissance survey that provides comprehensive areal coverage of sampling stations. Because no specific location can be considered to have been adequately sampled, with the possible exception of the USGS monitoring station at Warrendale, sampling locations for the Reconnaissance Survey should be determined based on the location of existing point sources, beneficial use areas, tributaries, and river segment boundaries, rather than on existing data.

TABLE 35. HIGH-PRIORITY PROBLEM AREAS IDENTIFIED IN THE LOWER COLUMBIA RIVER

Media	Segment	Compound
Water Quality		
Metals Bacteria	2A	Cadmium, Copper
Pesticides	2C	Heptachlor
Metals	3B	Chromium
Sediment		
Metals[a] Pesticides[b] PAHs	1A	Cadmium, Copper, Lead All pesticides Total PAHs
Metals Pesticides	1B	Cadmium Total DDT, Chlordane, Dieldrin, Other Pesticides
Pesticides	1C	Total DDT
Pesticides Dioxins and Furans	2A	Total DDT All Forms (congeners)
Pesticides PAHs PCBs Dioxins and Furans Resin Acids	2C	All Pesticides Total PAHs Total PCBs All Forms Total Resin Acids
Dioxins and Furans	3A	Total HpCDD and OCDD
Metals Pesticides Dioxins and Furans Resin Acids	4A	Copper, Lead Total DDT, DDD, DOE, DOT Total TCDF, Total HxCDF, Total HxCDD, Total HpCDF, Total HpCDD, OCDF, OCDD Total Resin Acids
Metals	4B	Manganese
Fish Tissue		
Pesticides	1A and 1B 2A and 2B 3A and 3B 4A and 4B	TCDF, TCDD TCDF, TCDD, DDE TCDF, TCDD, DDE TCDF, TCDD, DDE
PCBs	4A	Total PCBs

