FINAL REPORT
8526-07

LOWER COLUMBIA RIVER BI-STATE PROGRAM

RECONNAISSANCE SURVEY OF THE LOWER COLUMBIA RIVER

TASK 7: CONCLUSIONS AND RECOMMENDATIONS

MAY 25, 1993

Prepared By:
TETRA TECH

In Association With:
EVS CONSULTANTS
DAVID EVANS & ASSOCIATES

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The Lower Columbia River
Bi-State Water Quality Program

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This document includes a summary of the six major tasks performed as part of the lower Columbia River Reconnaissance Survey by Tetra Tech, Inc (Tt), EVS Consultants, Inc., and David Evans and Associates (DEA) Tetra Tech, Inc had the lead responsibility for Tasks 1, 2, 3, 6, and 7 (this document), and the review of all other documents produced as part of the Lower Columbia River Water Quality Bi-State Program. David Evans and Associates had the lead responsibility for Task 5, the nonpoint sections of Task 2, and production of the Columbia River GIS EVS Consultants was primarily responsible for Task 4 and the sediment chemistry and benthic sections of the Task 6 report The principal authors of each of the summary chapters are listed below

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LIST OF ACRONYMS

AOX	Adsorbable organic halogens
BHC	Benzene hexachloride for HCH (hexachlorocyclohexane)]
BCF	Bioconcentration factor
BOD	Biochemical oxygen demand
cfs	cubic feet per second
CREDDP	Columbia River Estuary Data Development Program
CROMS	ACOE's Columbia River database
CSO	Combined storm-sewer overflow
DDD	Dichloro diphenyl dichloroethane
DDE	Dichloro diphenyl dichloroethylene
DDT	Dichloro diphenyl trichloroethane
°C	Degrees centigrade
DL	Detection limit
DO	Dissolved oxygen
EMAP	U S EPA's Environmental Monitoring and Assessment Program
EPA	U S Environmental Protection Agency
ER-L	Effects-range low
EROD	Ethoxyresorufin O-deethylase
L	Liters
GIS	Geographical information system
IQR	Inter-quartile range
lb	Pounds
LC	Lethal concentration
LOEL	Lowest observed effects level
MFO	Mixed function oxidase
MGD	Million gallons per day

µg	Micrograms
mg	Milligrams
NASQUAN	National Stream Quality Accounting Network
NBS	National Bioaccumulation Study
NCASI	National Council of the Paper Industry for Air and Stream Improvement
NCBP	National Contaminant Biomonitoring Program
NOAA	National Oceanic and Atmospheric Administration
NOEL	No observed effects level
NPDES	National pollutant discharge elimination system
NYS	New York State
OAR	Oregon Administrative Rules
ODEQ	Oregon Department of Environmental Quality
OR	Oregon
PAH	Polycyclic aromatic hydrocarbon
PCB	Polychlorinated biphenyl compound
PCDD	Polychlorinated dibenzodioxin
PCDF	Polychlorinated dibenzofuran
pCi	Picocuries
PGE	Portland General Electric
pg	Picograms
ppm	Parts per million
QA	Quality assurance
QC	Quality control
RM	River mile
SMPTOX3	Simplified method program-variable complexity stream toxics model
STORET	U.S. EPA's data storage and retrieval system database
TCDD	Tetrachloro-dibenzodioxin
TCDF	Tetrachloro-dibenzofuran
TEC	Toxicity equivalent concentration
TMDL	Total maximum daily load
TOC	Total organic carbon
TOXIWASP	Toxics water analysis simulation program

TP	Total phosphorus
TSS	Total suspended solids
USACOE	U S Army Corps of Engineers
USGS	U.S Geological Survey
USFWS	U S Fish and Wildlife Service
WA	Washington
WAC	Washington Administrative Code
WATSTORE	USGS's data storage and retrieval system database
WDOE	Washington Department of Ecology
WWTP	Wastewater treatment plant

1.0 OBJECTIVES OF THE BI-STATE PROGRAM

The Columbia River is the largest river entering the northeastern Pacific Ocean, and is the second largest river in the United States in terms of volume discharged (Fox et al. 1984). The river's drainage basin, which covers 660,480 km^2 in the U.S. and Canada (Simenstad et al. 1990), is the focus for major fishing, forestry, hydroelectric, shipping, agricultural, manufacturing, and recreational activities.

The lower Columbia River is the section of the river from the river's mouth at Astoria, Oregon to Bonneville Dam at river mile 146. This section forms part of the border between Washington and Oregon, and supports the most concentrated population and industrial base along the U.S. portion of the river. The lower river's drainage subbasin contains several major tributaries. Much of the land use in the subbasin is devoted to forestry and to a lesser extent agriculture.

Major population centers on the lower Columbia River include Astoria, Portland, and St. Helens in Oregon and Ilwaco, Longview-Kelso, Kalama, Vancouver, and Camas-Washougal in Washington. The utility of the lower Columbia River as a major shipping channel has encouraged the development of major port facilities and heavy industrial activity in these population centers. The lower Columbia also supports major salmonid and sturgeon fisheries, and is home to three national wildlife refuges (Lewis and Clark, the Julia Butler Hansen and the Ridgefield National Wildlife Refuges) and a wildlife management area (Sauvie Island Wildlife Management Area). The estuarine portion of the lower Columbia also provides critical nursery and feeding habitat for several economically important fish and invertebrate species.

Increased urbanization, coupled with extensive industrial and agricultural activities along the lower Columbia River and in its drainage subbasin, have potentially resulted in longstanding detrimental impacts to the water quality of the river. The historical water quality problems have potentially caused significant damage to the region's fisheries resources and jeopardized beneficial and characteristic uses of the river. Public concern has also been expressed regarding the transport and impacts of toxic chemicals into the highly productive and sensitive estuarine habitats of the river.

In response to the water quality concerns regarding the river, the Oregon and Washington state legislatures directed the formation of the Bi-State Lower Columbia River Water Quality Program (Bi-State Program) in 1990. The Bi-State Program is a four-year plan designed to assess overall water quality and formulate management plans for the lower Columbia River. The Bi-State Program's overall four-year goals are:

- To identify water quality problems.
- To determine if beneficial/characteristic uses are impaired.
- To develop solutions to problems in the lower river.
- To make recommendations on a long-term bi-state framework.

The Bi-State Program is to accomplish these goals by carrying out the following tasks:

- Involve the public in management of the lower river through education and by inviting public participation.
- Develop work plans that identify the studies needed to characterize the river's water quality.
- Evaluate existing data and conduct reconnaissance surveys.
- Carry out baseline studies.
- Conduct advance studies and recommend long-term monitoring.
- Make recommendations to regulatory agencies.

2.0 SUMMARY OF FIRST YEAR'S STUDIES

The goal of the technical studies of the Bi-State program's first year was to establish the technical framework for determining the quality of the water, sediment and aquatic biota of the lower Columbia River, which will serve as the basis for directing further study efforts and corrective action as needed.

To meet this goal, the following activities were to be carried out:

1. Review and synthesize existing information to begin characterizing water quality and physical characteristics of the river system.

2. Identify study protocols and implement screening surveys to determine current conditions and provide a basis for determining and prioritizing further study needs.

3. Evaluate data collected during screening surveys.

4. Identify and prioritize future study and action needs.

The activities were implemented by completing the following seven tasks:

Task 1. Technical review of existing studies and data to determine water, biological and sediment quality status.

Task 2. Inventory and characterization of existing point, nonpoint and in-place pollutant sources for determining pollutants of concern and loading potential.

Task 3. Description of river dynamics, based on review of physical and hydrologic characteristics of the lower Columbia River, which will assist in determining the environmental fate of pollutants and developing monitoring approaches.

Task 4. Review of biological data and identification of potential biological indicators, to support development of a biological monitoring approach.

Task 5. Identification and location of beneficial uses of the river to begin identifying areas sensitive to pollution.

Task 6. Reconnaissance survey to begin to determine current water, biological and sediment quality conditions.

Task 7. Compilation of the above information in a manner that potential problems and further study or action can be identified and prioritized.

The present report presents the results of Task 7. The objectives and results of the first 6 tasks are summarized in the following sections.

2.1 TASK 1: EXISTING DATA REVIEW AND SYNTHESIS

2.1.1 Objectives

Task 1: Existing Data Review and Synthesis, was a technical review of existing studies and data to determine the water, biological, and sediment quality of the river. Task 1 had five objectives in gathering these data:

1. Compile and review existing studies and relevant data to begin characterizing the current water quality and physical characteristics of the lower Columbia River.

2. Identify potential problem areas.

3. Identify current and ongoing studies in the study area.

4. Identify data gaps.

5. Use results in the designs of the sampling plan for the reconnaissance survey (Task 6).

To complete these studies, the river was broken into several major and minor segments. Major segments represent areas with similar physical features and confluences of major tributaries (Figure 2.1-1). Subsegments were generally based on major geographical features along the river and confluences with smaller tributaries. Data examined from various studies in each of these segments are presented in four subtask reports that emphasize the recent data used to identify problem areas and data gaps within the study area:

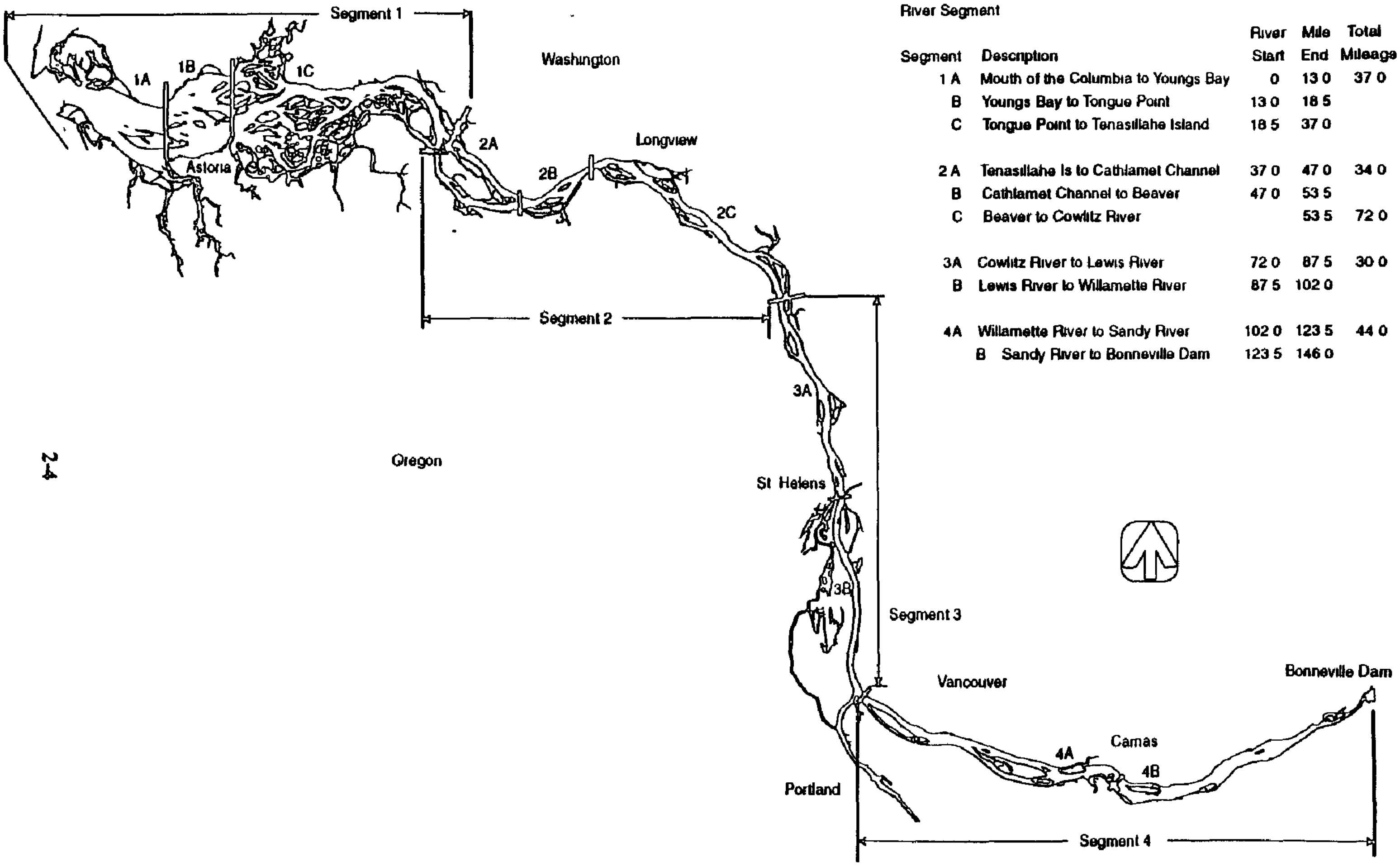
1. *Reconnaissance Survey of the lower Columbia River. Task 1. List of materials to evaluate* (Tetra Tech 1991a).