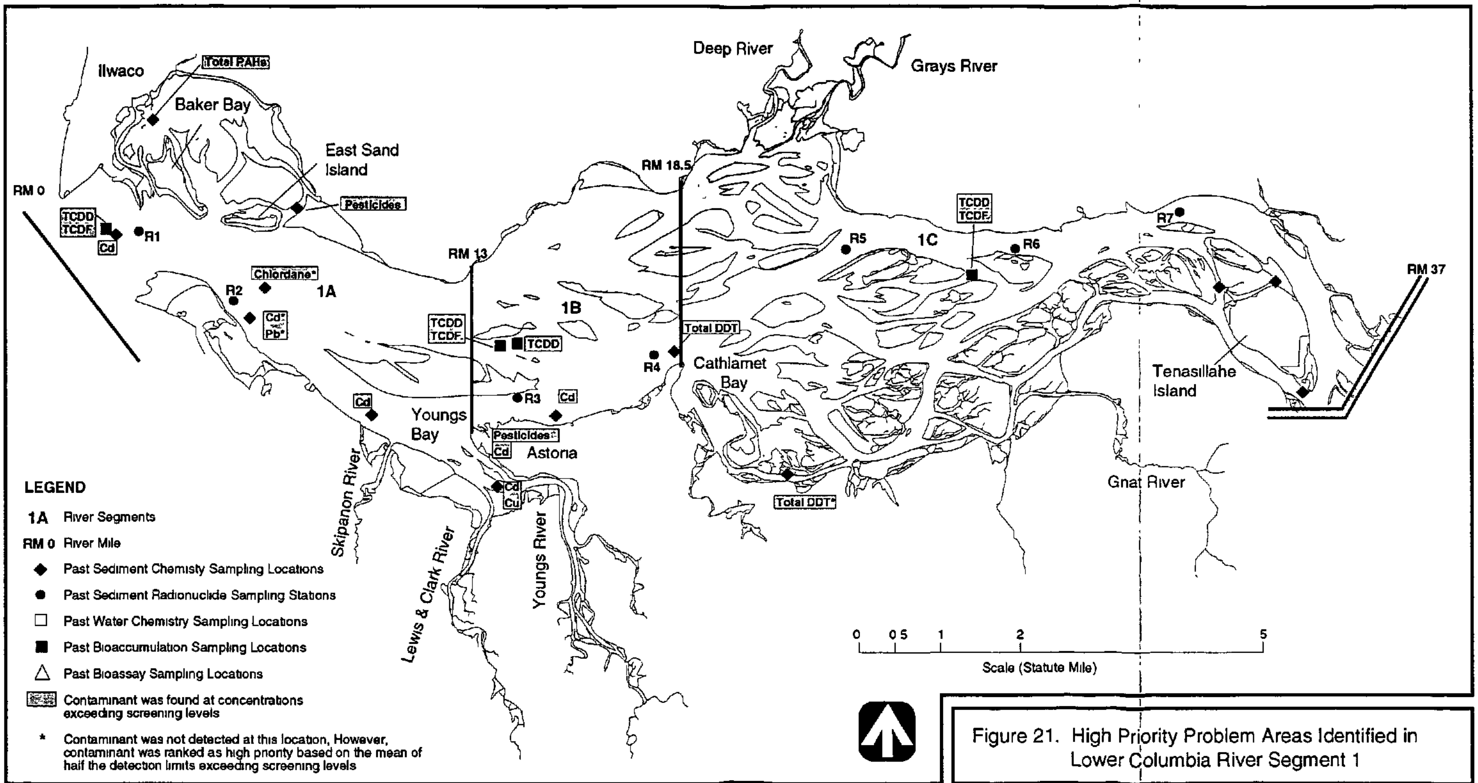


Figure 21. High Priority Problem Areas Identified in Lower Columbia River Segment 1

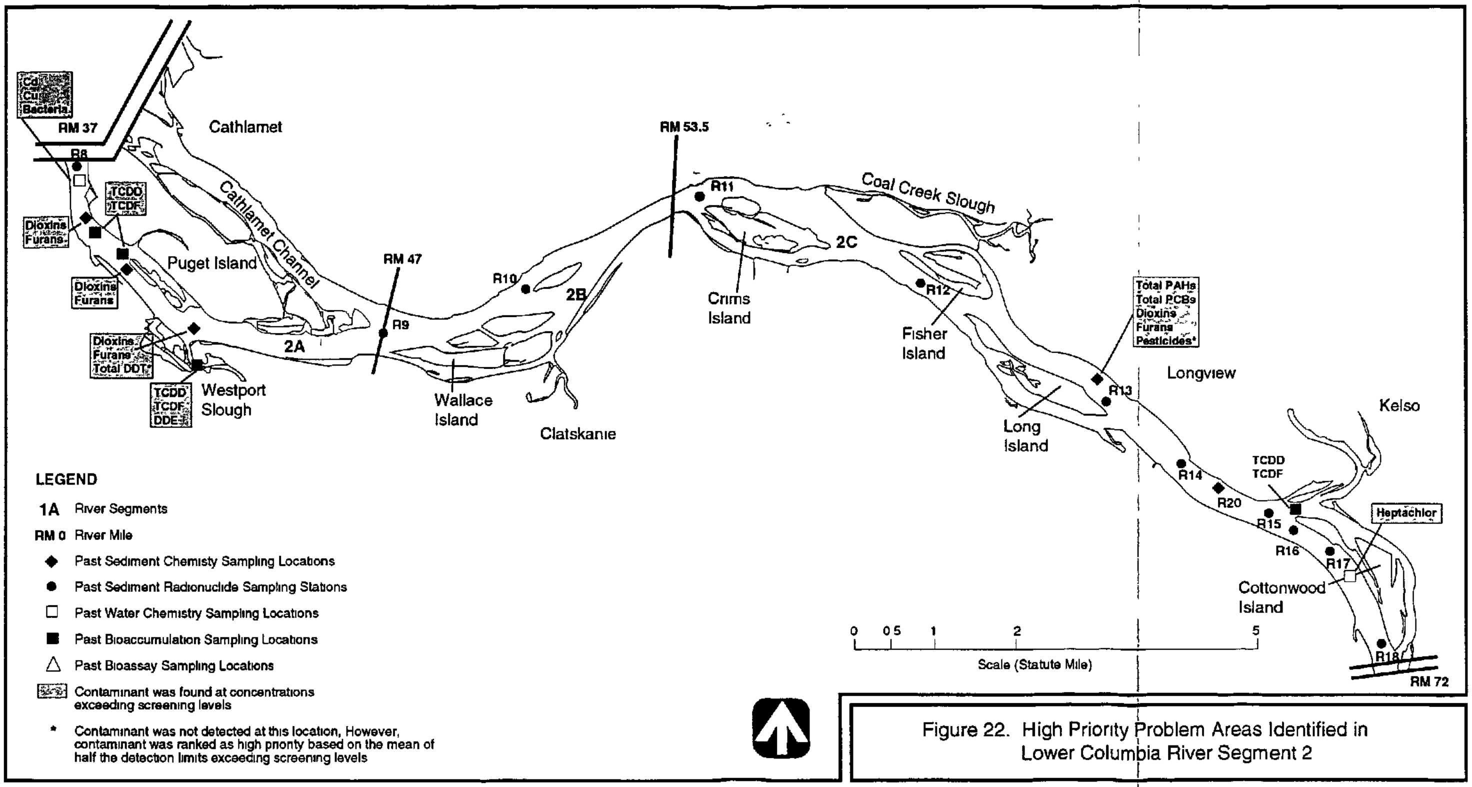


Figure 22. High Priority Problem Areas Identified in Lower Columbia River Segment 2

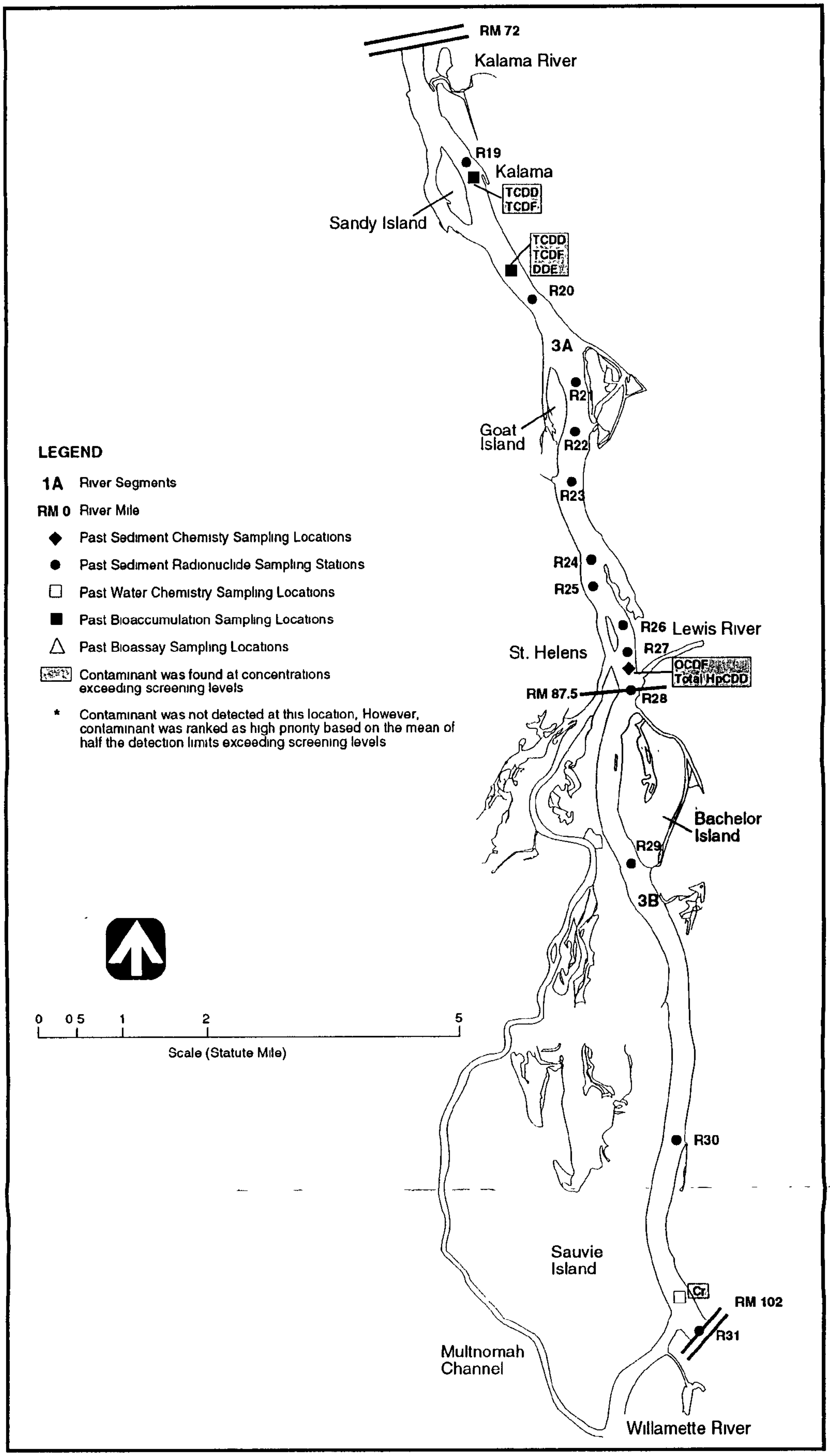


Figure 23. High Priority Problem Areas Identified in Lower Columbia River Segment 3