2. *Reconnaissance Survey of the lower Columbia River Task 1 report: Problem area and data gap identification ranking framework* (Tetra Tech 1991b).

3 *Reconnaissance Survey of the lower Columbia River. Task 1: Summary of existing data and preliminary identification of problem areas and data gaps* (Tetra Tech 1992a).

4. *Reconnaissance Survey of the lower Columbia River. Task 1: Summary report* (Tetra Tech 1992b).

The following sections briefly explain the major findings of Task 1.



River Segment

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

Figure 2 1-1 Vicinity Map of the lower Columbia River

2.1.2 Results

Data from several media, including the water column, sediments, benthic (bottom-dwelling) animals, fish, toxicity tests (bioassays), and tissue concentrations of contaminants (bioaccumulation) were evaluated for this task. Each data type was summarized by examining existing data (for years 1980 to 1991) for each of four major and ten minor divisions of the lower river. Within each segment, potential problem areas and data gaps were identified.

Results of the problem area identification analyses for each data type were 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).

This section summarizes the results of the rankings and attempts to provide an overall assessment of data availability, data gaps, and potential problem areas. Generally, three limitations weakened the analyses for each data type: 1) adequate data were often not available, 2) methods and/or laboratory detection limits varied considerably among the studies or were not reported making comparisons difficult, and 3) 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. Although the sediment data were particularly useful, even the best data were still too limited to make a scientifically valid evaluation of sediment conditions on the river.

Many studies have been conducted on the lower Columbia River since approximately 1980. Although data older than ten years may have some utility (e.g., if ten years ago fluoride contamination caused a serious fish kill it may be relevant if flows and/or permit levels are changed), but use of this older data was limited by cost and relative benefit. Most of those studies were done in association with the Columbia River Estuary Data Development Program (CREDDP) to investigate and characterize ecological, physical, and chemical conditions (e.g., trophic linkages, tidal vs. fluvial influences) in the estuary. Other studies focused on the maintenance and dredging of the main navigational channel or harbor areas and involve sediment contaminants. The U S. Geological Survey (USGS) has provided long-term water quality monitoring data from two sites 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 (e.g., water column, sediments, and fish and shellfish tissue). In addition, very little data exist from depositional areas where contaminants would be expected to accumulate.

Data on contaminant concentrations in wildlife, fish, and invertebrate tissues are 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, system-wide 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 in terms of methods used and parameters analyzed. Such a lack of consistency greatly limits the comparisons and conclusions that can be made from the existing data.

Results of each medium evaluation will be discussed in the following sections. The results for each medium include a general review of the existing data, an integrated summary of available data, and comparison of the summarized data to screening levels. Potential problem areas based on the available data exceeding screening levels are then discussed for each medium.

2.1.2.1 Water Column. 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 were 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 and may be due in part to attenuation of contaminants throughout the water column and to the analytical detection limits achieved in these studies.

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 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 at low concentrations.

Based on the available water quality data, data are insufficient to identify consistent trends in lower Columbia River water quality with respect to federal and state water quality criteria. In general, temperature is commonly measured, but no substantial violations have been documented. Additionally, bacteria data are very sporadic, with no significant violations noted. 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 in the lower river. 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, or Kalama.

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 was 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 applicable freshwater water quality criterion, 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. In this evaluation, data from each measured parameter at a given water quality station were compared against the detection limit and the water quality criterion. 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 a given parameter was not detected 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 2.1-1 and Figures 2.1-2 through 2.1-5 summarize the results of this evaluation of the water quality data.

The majority of the water quality stations from which acceptable data are available were classified as medium-priority. Most of the stations classified as medium- or high-priority, however, have not been sampled within the last ten years (i.e., the period over which existing data were evaluated). Water quality in a dynamic system such as the lower Columbia River is dependent primarily on active pollutant sources, unlike sediment and tissue quality, which are also affected by previous pollutant sources in the form of sediment deposition. Thus, water quality measurements of ten or more 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 certain data from the USGS stations at Beaver Army Terminal and Warrendale were classified as medium-priority. The parameters which triggered the medium priority classification were all trace metals, with the exception of bacteria at Beaver Army Terminal. Two of the three bacteria samples, included in the Task 1 review, at Beaver Army Terminal contained detectable levels of fecal coliforms with a mean of 7 colonies/100 mL. 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 did not support identification of any water quality problem areas with respect to toxic substances on the lower Columbia River.

TABLE 2.1-1. HIGH-PRIORITY PROBLEM AREAS[a] IDENTIFIED IN TASK 1 OF THE BI-STATE PROGRAM

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

[a] Specific areas are shown in Figures 2.1-2 to 2.1-5

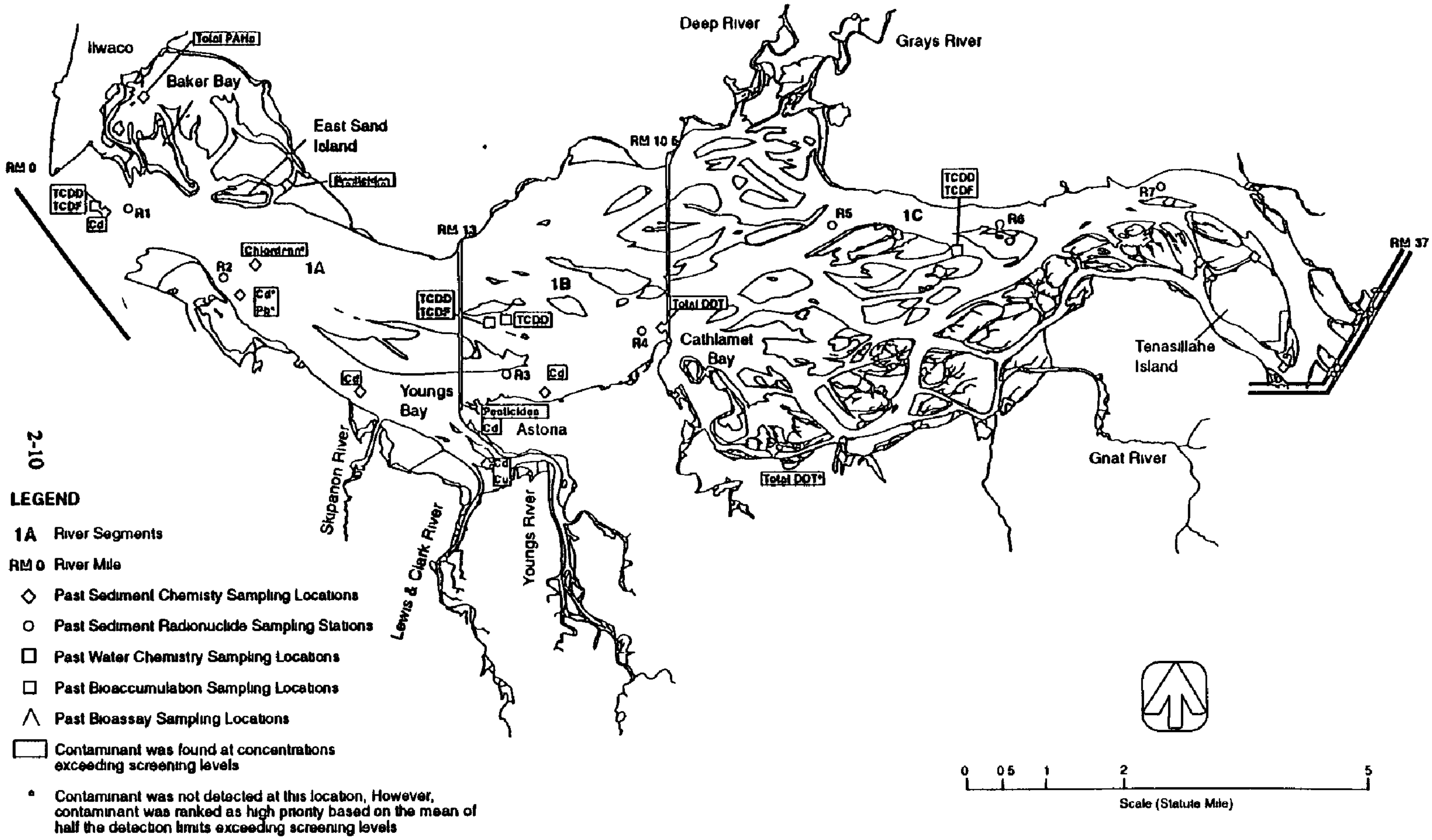


Figure 2.1-2 High Priority Problem Areas Identified in lower Columbia River Segment 1.

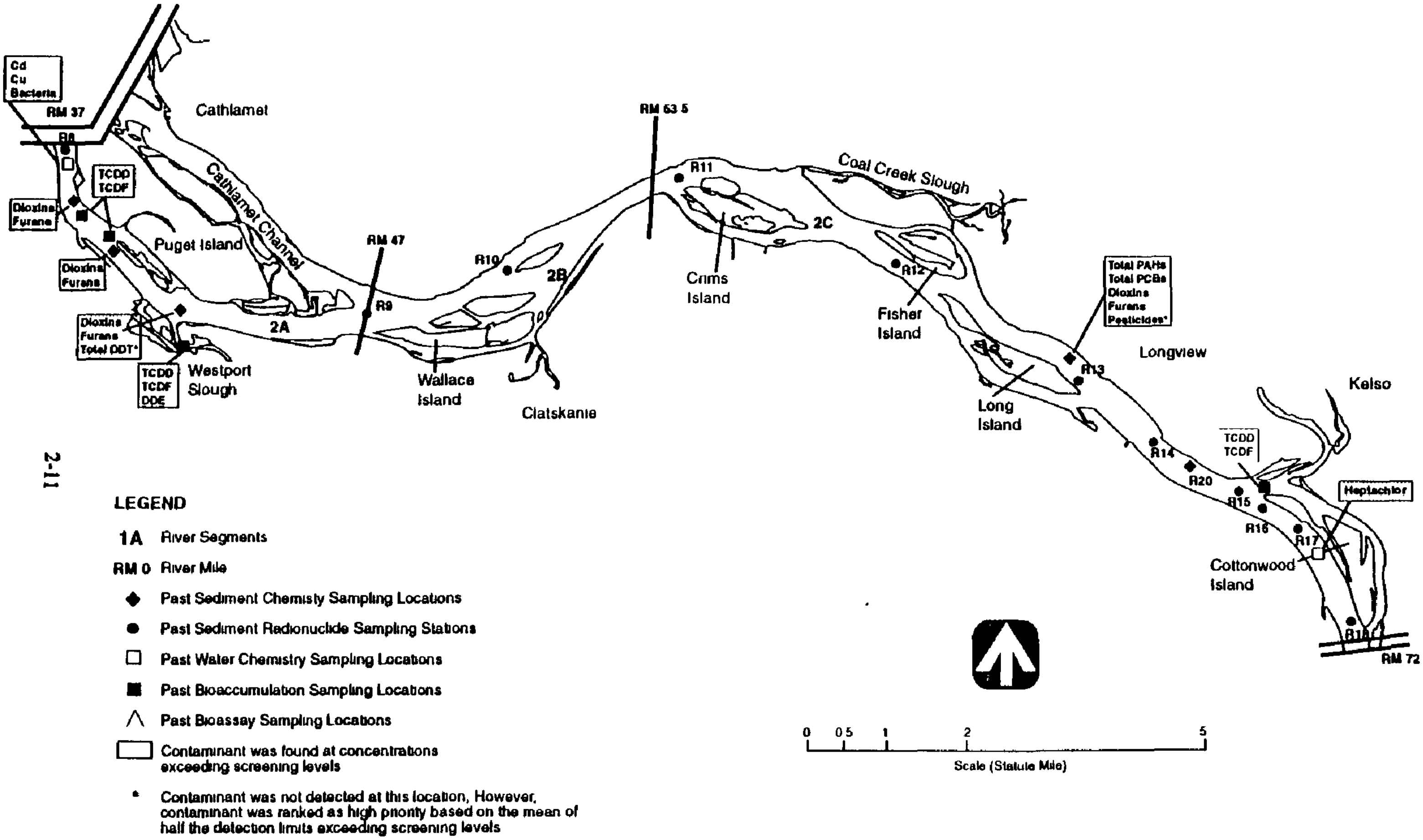


Figure 2 1-3 High Priority Problem Areas Identified in lower Columbia River Segment 2.

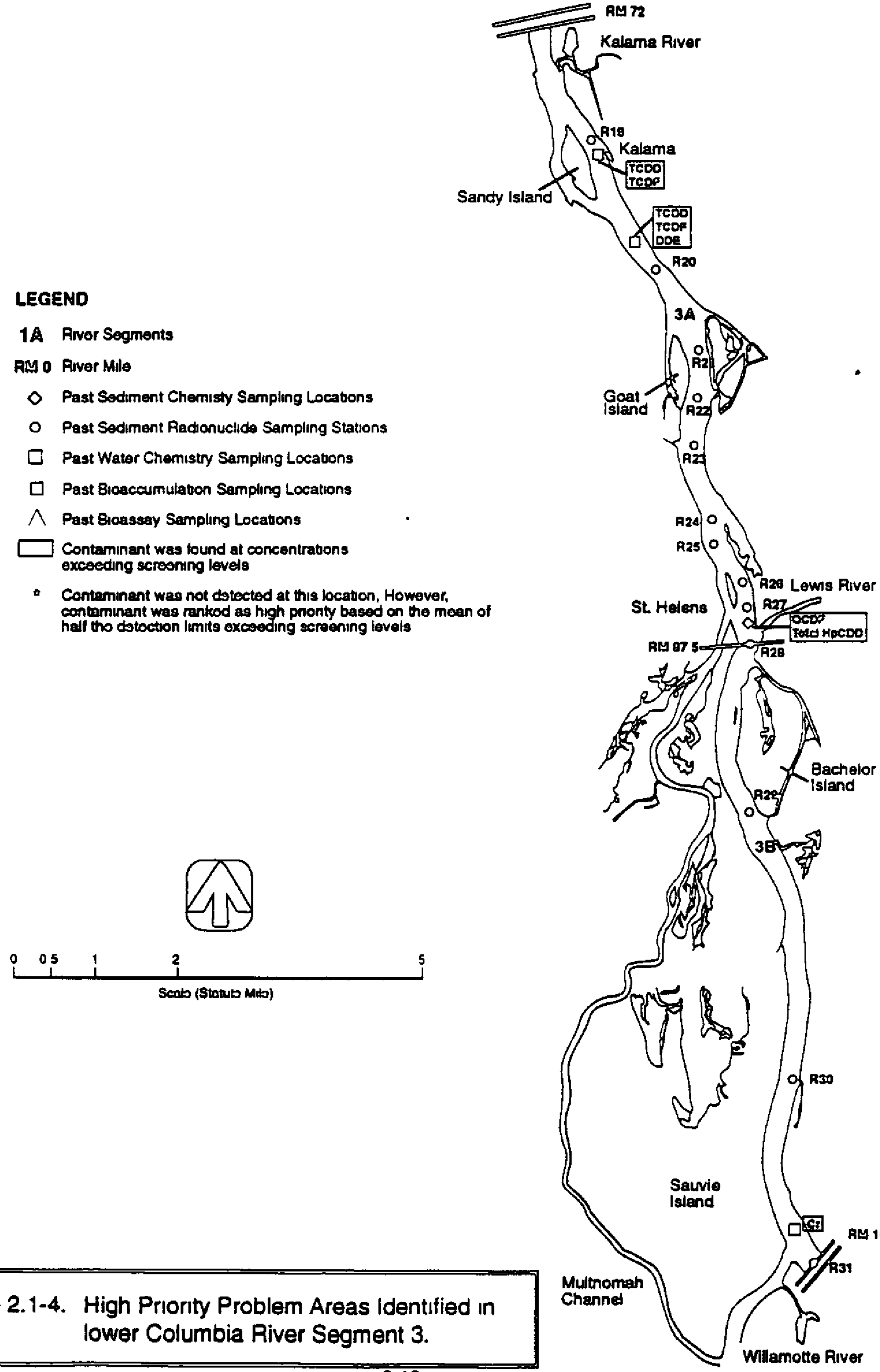
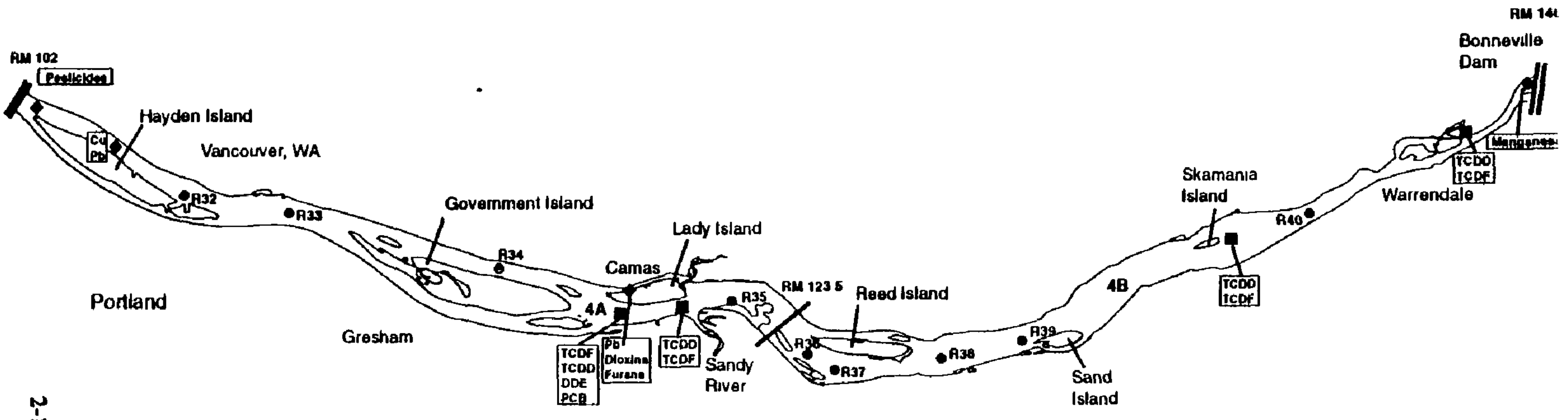


Figure 2.1-4. High Priority Problem Areas Identified in lower Columbia River Segment 3.



LEGEND

1A River Segments

RM 0 River Mile

◆ Past Sediment Chemisty Sampling Locations

● Past Sediment Radionuclide Sampling Stations

☐ Past Water Chemistry Sampling Locations

■ Past Bioaccumulation Sampling Locations

/\ Past Bioassay Sampling Locations

▭ 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

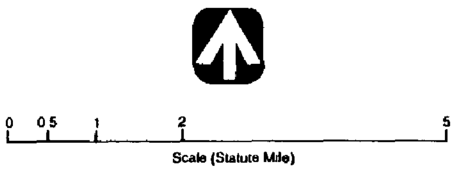


Figure 2 1-5 High Priority Problem Areas Identified in lower Columbia River Segment 4.

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.

2.1.2.2 Sediments. 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. Historical sampling stations tended to be concentrated in bays, harbors, and main channel dredging sites with little sampling in backwaters, sloughs, and depositional areas. Nearly all the stations were sampled in single sampling events, with no consistency in the suite of chemical parameters measured at each site. No studies have attempted a systematic survey aimed at assessing the overall state of sediments in the entire lower Columbia River.

Only a very general assessment of the historical state of sediment contamination was 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. These studies were conducted in both active and depositional areas of the estuary, with most sampling stations associated with dredging areas. Metals were 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 detectable 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 (Figures 2.1-2 through 2.1-5, Table 2.1-1) 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.

Comparisons of historical sediment radionuclide levels (from studies performed in the 1970s) with derived screening levels (the lowest 10th percentile) revealed that radionuclide concentrations were elevated at all the locations surveyed. With the exception of potassium-40 (a naturally occurring radioactive isotope), 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 However, this assumption should be tested by sampling radionuclide levels in deeper layers of sediments

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 in this segment.

With the exception of a few locations around heavily industrialized urban areas on the river (e.g., Longview, Portland/Vancouver), an evaluation of the historical data (by comparison to the screening levels) suggests that sediment quality is not generally an issue of high concern. This evaluation is, however, strongly qualified 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 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 sediments. A systematic survey of sediments at strategic locations throughout the lower river is strongly recommended to derive a scientifically sound assessment of current conditions in the lower Columbia River.

2.1.2.3 Benthic Infauna. Over 20 reports describing benthic macrofauna of the lower Columbia River were reviewed. Most studies were focused on river segment 1, primarily as studies conducted for the Columbia River Estuary Data Development Program (CREDDP) in the early 1980s. Several other studies addressed problems associated with the effects of dredged-material disposal on benthic assemblages. Reports were rejected if their methods were inadequate, data were obviously flawed, or if no data beyond species lists were presented. Because of inconsistent methods and analyses, only total macrofaunal densities and the densities of dominant taxa (or major taxonomic groups) were uniformly available among studies. The available benthic infauna data are useful only for describing general trends of density and dominant taxa. Most information on benthic infauna in the lower Columbia River are limited by inadequate reference areas, inconsistent methods, and their design as studies characterizing rather than identifying affected areas.

The model of macrofaunal distributions described by Holton et al. (1984) for the Columbia River estuary is supported by the data reviewed for Task 1. 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 2.1-2). 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 matter. This phenomenon has also been described by other authors (Davis and Spies 1980; Rao 1980; Kaniewska-Prus 1983). Like polychaetes in the marine and estuarine environment, 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. 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.

TABLE 2.1-2. 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 Oligochaetes Amphipods Copepods	$<5,000/m^2$
		Unprotected flats	Nematodes Oligochaetes *Corophium salmonis* *Eohaustorius estuarius*	$<5,000/m^2$
		Protected flats	Oligochates *Hobsonia florida* *Pseudopolydora kemp* *Macoma balthica*	10,000-30,000/m^2[a]
Transition	1C, 2A	Channel	Oligochaetes *Corophium salmonis* Heleid larvae	$<5,000/m^2$
		Unprotected flats	Oligochaetes *Corophium salmonis* *Corbicula manilensis* *Neanthes limnicola* Ostracods Chironomid larvae	500-12,000/m^2[b]
		Protected flats	Nematodes Oligochaetes *Corophium salmonis*	$>10,000$-35,000/m^2
Freshwater	2C		Oligochaetes *Corophium salmonis* *Corbicula manilensis* Heleid larvae	$<5,000/m^2$
	3A-4B		Oligochaetes *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.

Based on the availability of historical data for this review, it was recommended that future benthic 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. The stratified sampling design and multivariate analytical techniques used by Holton et al. (1984) were recommended to describe the lower Columbia River study area as a whole to provide a tool for describing the relationships between community composition and environmental parameters.

2.1.2.4 Fish Communities. 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 no specific studies where an assessment of a potential problem area occurred. 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 the effects of degraded water quality.

2.1.2.5 Bioaccumulation. 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. Environmental Protection Agency's (U.S. EPA's) Bioaccumulation of Selected Pollutants in Fish (U S. EPA 1991a, 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 the U.S. Fish and Wildlife Service and the Oregon Department of Environmental Quality) were not available and were not used in the analysis and summary. However, information about the ODEQ study was factored into the development of the sampling plan for Task 6 and subsequent data analysis.

A total of twenty sampling stations with tissue bioaccumulation data were utilized in the accepted studies. 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.

The most commonly detected pollutants were determined to be:

- Tetrachloro-dibenzofurans (TCDFs or furans)
- Tetrachloro-dibenzodioxins (TCDDs or dioxins)
- Mercury
- Dichloro diphenyl dichloroethylene (DDE)
- Polychlorinated biphenyls (PCBs).

Pollutant levels were prioritized for fish species within each river segment by comparison of data from previous studies to screening levels. The screening levels used for this comparison were the lowest values among two sources.

- The reported median value of individual contaminant concentrations observed nationwide in the National Bioaccumulation Study (U.S. EPA 1991a)
- The tissue level corresponding to the U.S. EPA chronic freshwater criteria (calculated using the Bioconcentration Factor, or BCF).

This prioritization of pollutants allowed for the comparison of problem pollutants between species and river segments. Dioxins and furans consistently appear as high priority pollutants in all non-anadromous species in all river segments (Table 2.1-1). These compounds were also assigned a high ranking for the anadromous chinook salmon, but not for the coho or steelhead. The DDT (dichloro diphenyl trichloroethane) 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 (Figures 2.1-2 through 2 1-5 and Table 2.1-1).

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, 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 exposed to contaminants when they consume prey that contain some level of pollutants. 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 (Henny 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 adverse impact.

2.1.2.6 ***Bioassays.*** 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 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. No locations in the studies examined showed evidence of high mortalities.

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.

2.1.3 Data Gaps

This section summarizes and assesses availability of data and identifies data gaps from the media reviewed. Consideration of all the data (or lack of data) from the different media reviewed allows a more complete assessment of water quality.