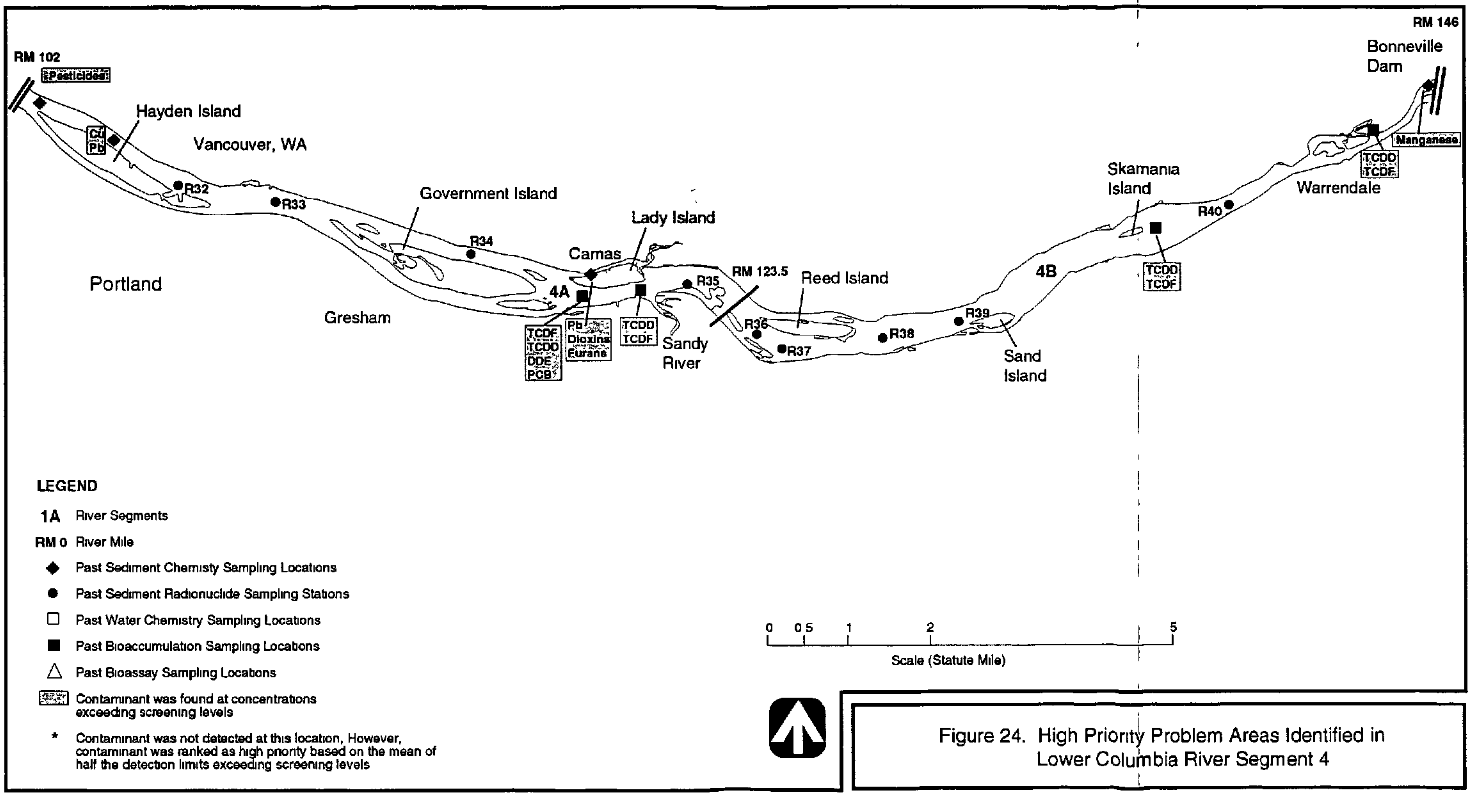


Figure 24. High Priority Problem Areas Identified in Lower Columbia River Segment 4