Many studies have been conducted on the lower Columbia River since approximately 1980. Most of those were done in association with CREDDP to investigate and characterize conditions in the estuary. There are many studies that focused 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 sites in the lower river measuring conventionals, nutrients, and metals. Other agencies, firms and educational institutions have undertaken site-specific studies ranging from sediment bioassays to fish tissue bioaccumulation to National Pollutant Discharge Elimination System (NPDES) monitoring studies. These studies are useful for their intended purposes, however, there is a general lack of studies that survey the entire lower Columbia River.

Of all the sediment studies reviewed, the study closest to a general reconnaissance survey design was conducted by the Washington Department of Ecology (WDOE) to assess sediment conditions including sediment contaminant concentrations and sediment-toxicity at five Columbia River ports (Johnson and Norton 1988). For some segments of the river, sediment contaminant concentrations are completely unstudied. In addition, very little sediment data exist from depositional areas where contaminants would be expected to accumulate.

Likewise no attempt has been made to characterize the water quality over the length of the river. Data for characterizing contaminant concentrations in water are particularly absent and are defined as a high-priority data gap (Table 2.1-3).

Data on contaminant concentrations in fish and invertebrate tissues are also generally lacking. Bioaccumulation data are currently being collected by several state and federal agencies, and these studies

TABLE 2.1.-3. DATA GAPS IDENTIFIED BY TASK 1 OF THE BI-STATE PROGRAM	
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

will contribute greatly to the bioaccumulation database. However, system-wide ecological data do not exist either for benthic macrofauna or for fish assemblages (Table 2.1-3).

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

2.1.4 Conclusions

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.

Observations drawn from the existing data are summarized below for each medium.

2.1.4.1 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 based 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 were found (although see Section 2.1.2.1 for discussion of these data). Based on the limited data available, however, the entire lower Columbia River is a data gap for water quality (Table 2.1-3).

2.1.4.2 Sediments. Based on contaminant screening levels, approximately ten potential problem areas were identified from existing sediment data (see Figures 2.1-2 through 2.1-5; Table 2.1-1). The most prominent areas were Ilwaco, Camas Slough, Longview, and the Portland/Vancouver area. At most other locations, measured contaminant levels were either below the screening levels or were undetected (Table 2.1-1). 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.

*2.1.4.3 **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 2.1-3)

*2.1.4.4 **Fish Communities.*** No existing studies were found that used fish communities to assess pollution impacts on the aquatic environment of the lower Columbia River. Therefore, this indicator is a data gap (see Table 2.1-3).

*2.1.4.5 **Bioaccumulation.*** Based in 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 2.1-2 through 2.1-5, Table 2 1-1). 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.

*2.1.4.6 **Bioassays.*** Based on limited bioassay data, *Hyalella* mortality data 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

2.2 TASK 2. INVENTORY AND CHARACTERIZATION OF POLLUTANTS

The purpose of Task 2 was to inventory and characterize existing sources of pollution to the lower Columbia River below Bonneville dam. Potential pollutant sources were organized into three main categories based on their origins: point sources, non-point sources, and in-place pollutant sources. Pollutants from point sources enter the river from discrete sources that discharge directly, usually via pipes or outfalls, to the waters of the lower Columbia River. Non-point pollutants enter the river from dispersed land or water-based activities such as surface runoff, atmospheric deposition, groundwater transport, and discharge from tributaries. In-place pollutants were defined as land-based contaminants associated with hazardous waste sites, sanitary landfills, and septic tanks near the river.

2.2.1 Objectives

Task 2 reports addressed the following four objectives:

- To organize and summarize available data and estimates on pollutant loading (i.e., the amount of pollutants entering the river over a specified period of time) to the lower Columbia River from point sources, major tributaries, and in-place pollutant sources.

- To inventory sites and activities that may contribute to non-point source pollution loading to the lower Columbia River.

- To identify data gaps that hinder the inventory, characterization, and estimation of loading of pollutants to the lower Columbia River.

- To provide information useful for the formulation of the reconnaissance survey sampling plan.

To achieve these objectives, Task 2 was subdivided into several subtasks. First, a list of information sources to be used for data analysis and pollution loading calculations was compiled and submitted to the Columbia River Bi-State Committee. Second, a detailed data analysis report on pollution entering the lower Columbia River was prepared. This report contained discussions of point sources, land use, tributary pollutant loading, non-point sources, and in-place pollutant data. Estimates of pollutant loading were made for point sources regulated by Oregon and Washington's National Pollution Discharge Elimination System (NPDES) permits and for selected major tributaries to the lower Columbia River Third, a summary report of the work conducted as part of Task 2 was prepared and submitted to the Columbia River Bi-State Committee. This report provided a less technical, and more concise, overview of the data presented in the data analysis report.

These three subtasks were completed in the form of following reports:

- *Reconnaissance Survey of the lower Columbia River. Task 2: List of sources of information to evaluate* (Tetra Tech 1991c).

- *Reconnaissance Survey of the lower Columbia River. Task 2 data analysis report: Inventory and characterization of pollutants* (Tetra Tech 1992c).

- *Reconnaissance Survey of the lower Columbia River. Task 2 summary report: Inventory and characterization of pollutants* (Tetra Tech 1992d).

2.2.2 Results

Pollutant loading estimates were made for fifty-four NPDES-permitted point sources and discharges from six selected tributaries that discharge directly to the lower Columbia River. All point sources evaluated were located within the study area and their loading estimates were based on 1989 and 1990 data. Although point and nonpoint sources that discharge to the upper river and lower river tributaries were not included within the scope of this study due to program funding limitations, discharges from above Bonneville Dam and along tributaries were evaluated as a single source of pollutant loading (via the upper river and tributaries) to the study area. Discussions of non-point pollution sources included runoff from forest, agricultural, residential, and urban lands as well as combined sewer overflows (CSOs) from urban stormwater/wastewater collection systems, atmospheric deposition, and accidental chemical spills. Pollutants associated with hazardous waste sites, landfills, and septic tank failures were also discussed in Task 2. All landfills and hazardous waste sites within one mile of the lower Columbia River were evaluated. Septic tank data were evaluated by county The locations of the identified point sources, tributaries, and landfill and/or hazardous waste sites are identified in Figures 2.2-1 through 2.2-8

Because of the lack of data, pollutant loading to the lower Columbia River could be estimated only for NPDES-permitted point sources, the upper Columbia River, and a few tributaries. In addition, sufficient data to enable loading calculations were available only for certain pollutants; data were most deficient for toxic pollutants, such as metals and organic compounds, and nutrients For point sources, data were most complete for wastewater discharge, BOD, and TSS. For estimates of tributary loading, data were most complete for discharge volumes, TSS, metals, and other inorganic constituents including nutrients. Therefore, limited specific comparisons are possible between point sources and tributary loading data.

Because the upper Columbia River and tributaries to the lower Columbia River contain pollutants from point, non-point, and in-place sources, these rivers integrate the pollutant loading from these sources within their basins. Tributaries that drain extensive areas of developed agricultural, forest, and urban

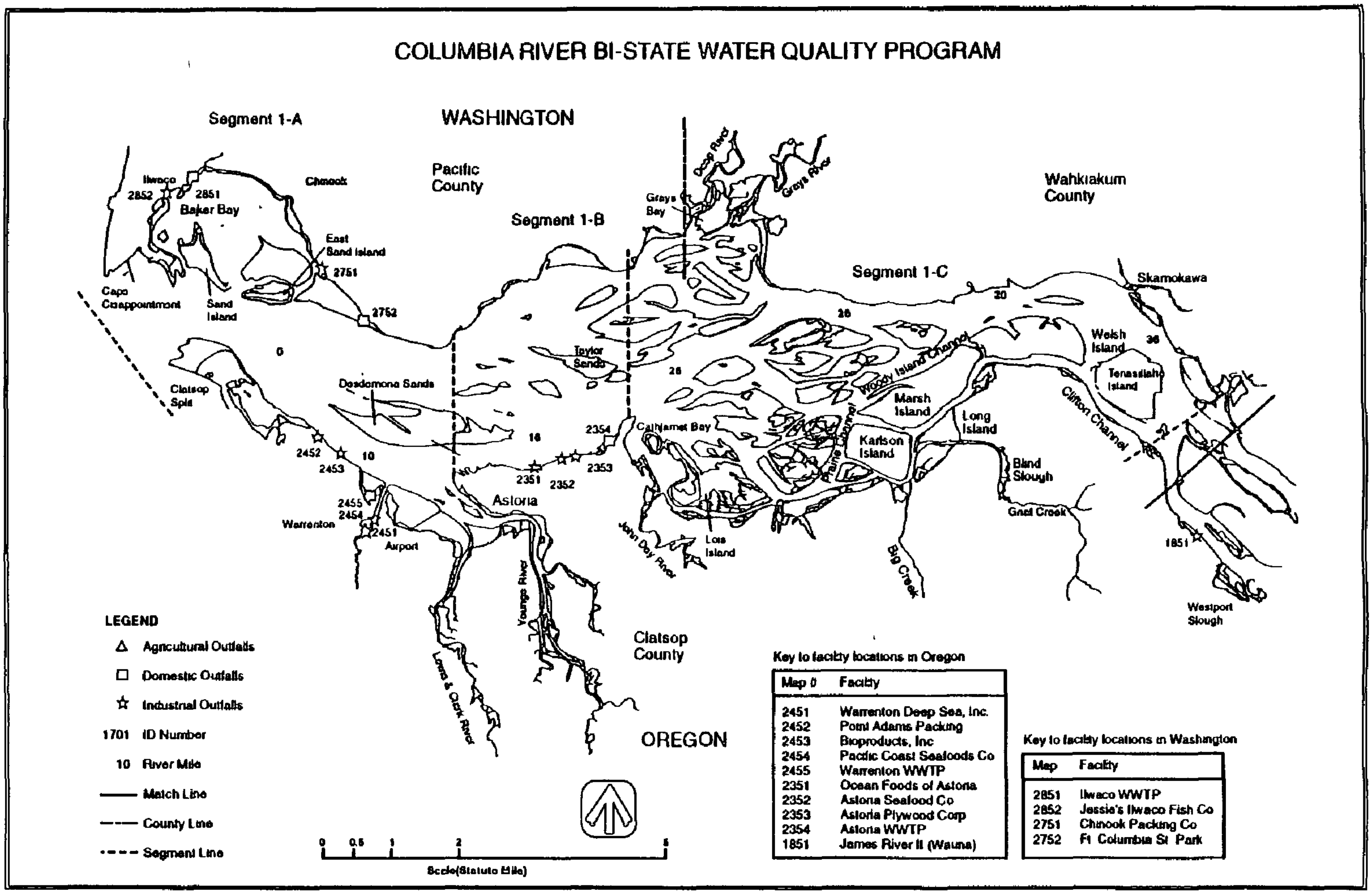


Figure 2 2-1 Locations of NPDES-Permitted Point Sources That Discharge Directly to River Segments 1A Through 1C on the Lower Columbia River

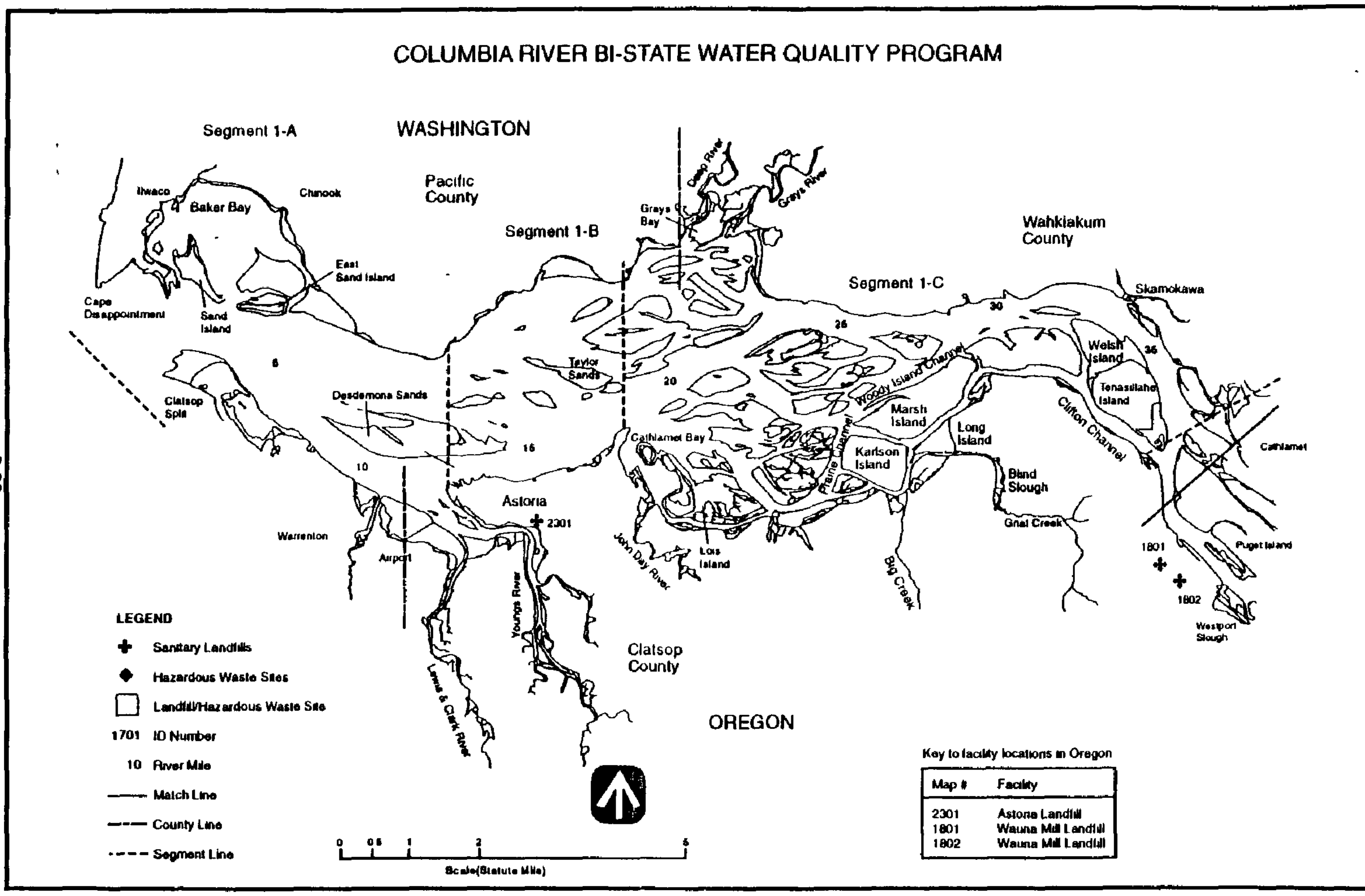


Figure 2 2-2 Locations of Landfills and Hazardous Waste Sites Along River Segments 1A Through 1C on the Lower Columbia River

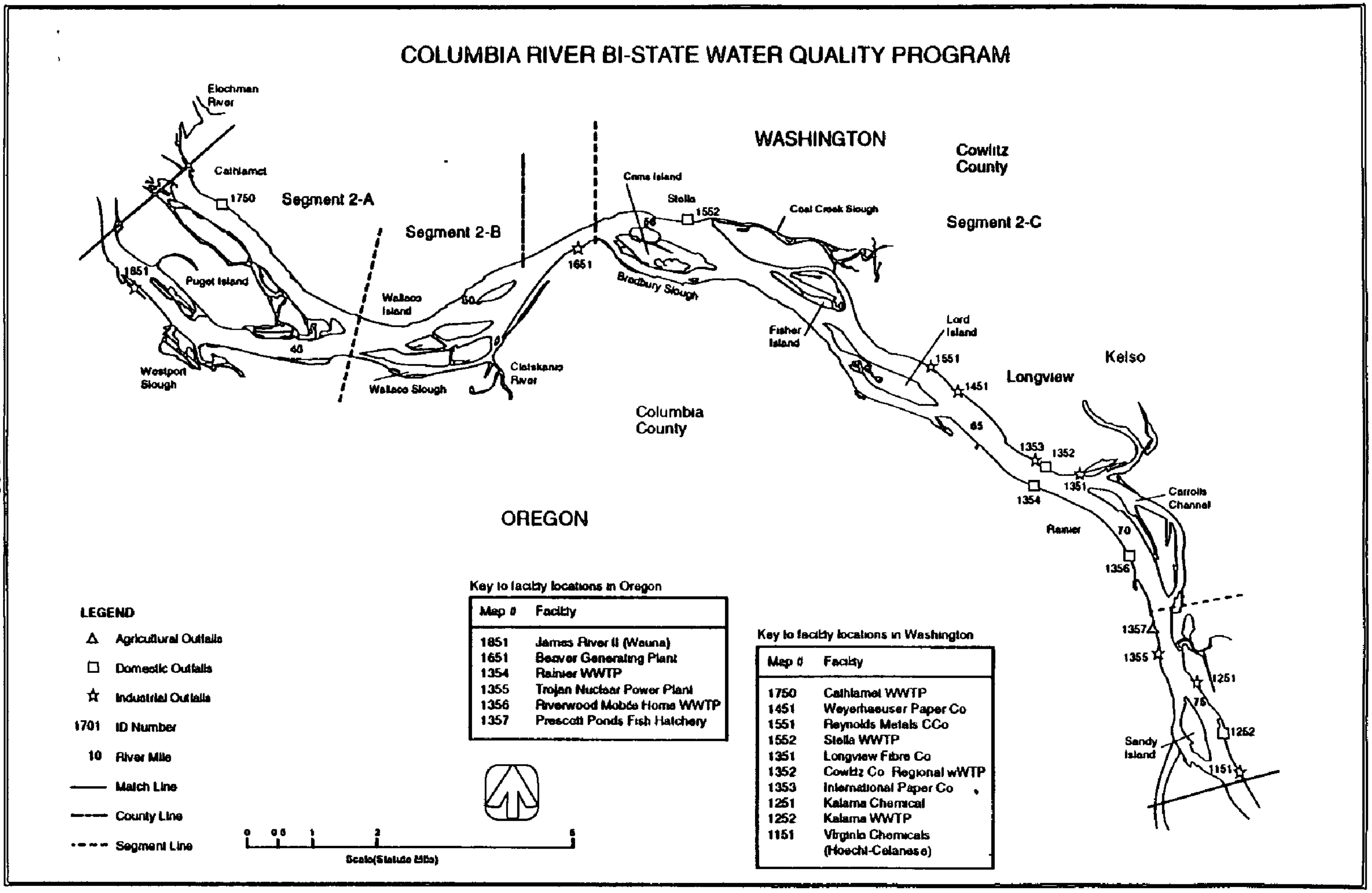
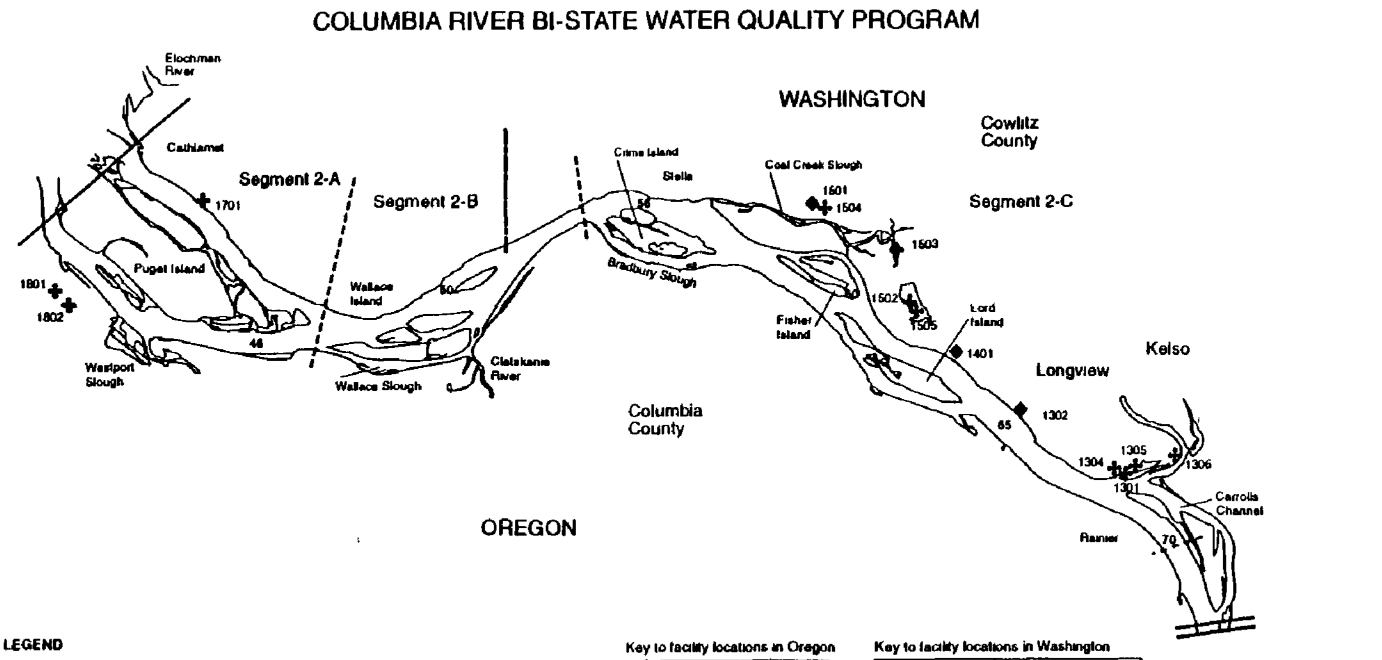


Figure 2.2-3 Locations of NPDES-Permitted Point Sources That Discharge Directly to River Segments 2A Through 2C on the Lower Columbia River



LEGEND

- ✚ Sanitary Landfills
- ◆ Hazardous Waste Sites
- ☐ Landfill/Hazardous Waste Site
- 1701 ID Number
- 10 River Mile
- ——— Match Line
- —·— County Line
- - - - - Segment Line

Scale (Statute Mile): 0, 0.5, 1, 2, 5

Key to facility locations in Oregon

Map #	Facility
1801	Wauna Mill Landfill
1802	Wauna Mill Landfill

Key to facility locations in Washington

Map #	Facility
1701	Cathlamet Dump
1501	Ostrander Rock Disposal
1502	Radakovich (Mt Solo) Landfill
1503	Coal Creek Landfill
1504	Ostrander Rock Landfill
1505	Radakovich (Mt Solo) Landfill
1401	Reynolds Metals
1301	Longview Fibre
1302	Weyerhaeuser
1304	International Paper Landfill
1305	Longview Fibre Landfill
1306	Cowlitz County Landfill

Figure 2 2-4 Locations of Landfills and Hazardous Waste Sites Along River Segments 2A Through 2C on the Lower Columbia River