3.3 SEDIMENTS

Areas of the lower Columbia River with high observed concentrations of sediment contaminants, as well as areas with little to no data on sediment chemistry have been identified based on a review and evaluation of previous studies. Location 4-Chinook Channel, 8-Young's Bay, 9-around Astoria, 15, 16, 17-around Wauna, 19-Longview, 24, 25-in the Portland/Vancouver area, and 27-Camas are considered potential problem areas or "hot spots" based on at least two sediment contaminants being detected above screening levels (or detected in the case of dioxins and furans) (see Figures 21-24; Table 35). Several areas of the lower Columbia River contain limited or no data on sediment chemistry (Table 34). These areas include: river segments 2B and 3B for which no data exist; and locations 15 and 16 where sediment metal concentrations were not measured.

Sediment dioxin and furan measurements were only conducted at six locations, and resin acids were measured only at four locations in the lower Columbia River, despite the sizeable pulp and paper mill operations in the area.

In general, spatial coverage of sediment sampling is limited in the river. Large areas in several of the river segments have not been sampled for contaminant levels (see Figures 9-12; Table 34).

Based on these observations, the following recommendations for the design of the reconnaissance survey sampling plan can be made:

- Sample sediments in areas from the mouth of the river to Bonneville Dam to provide an overall characterization of sediment quality. Ensure that adequate coverage of stations is accomplished for all river segments (e.g., segments 2B and 3B).

- Collect sediment samples from all habitat types but focus sampling in depositional areas where contaminants would be expected to accumulate.

- Analyze sediment samples for a broad range of compounds such as all priority pollutants and include additional chemicals of concern. Analyze as many samples as possible for dioxins/furans at locations throughout the lower river. Coordinate sampling and analyses of dioxins/furans with the ongoing Oregon DEQ tissue studies.

3.4 BENTHIC INFAUNA

Problem areas (i.e., sites where the structure of the benthic infaunal assemblage indicates disturbance by anthropogenic factors) have not been identified in the lower Columbia River. Much of the historical work addresses changes in benthic communities associated with the disposal of dredged materials. These study sites are located in erosional environments, dominated by medium sands, and are not expected to accumulate pollutants.

Two of the studies reviewed addressed specific pollution events. Investigators of a copper concentrate spill at the bulk loading facility at the Port of Vancouver (Century West Engineering Corporation 1989) reported the densities of members of major taxonomic groups at stations up to 640 m downstream. Unfortunately, these data are too gross and unfocused to permit testing of hypotheses relating to toxic effects of the spill, short of complete burial of the benthic community. The Columbia River oil spill study (Blahm et al. 1980) is similarly flawed. Invertebrates are again identified only to major taxa so that perturbations in community structure can be identified only on a gross scale.

Currently, some description of benthic macrofaunal communities is available for every segment of the lower Columbia River except Segment 2B, Cathlamet Channel to Beaver (see Figures 13 through 16; Table 20). Sampling of depositional areas has been, in general, relatively sparse. In addition, although a great deal of data is available for the upper and lower zones of the estuary, information is relatively sparse for Segment 1B, Youngs Bay to Tongue Point.

Data on benthic macroinvertebrates vary greatly in quality. Holton et al. (1984) produced detailed information on the distributions, population dynamics, and life histories of macrofauna for the Columbia River Estuary Data Development Program but their efforts were limited to the lower 46 miles of the river. Several recent reports by the National Marine Fisheries Service, Pt. Adams Biological Field Station, described species abundances at sites in the unprotected flats stratum of the estuary and in the center and along the sides of the main channel at sites up to RM 127. However, little information of this quality is available for depositional areas, protected flats, and minor channels where pollutants are expected to accumulate. Most of the older studies (i.e., those conducted prior to 1980) identified benthic organisms only to the level of major taxonomic groups. Because individual taxa are likely to differ in their physiological tolerances and requirements, it is difficult to assess the effects of human activities on communities described on such gross scale. Peaks in the reproduction and recruitment of individual species of polychaetes, bivalves, and amphipods at a site may be somewhat predictable but are likely to vary in timing and magnitude from year to year.

Based on the existing data (good historical coverage of the estuary, very limited data in the freshwater reach) it is not possible to make an assessment of the usefulness of benthic communites in identifying impacted areas along the river. Therefore, the following recommendations for the reconnaissance survey can be made:

- Benthic communities should be sampled throughout the river to better characterize the community types in different reaches and habitats (e.g., main channel, protected flats, depositional areas). Some sampling stations should be located in areas of the river where little or no data exist.

- Benthic community stations should be located at the same stations as the sediment chemistry stations. This will allow an examination of the usefulness of benthic communities as indicators of sediment quality.

- More information is needed on the life histories of individual species of macrofauna, especially in segments 2–4 of the lower Columbia River. However, it is not recommended that life history studies be conductred in the first phase of the Bi–State Program.

3.5 FISH COMMUNITIES

Because of the mobility, seasonal presence, and anadoromous life histories of the fish that reside in the study area, it is not appropriate to use fish assemblages as an indicator of problem areas within the lower Columbia River. As discussed, the physical, biological, and ecological relationships that govern the presence or absence of fish communities is complex and at times not entirely understood. In order to separate the effects of pollutants from the effects of other environmental conditions on fish assemblages and populations, the input of toxic substances would have to be quite high. The effects of lower, longer–term inputs of toxic substances are probably undetectable at the fish community level or are indistinguishable from other environmental variables that affect fish assemblages. The most appropriate use of fish community data would be to identify those individual species in the study area that have ecological linkages to contaminated areas. Those species with a sufficient ecological link to problem areas may be appropriate to study biological endpoints such as bioaccumulation and enzyme activity.

The largest data gaps regarding fish assemblages and their ecological relationships are for river segments 2, 3, and 4. As discussed, very few studies have been conducted in these freshwater reaches of the river compared to the estuary. Data on species assemblages, seasonal presence, habitat types, major and minor prey, and prey densities are necessary to more fully understand the ecological relationships of fish in River Segments 2, 3, and 4. Data should be collected and evaluated geographically and temporally, similar to those studies conducted in the estuary.

3.6 BIOACCUMULATION

Based upon the detected levels of contaminants analyzed in fish tissues from previous studies and the screening levels illustrated in Table 30, pollutant levels were prioritized for fish species within each river segment. These resultant priorities are summarized in Table 31.

This prioritization of pollutants allowed for the comparison of problem pollutants between species and river segments. As shown in Table 31, dioxins and furans consistently appear as high priority pollutants in all non-anadromous species in all river segments. These compounds were also assigned a high ranking for the anadromous chinook salmon, but not for the coho or steelhead. The DDT pesticide degradation product, DDE, ranked as a high priority in suckers from river segments 2 through 4 (it was not analyzed in segment 1). DDE and PCBs also ranked as high priorities for carp in river segment 4.

There are several noticeable data gaps from the accepted studies. Historical data on fish and wildlife bioaccumulation of contaminants of concern in the lower Columbia River lack consistency in species and geographical coverages to provide a comprehensive assessment of bioaccumulation effects in the study area. Whereas the twenty accepted fish bioaccumulation stations generally were collected throughout the study area, many of the anadromous species analyzed are not known to spend much time feeding in the river. Although these anadromous fish (e.g. salmon and steelhead) are useful for control groups and for human exposure potential through consumption, they do not provide information on bioaccumulation from the river, by themselves. There is a noticeable lack of comprehensive, well replicated fish samples from species that spend their life feeding in the study area. In addition, an inconsistent suite of chemicals were analyzed between the different studies.

Based upon the analyzed potential problem areas and data gaps, several recommendations for the sampling plan can be made:

- Analyze the same species or suite of species for the same contaminants throughout the study area. Of course, this is dependent on finding species that consistently occur within the study area.

- Include analyses of dioxins, furans, and organochlorine pesticides to determine if historic trends are verified.

- Select non-anadromous species that spend the majority of their life histories feeding within the study area.

- Analyze a similar suite of chemicals in tissues as are being analyzed in sediment and water, for information about bioaccumulation rates.

Three ongoing studies (U.S. Fish and Wildlife Service 1990, 1991; Oregon Department of Environmental Quality 1990) are more comprehensive in scope than the existing studies. All three of these studies intend to analyze PCBs, pesticides, and dioxin/furans. In all three studies, carp will be collected. Northern squawfish and crayfish will be collected in two of the three studies. With respect to the sampling effort planned for the reconnaissance survey, the sampling design of the three ongoing studies should be complemented, not repeated.

3.7 BIOASSAY

Existing bioassay data using lower Columbia River media are extremely limited, making identification of problem areas based on bioassay data alone impractical. The bioassay studies collected as part of Task 1 encompass only a small range of the potential areas of concern. Amphipods have been used in several sediment bioassays, allowing some comparison of toxicity between different sites on the lower Columbia River. Little or no information is available on the potential toxicity of sediments found away from potential point sources of pollution.