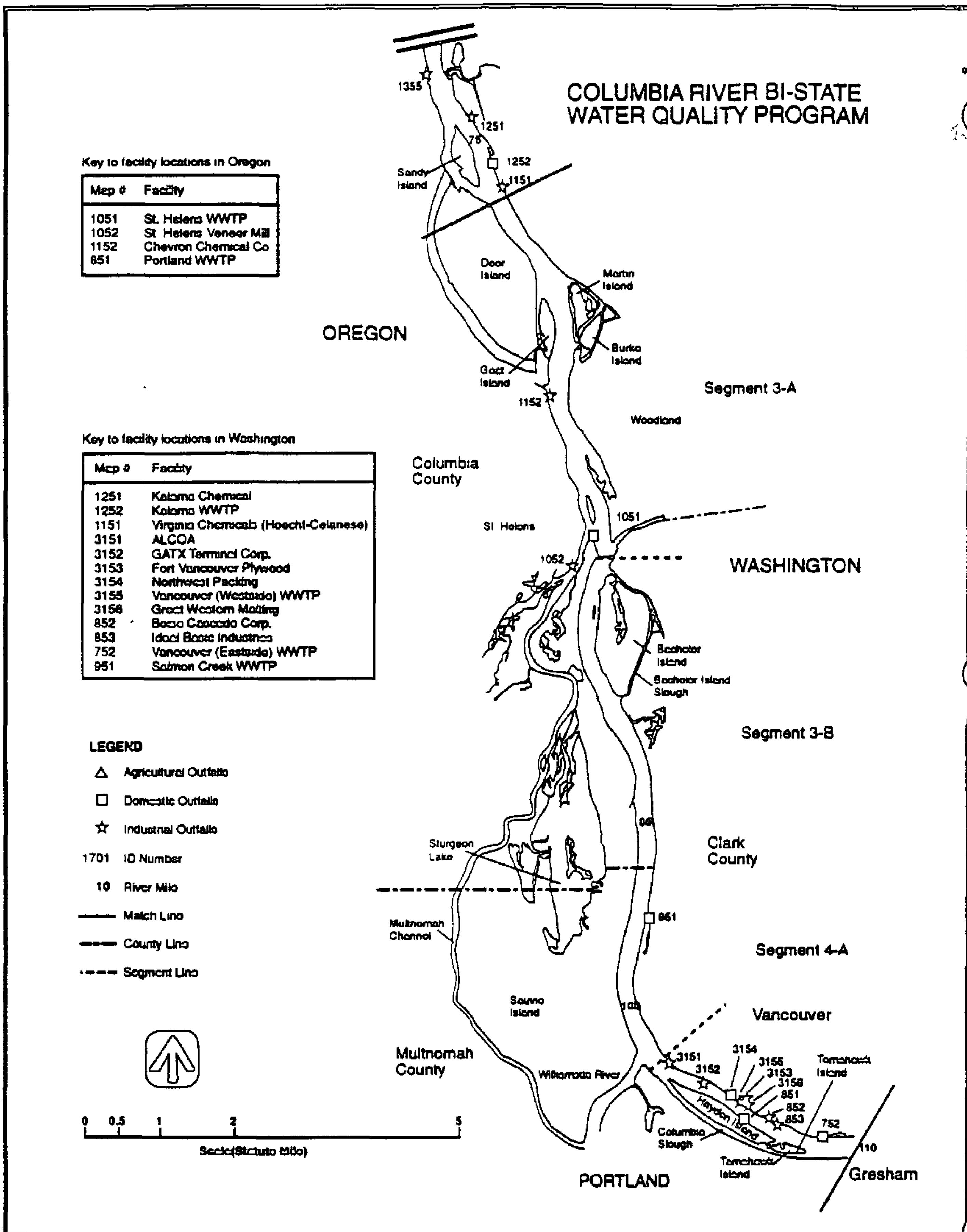
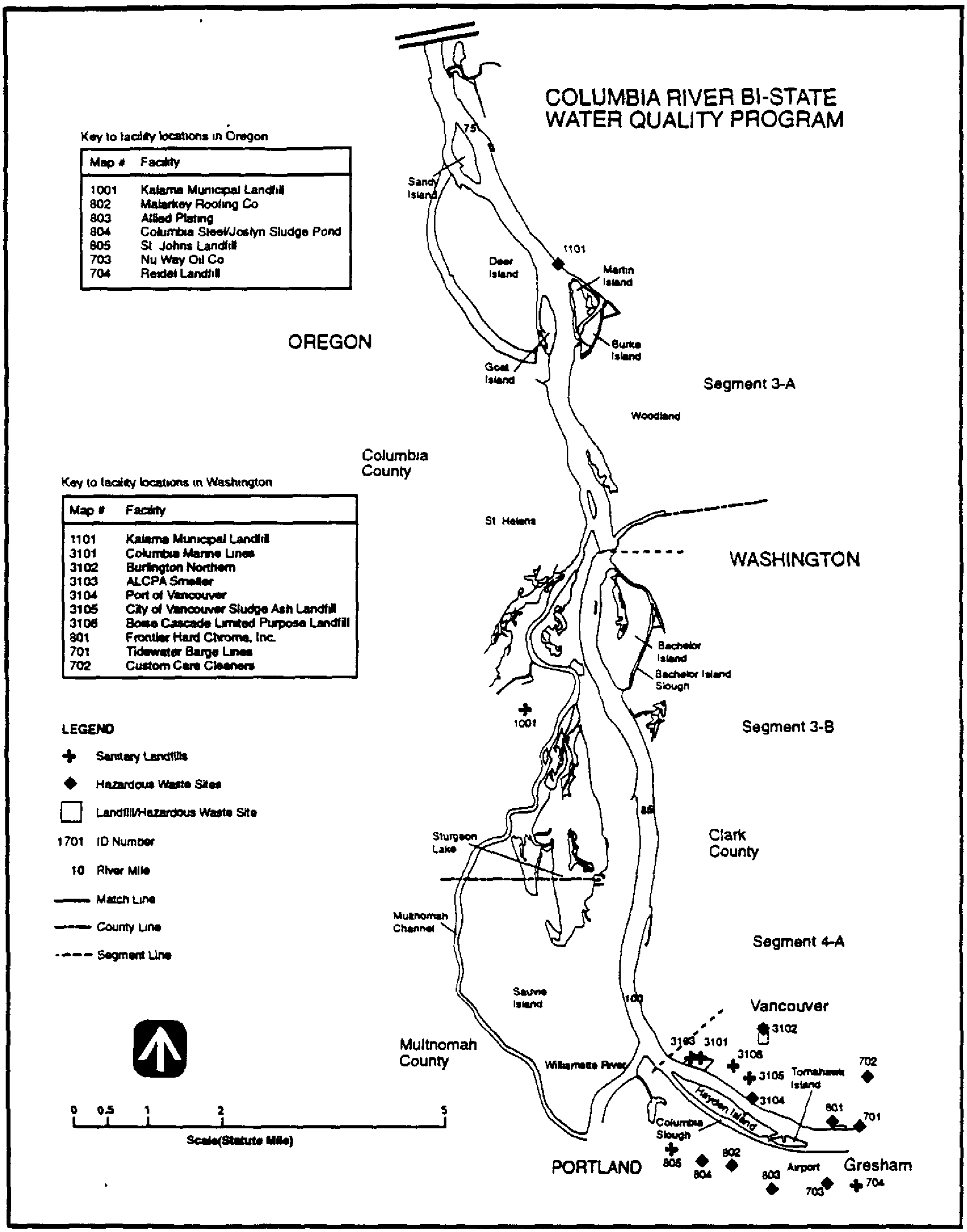


Figure 2.2-5. Locations of NPDES-Permitted Point Sources that Discharge Directly to River Segments 3A and 3B on the Lower Columbia River



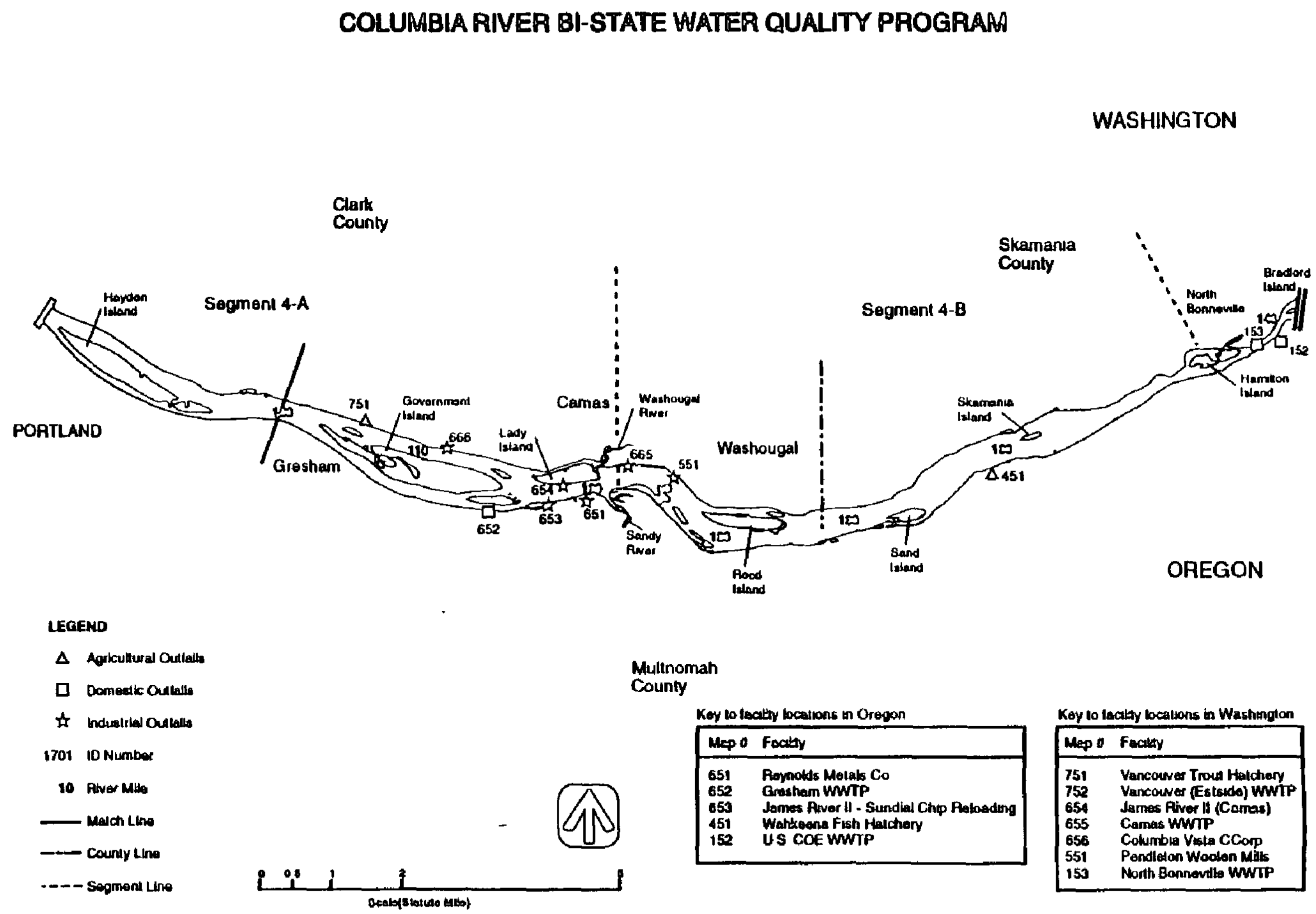
Key to facility locations in Oregon

Map #	Facility
1001	Kalama Municipal Landfill
802	Malarkey Roofing Co
803	Allied Plating
804	Columbia Steel/Joslyn Sludge Pond
805	St Johns Landfill
703	Nu Way Oil Co
704	Reidel Landfill

Key to facility locations in Washington

Map #	Facility
1101	Kalama Municipal Landfill
3101	Columbia Marine Lines
3102	Burlington Northern
3103	ALCPA Smelter
3104	Port of Vancouver
3105	City of Vancouver Sludge Ash Landfill
3106	Boise Cascade Limited Purpose Landfill
801	Frontier Hard Chrome, Inc.
701	Tidewater Barge Lines
702	Custom Care Cleaners

Figure 2.2-6. Locations of Landfills and Hazardous Waste Sites Along River Segments 3A and 3B on the Lower Columbia River



Map #	Facility
651	Reynolds Metals Co
652	Gresham WWTP
653	James River II - Sundial Chip Reloading
451	Wahkeena Fish Hatchery
152	U S COE WWTP

Map #	Facility
751	Vancouver Trout Hatchery
752	Vancouver (Estside) WWTP
654	James River II (Camas)
655	Camas WWTP
656	Columbia Vista CCorp
551	Pendleton Woolen Mills
153	North Bonneville WWTP

Figure 2 2-7 Locations of NPDES-Permitted Point Sources that Discharge Directly to River Segments 4A and 4B on the Lower Columbia River

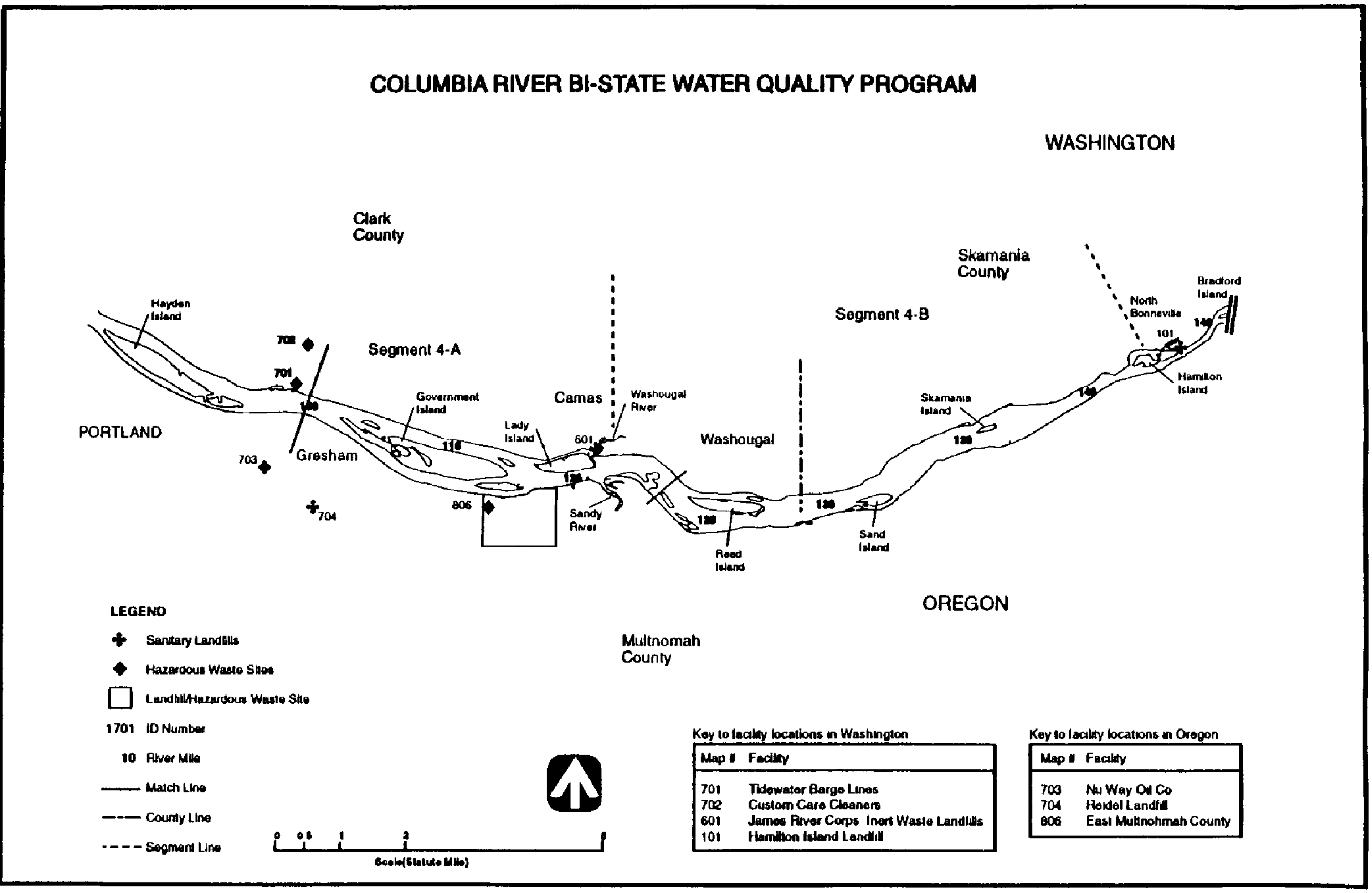


Figure 2 2-8 Locations of Landfills and Hazardous Waste Sites Along River Segments 4A and 4B on the Lower Columbia River lands (e.g., the Willamette River) are likely significant sources of pollutants to the lower Columbia River. Although specific information is not available at this time, non-point and in-place pollutants within these large drainage basins may be more relevant to pollutant loading to the lower Columbia River, especially persistent toxic pollutants, than is non-point and in-place pollutant loading from nearshore areas along the river.

2.2.2.1 Wastewater. The total discharge of wastewater from NPDES-permitted facilities in the lower Columbia River averaged 475 MGD for the years 1989 and 1990. Wastewater discharge from the pulp and paper industry accounts for about half (52 percent) of this total, with wastewater discharge from major municipal sources accounting for the next largest fraction (32 percent). Together the six pulp and paper mills along the lower Columbia River and the municipal wastewater treatment facilities in the cities of Astoria, St. Helens, Portland, and Gresham, OR, and Longview and Vancouver, WA account for 84 percent of the wastewater discharged from permitted point sources directly to the lower Columbia River. The next largest source is major chemical industry discharges, which account for less than 8 percent of the total wastewater volume.

To put the discharge from NPDES point sources into perspective, the rate of wastewater discharge from these sources can be compared with the discharge from tributaries entering the lower Columbia River, and the discharge of the upper Columbia River to the lower Columbia River measured at Warrendale, OR below Bonneville Dam. The annual average NPDES-permitted point source wastewater discharge (475 MGD) is roughly equivalent to 75 percent of the annual average discharge from the Kalama River (653 MGD) - the fifth largest tributary to the lower Columbia River The NPDES discharge is less than 0.4 percent of the rate of water flow entering the lower river from the upper Columbia River (120,000 MGD).

2.2.2.2 Total Suspended Solids. The total discharge of total suspended solids (TSS) from NPDES-permitted facilities that discharge wastewater directly to the lower Columbia River averaged 140,000 lb/day for the years 1989 and 1990. Wastewater discharge from the pulp and paper industry accounts for about three quarter (76 percent) of this total, with wastewater discharge from major municipal sources accounting for the next largest fraction (22 percent) Together the six pulp and paper mills along the lower Columbia River and the municipal wastewater facilities in the cities of Astoria, OR, St. Helens, Portland, and, Gresham, OR, and Longview, and Vancouver, WA account for 99 percent of the TSS discharged directly to the lower Columbia River.

The discharge of TSS to the lower Columbia River from point sources is only a very small fraction of that entering the river from the upper Columbia River and tributaries. The discharge of TSS from point sources is approximately 3 percent of the annual average TSS discharge from the Willamette River (4,720,000 lb/day) and less than 1 percent of the TSS entering the lower river from the upper Columbia River (18,700,000 lb/day).

2.2.2.3 ***Biochemical Oxygen Demand.*** The total discharge of biochemical oxygen demand (BOD) from NPDES-permitted facilities that discharge wastewater directly to the lower Columbia River averaged 73,300 lb/day for the years 1989 and 1990. The pulp and paper industry discharged the largest amount (66 percent) of BOD. The second largest discharge was from major domestic facilities (32 percent). Together, these two sources accounted for 98 percent of the NPDES-permitted BOD loading directly to the lower Columbia River. No data on BOD for the tributaries was available and therefore, no comparison of point source BOD loading with tributaries is possible.

2.2.2.4 ***Bacteria.*** Data on the concentration of fecal coliform bacteria were identified for direct NPDES-permitted point sources only. No data were identified on direct estimation of pathogenic organisms from the various pollutant sources. In general, only treated sanitary/domestic wastewater discharges are required to regularly determine the concentration of fecal coliform bacteria in effluent. While occasional, elevated concentrations of fecal coliform bacteria occur, on a seasonal average these concentrations are typically within their NPDES permit limits. A few samples of the treated process wastewater from the Weyerhaeuser Paper Co. (Longview) pulp and paper mill and the final effluent from the City of St. Helens WWTP (which treats the primary treated wastewater from the Boise Cascade pulp and paper mill) had elevated concentrations of fecal coliform bacteria. NPDES permit effluent limits did not apply to these sources, and the human health significance of their presence is not presently known. However, there are typically no untreated human fecal wastes discharged to pulp mill processing wastewater. The primary strain of bacteria detected in pulp and paper mill's secondary process effluent may be the thermotolerant bacterium *Klebsiella pneumoniae*, which is not specifically of fecal origin (NCASI 1972, NCASI 1975, Cabelli et al. 1983, Dufour 1984). Thermotolerant *Klebsiella* identified in the fecal coliform test are common in the effluent of wood pulp and paper, and textile mills (Dufour and Cabelli

1976, Niemelä and Väätänen 1982, Geldreich and Rice 1987). The high incidence of *Klebsiella* in industrial effluents and receiving waters is one of the reasons why the U.S. EPA recommended the enterococcus standard for the protection of marine and freshwater bathers instead of the previous fecal coliform standard (Cabelli 1983, Dufour 1984) which is still applied by the states of Oregon and Washington.

2.2.2.5 Metals and Other Mineral Elements. Several metals and other mineral elements are discharged by NPDES point sources to the lower Columbia River Point source discharges of aluminum, barium, copper, iron, fluoride, manganese, and sodium are only a small fraction of that entering the lower Columbia River from tributaries and the upper Columbia River. The point source loading of these constituents to the river is between 0.4 to 7 percent of that entering the river from the Willamette River and less than 1 percent of that entering the lower river from the upper Columbia River. Conclusions regarding the significance of point source discharges of other metals (arsenic, antimony, cadmium, chromium, lead, mercury, molybdenum, nickel, silver, and zinc) are difficult to ascertain because point source and tributary loading estimates are based, at least in part, on values reported as not detected.

Although data for metals and other mineral elements (e.g., boron and fluoride) were limited, some comparisons between permitted point sources, the Willamette River, and loading from the upper Columbia River can be made. Estimated aluminum loading from the Willamette River in 1989 was 7,590 lb/day while estimated aluminum loading to river segments 2C, 3A, and 4A from permitted point sources was estimated at 24, 73, and 47 lb/day, respectively. Estimated loading of iron from the Willamette River was 11,200 lb/day and 110,000 lb/day from the upper Columbia River. Estimated iron loading to river segment 4A from permitted point sources was 155 lb/day. Although point source loading of sodium to river segment 3A was estimated at 3,642 lb/day, sodium loading from the Willamette River alone was estimated at 852,000 lb/day. Fluoride loading from point sources was estimated at 895 lb/day, while loading estimated for the upper Columbia River was over 200,000 lb/day.

Few data are available for metals that commonly occur in trace concentrations in the natural environment because the concentration of these metals are often below the analytical detection limits used in their analysis. These common trace metals are arsenic, beryllium, cadmium, chromium, cobalt, copper, lead, mercury, molybdenum, nickel, selenium, silver, and zinc. These metals are typically undetected, with the exception of copper, in water samples from the Willamette River and the Warrendale NASQUAN stations. Thus, the relative contribution of these metals remains uncertain, although it is possible that point sources are a significant source. For example, the loading of zinc from the Willamette River (based on detected concentrations) was 556 lb/day, while estimated zinc loading from direct permitted point sources to river segment 4A was 70 lb/day However, a great deal of uncertainty surrounds estimates of metals loading from tributaries and the upper river because of the uncertain quality of the NASQUAN data (e.g., Windom et al. 1991) and the lack of data on bedload transport of contaminants. Non-point sources such as urban runoff, atmospheric deposition, and in-place pollutants may also be a significant source, but at present no loading data are available for comparison.

2.2.2.6 Nutrients. Estimates of direct point source loading of nutrients was generally inadequate for determining the relative importance of the various sources to nutrient loading to the lower Columbia River. This is due to the lack of nutrient loading information from major municipal/domestic point sources and pulp and paper industry facilities, non-point sources, and in-place pollutants. Estimated loading of total phosphorus, ammonia nitrogen, and nitrate-nitrite nitrogen from the Willamette River was 14,500, 51,800, and 118,000 lb/day, respectively Nutrient loading from point sources was available from only two chemical facilities. Ammonia nitrogen loading was estimated at 57 lb/day and total phosphorus loading was estimated at 2.6 lb/day Although nutrient loading from the Willamette River and the upper Columbia River is large, data are needed on the significant point source discharges, stormwater runoff directly to the river, and septic tank nutrient contributions to adequately determine the relative significance of these sources.

2.2.2.7 Organic Pollutants. Even less data are available for the evaluation of the relative importance of organic pollutant loading to the lower Columbia River. No data are available from the major tributaries, and organic pollutant loading estimates from point sources are incomplete. Although limited data are available on petroleum spills to the river and its tributaries, the information suggests that a few large accidents account for most of the quantities reported. Organic pollutants of anthropogenic origins (e.g., pesticides, U.S. EPA priority organic pollutants, dioxins, and petroleum products) likely pose serious environmental concerns. However, lack of data on these pollutant sources prevents determining their relative importance at this time.

2.2.3 Data Gaps

An attempt was made to inventory and characterize the pollutant sources and pollutant loading to the lower Columbia River below Bonneville Dam. Information was identified for point and non-point sources of pollutants including municipal, industrial, and agricultural point source discharges, loading from tributaries and the upper Columbia river, in-place pollutants (hazardous waste sites and landfills), accidental spills, and atmospheric deposition. Land use in the counties that border the Columbia River below Bonneville Dam was also summarized, and the types of pollutants associated with those uses were described. However, data gaps prevented an adequate assessment of pollutant loading to the river. This section discusses these gaps and recommends general measures for gathering the information needed to determine more precisely the relative contribution of specific pollutants of concern from the pollution sources.

*2.2.3.1 **Point Sources of Pollution.*** The regulatory permit process for point sources is generally designed to ensure that after wastewater is initially diluted in a defined mixing zone, chronic water quality criteria will not be violated, although mixing zones have not yet been defined for all permitted point sources. Within a defined mixing zone, less restrictive acute water quality criteria or other state designated standards may apply. NPDES-permitted discharges are required only to monitor pollutant variables that will most likely cause receiving water criteria to be violated. Therefore, some permitted dischargers may monitor fluoride, boron, antimony, and benzo(a)pyrene while other dischargers may monitor only BOD and TSS. However, for the purpose of assessing pollutant loading and eventually modeling a variety of chemicals and elements, a loading estimate is needed for each pollutant from each point source. For this study, loading data were most complete for wastewater discharge, BOD, and TSS. Data were inadequate for assessing the relative contribution of nutrients, metals, and organic compounds from the various point sources.

*2.2.3.2 **Land Use.*** For this study, land-use data were presented by county and the type of pollutants associated with each land-use classification were identified. Analysis of the sources and quantities of pollutants entering the lower Columbia River below the Bonneville Dam suggests that much of the non-point source pollution entering the river does so indirectly via large tributaries. Therefore, information on land use within the larger drainage areas may be more relevant than the land-use information on counties bordering the lower river. The land-use information available was too general for an assessment of the relative proportion of land-use types in the area immediately adjacent to the river.

2.2.3.3 Urban Stormwater and Combined Sewer Overflow (CSO) Runoff. No data were identified on contaminant loading from urban stormwater and CSOs. Some data are expected from the City of Portland and Multnomah County after stormwater NPDES permit applications have been submitted. Other data may become available from industrial and port facilities along the river.