The considerable variation in results further complicates interpretation of the data. For example, although sediments collected around Longview resulted in a 22.5 percent mortality using *Daphnia* as the test species. The same sediment resulted in zero percent mortality using *Hyalella* as the test psecies. *Daphnia* mortality using sediments from a reference area (Reed

Island) was higher than that observed with Longview sediments, suggesting that the 22.5 percent mean mortality was no dur to the toxcitiy of Longview contaminants.

Based on the limited data and distribution of test sediments and water samples, it is not possible to identify problem area in the lower Columbia River. The entire strech of river might be considered a data gap in terms of sediment toxicities to bioassay organisms (Table 34)

Several recommendations for the reconnaissance survey sampling plan can be made:

- Although bioassays have been shown to be useful indicators of sediment toxicity in many environments, the tests performed in the lower Columbia River have been few in number and have had inconsistent results. Therefore, it is not recommended that bioassays be performed in the first phase of the Bi-State Program.

- Several different test species have been used in the lower Columbia River. Most are well established bioassay organisms but are not native to the river. Review of the benthic community data indicates that the amphipods *Eohaustorius estuarius* and *Corophium salmonis* are present in the marine and freshwater portions of the river and could be used as within-system test organisms.

- Use of bioassays in later phases of the program may be appropriate after further verification of their usefulness.

4.0 CONCLUSIONS AND RECOMMENDATIONS

Over 160 documents were collected, reviewed, and evaluated for existing data on the water column, sediments, and biological quality of the lower Columbia River. These studies were used to characterize the lower river quality and to identify potential problem areas and data gaps. Limitations of the data for all media prevented an integrated analysis of data from location to location. The problem areas, data gaps and existing station locations were recorded and analyzed to fully complement and contribute to the design of the reconnaissance survey sampling plan design.

The following observations were drawn from the existing data:

- **Water Column.** Metals and organic compounds have generally not been detected in water samples. Nutrient data do not indicate problems with over abundances of nutrients. The designation of medium- or high-priority sampling areas was due on pre-1981 data. Among recently sampled locations, neither medium-priority nor high-priority designations were made, except for Warrendale and Beaver Army Terminal stations where metals concentrations were found. Based on the limited data available, however, the entire lower Columbia River is a data gap for water quality (see Table 34).

- **Sediments.** Based on contaminant screening levels, approximately ten potential problem areas were identified from existing sediment data (see Figures 21–24; Table 35). The most prominent areas were Ilwaco, Camas Slough, Longview, and Portland/Vancouver area. Most data showed contaminant levels either below the screening levels or at undetected values. Data interpretation between studies was difficult because of the inconsistent suite of chemicals analyzed, varying sediment types, differing analytical techniques, and large time spans between surveys.

- **Benthic Invertebrates.** Very limited information on impacts to benthic invertebrate populations was available for the lower Columbia River. For benthic populations in depositional environments, there is some limited data on river segment 1. Benthic invertebrates are a data gap for most of the lower Columbia River (see Table 34).

- **Fish Communities.** No existing studies were found that used fish communities to assess impacts to the aquatic environment of the lower Columbia River. Therefore, this indicator is a data gap (see Table 34).

- **Bioaccumulation.** Based on the relatively few station locations and small suite of chemicals analyzed, dioxins, furans, and DDE exceeded screening levels in most segments of the river (see Figures 21-24; Table 35). Total PCBs were exceeded in carp in river segment 4 (the uppermost segment). However, bioaccumulation data interpretation was very limited given the highly variable suites of chemicals analyzed at most stations.

- **Bioassays.** Based on limited bioassay data, *Hyalella* mortality data also suggest a medium-priority problem area near Longview in river segment 2. Kalama and Reed Island, in river segments 3 and 4, respectively, are also classified as medium priority areas.

Specific recommendations for each medium were presented in Section 3.0 and will not be repeated here. However, two general recommendations are discussed below:

- To characterize the existing health of the lower Columbia River, a much more coordinated effort among state, federal, and local agencies will be required. This coordination should entail standardizing the field and analytical techniques used to collect new data. Lack of consistency was one of the greatest limitations of the existing data for evaluating water quality conditions.

- The existing reference database should be maintained and updated periodically so that there is a central repository for existing studies conducted on the lower Columbia River.

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