2.2.3.4 Tributary Pollutant Loading. Tributary loading, including the input of pollutants from the upper Columbia river, includes point, non-point, and in-place pollutants. The limited data available indicates that tributaries may be a significant source of some pollutants, but several difficulties prevented more precise determination of the relative importance of tributary pollutant loading. Although tributary pollutant data were identified, this information was generally incomplete for BOD and organic compounds. No data were available on pollutants associated with bedload transport. More data were available on metals, nutrients, and TSS, but recent work has cast doubt on the accuracy of the USGS NASQUAN metals data (e.g., Windom et al. 1991) used in this report to estimate loading from the upper Columbia River. Reported metals concentrations could be as much as ten times or more too high. Data interpretation was further complicated because of inconsistencies between flow monitoring stations and water quality monitoring stations.

2.2.3.5 Atmospheric Pollutant Deposition. Studies of the relative contribution of some atmospheric pollutants in other areas of the country indicate that atmospheric sources of some pollutants (e.g., mercury, nitrogen, and PCBs) may be important. To evaluate the relative importance of atmospheric pollutant deposition to the lower Columbia River, atmospheric deposition data are needed based on samples collected within the drainage area. Atmospheric deposition of pollutants is presently measured at only one location in the lower Columbia River basin near the City of Portland. However, these data are limited to concentrations of calcium, magnesium, sodium, potassium, sulfate, chloride, and inorganic nutrients. Presently, the relative contribution of atmospheric pollutants, especially mercury or organic compounds, cannot be assessed. However, because tributaries capture much of the pollutant loading from atmospheric sources, tributary monitoring may account for much of the indirect atmospheric pollutant load to the river.

2.2.3.6 In-Place Pollutants. Few loading data were available for assessing the potential pollutant loading due to in-place pollutants. An estimate is needed of loading due to hazardous waste sites and landfills. Although data characterizing the actual contamination of landfills and hazardous wastes were essentially adequate, sparse data were available addressing the soil hydraulic conductivity and groundwater flow rates necessary to calculate loading rates.

2.2.4 Conclusion

The Task 2 report summarized available data and information on point, nonpoint, and in-place pollutants. Data were most complete for point sources and major tributaries to the lower Columbia River. These data were adequate for comparison of discharge and TSS. However, data gaps were noted that prevented adequate characterization and quantification of pollutant loading from these three pollutant sources for an assessment of the relative importance of each source. However, limited comparisons for point source and tributary loading indicate that large tributaries in the lower river (e.g., Willamette River) and discharge from the upper Columbia River basin may be significant sources of suspended solids and some metals and other mineral elements (aluminum, barium, copper, iron, fluoride, manganese, and sodium) to the lower river. However, due to limitations of point source loading estimates and typically low (below detection limits) concentrations of several trace metals (arsenic, antimony, cadmium, chromium, cobalt, lead, mercury, molybdenum, nickel, silver, and zinc) in tributaries and in the upper river, and uncertainty in USGS NASQUAN data, the relative importance of sources of these metals can not be presently assessed. Data on organic pollutant loading is even more limited and therefore, the relative importance of sources of organic pollutants can not be assessed. These data gaps prevent an adequate assessment of the relative importance of sources of these pollutant types which would allow water quality managers to develop pollution control strategies that would target the most significant sources of each pollutant type. These strategies would be the most effective means of reducing pollutant loading to the lower Columbia River.

2.3 TASK 3: PHYSICAL AND HYDROLOGICAL CHARACTERISTICS

2.3.1 Objectives

The objectives of Task 3 were 1) to describe the physical and hydrologic characteristics of the lower Columbia River, 2) describe characteristics of the sediment transport and fate of sediments, 3) make recommendations on modeling approaches for the prediction of fate and transport of contaminants, and 4) recommend how the models could be applied to the lower Columbia River system. This task was divided into three subtasks, to be completed in the form of following reports:

- *Reconnaissance Survey of the lower Columbia River. Task 3: Review of hydraulic, hydrologic, sediment transport, and geomorphic characteristics of the lower Columbia River* (Tetra Tech 1992e).

- *Reconnaissance Survey of the lower Columbia River. Task 3: Report on conceptual modeling and recommendations for numerical models* (Tetra Tech 1992f).

- *Reconnaissance Survey of the lower Columbia River. Task 3: Final task report and recommendations* (Tetra Tech 1992g).

This section summarizes the above three reports It summarizes the physical and hydrologic characteristics of the lower Columbia River, summarizes the numerical strategies for modeling the water quality, and concludes with recommendations on numerical modeling approaches for future studies.

2.3.2 Results

2.3.2.1 Hydrologic and Physical Characteristics. In this subtask, existing information on the physical and hydrological characteristics of the lower Columbia River was identified and summarized. A great deal of existing information was gathered through review of reports and files of the U S. Army Corps of Engineers (USACOE) and U.S. Geological Survey (USGS), as well as other federal, state, and local agencies. In addition, interviews were conducted with personnel at these agencies who have extensive knowledge and experience on the Columbia River There have been several major programs, such as the Columbia River Estuary Data Development Program (CREDDP), and physical and numerical modeling studies performed by the USACOE, which have resulted in a thorough characterization of certain processes and locations within the lower Columbia River.

The following sections summarize the findings of subtask 1, the review of hydrologic and physical characteristics.

River Segmentation--The physical processes of the lower Columbia River vary considerably as the river is transformed from a riverine to an estuarine environment. The river widens from approximately 2,100 feet at River Mile (RM) 53 to about 47,000 feet in some reaches of the estuary.

Associated with the width changes is a variation in river velocity and sediment transport capability Other changes that occur in the lower river and estuary include increased tidal influence and the presence of a saltwater wedge.

During the course of the Task 3 study, two useful classifications were developed for subdividing the river into similar reaches or segments The first classification (Subtask 1) was based on physical or political characteristics. This classification was used primarily for siting sampling stations during design of the reconnaissance survey Field sampling (Task 6) was prioritized within each segment to fill gaps in the existing data. The second classification (Subtask 2) was developed for modeling purposes, dividing the lower Columbia River into segments for which different types of models were appropriate. The river segmentation by river mile for the two classification schemes is shown below

Segment No.	Subtask 1	Subtask 2
1	0-37	0-37
2	37-72	37-54
3	72-102	54-146
4	102-146	

In the following sections, the physical properties of the lower Columbia River are discussed with respect to segmentation.

Hydrogeologic Characteristics--The Columbia River is the largest river to discharge to the Pacific Ocean. The Columbia River drains about 258,000 square miles of the northwestern United States and southwestern Canada. The river has a distinct bi-modal flood season. The largest floods are associated with flow from the upper Columbia River Upstream of Bonneville Dam, floods are caused by springtime snowmelt in areas generally east of the Cascade Divide between April and June Wintertime rainstorms in areas west of the Cascade Divide cause winter floods that equal or exceed the mean during the period from November through March. The lowest discharges occur during September and October (Simenstad 1990).

The upper Columbia is heavily regulated. Above the Bonneville Dam, there are 52 multipurpose projects located on the Columbia River and/or its major tributaries. Project storage exceeds 35 percent of annual flow. The average annual discharge on the main stem above Bonneville is about 194,000 cubic feet per second (cfs). The average annual discharge at the mouth of the estuary approaches 260,000 cfs. The Willamette River is the major tributary (contributing an average of 65 percent of the total tributary flow to the lower river) on the lower Columbia River, discharging into the Columbia River at RM 101.

The lower Columbia River is classified as a lowland river with a low gradient approaching 0.001 percent. Tidal impacts related to river stage are noted throughout the study area and flow reversals have been detected as far upstream as RM 95 (Eriksen, personal communication, July 1991). Major flow reversals of significant time duration relative to sediment transport impacts are not expected upstream of Segment 2 (RM 73). The saltwater prism reaches up to RM 27 during low flows and neap tide, with a 7 to 10 mile difference between high and low freshwater discharge (Jay 1984). During ebb tide and high river discharge, the salt wedge can be advected completely out of the estuary.

Hydraulic Characteristics--The dominant hydraulic characteristic of the lower river is the relatively high velocity of the river during most conditions. Velocities greater than 5 knots (8.41 ft/sec) occur during average ebb stage even though the bed slope in the river is low (approaching 0.001 percent), largely due to the high discharge and low resistance to flow Downstream velocities in all four segments are moderated at low flow (less than 150,000 cfs) by tidal conditions.

Complex conditions in the estuary consist of three-dimensional flows through deep channels of variable salinity, which meander past shallow bays, flats and islands in a wide coastal plain-type estuary. These conditions make the measurement and prediction of current directions and velocities (a necessity for contaminant transport predictions) extremely complex. The tidal flow takes place mainly through the north channels of the estuary, while the river flow occurs along the deep thread of the estuary, confined by the navigational channel. River conditions upstream of the estuary tend to be relatively less complex, with a typical uni-directional flow. The presence of multiple channels, tributary influence, and tidal moderation must be considered in model selection.

Sediment Transport--Sediment transport and fate is important because of the affinity of many contaminants to fine sediments, typically smaller than very fine sand grain sizes (i.e., less than 0.08 millimeters). Applying modeling techniques to better understand sediment transport and deposition processes will allow identification of contaminant sources and determination of contaminant impacts. Knowledge of sediment transport is also required to predict dredging activities related to maintenance of the navigation channel. The lower Columbia River transports significant amounts of sediment which are sand-sized and smaller. The transport mechanism is either as suspended sediments (fine silt and clay) or as bed load (sand). Throughout the lower Columbia River, fine sediments will be deposited only in low energy environments located in sloughs, back channels, and within the estuary.

Jay and Good (1978) and Haushild (1966) have estimated that the total suspended load of fine grain sediments in the lower Columbia River averages approximately 10 million tons/year. Following the eruption of Mt. St. Helens in 1980, the suspended load measured at Longview (RM 67) increased by an estimated 41 percent. Limited bed deposits of fine grain sediment were found in the river upstream of Segment 1, with greater than 86 percent of the bed covered with waves varying from 3 to 20 ft high, and 60 to 500 ft long (USACOE 1986). This suggests that deposition of fine sediments is temporary during low river stages and that long-term deposits are limited in area in the river, but increase in the estuary.

It is estimated that 20-30 percent of the suspended sediments transported to the estuary from upstream are retained, approximately 2 to 3 million tons per year. A range of 1 to 2 million tons of sand per year is estimated to enter the estuary as bed load (Whetten 1969; Ogden Beeman Associates 1984).

The Columbia River Estuary bed is principally fine sand-sized sediment (0.039 to 1 mm) with a mean size of 0.17 mm (Sherwood and Craeger 1990), and a few sheltered or shallow water areas that are silt-sized (USACOE 1986). The bed material texture demonstrates seasonal variations, with sediments tending to be finer near the end of a low flow period and coarser after a high discharge (Whetten et al. 1969; Forster 1972; Sternberg et al. 1977). Discharges approaching 500,000 cfs and higher will transport sand beyond the mouth (USACOE 1986)

Geomorphic Characteristics--The geomorphology of the lower Columbia River may be characterized as an extremely straight alluvial channel with numerous mid-channel bars and islands. Most of the bank material in the lower river is non-cohesive silty sand and is extremely susceptible to bank erosion. High current velocities directed towards the river banks, and the virtual elimination of sediment upstream of Bonneville Dam, have increased the rate of bank erosion (USACOE 1986). The main navigation channel is dredged to a much greater depth than natural conditions, which may in turn result in further changes in river morphology. As the river velocity slows in the vicinity of the estuary, it deposits much of its sediment load. This sediment deposition process has resulted in the formation of a wide, multichannel river, with bifurcations and diverse sediment sizes.

2.3.2.2 Numerical Modeling. The approach to the numerical modeling was to 1) identify the modeling studies on the lower Columbia River, 2) identify state-of-the-art river models, based on up-to-date investigations on similar river and estuary systems, and 3) select and recommend the models that best suit the study requirements. The following sections summarize the findings of the Subtask 2.

Conceptual Model–There are a number of complex physical processes that occur in a dynamic water way such as the lower Columbia River. A conceptual model attempts to simplify many complex physical processes into simple mechanisms that are amenable to mathematical analysis and numerical solution. The motion of water in the lower Columbia River is affected by several processes:

- **River Discharge** - Total upstream discharge is directly responsible for the net flow downstream. The upstream discharge is dependent upon the releases from flow storage facilities, discharges from the tributaries, and hydrologic and meteorological parameters.

- **Gravitational Force and Resistance** - The gravitational force is responsible for inducing the downstream river flow The parameters governing the gravitational effect on the flow are the slope of the river bed and the free surface slope (depends on discharge, tide and bathymetry) of the river. River bed friction, which depends on flow velocities, opposes the flow and results in transport of sediments with the flow.

- **Geography** - Rivers with large curvatures are affected by the force of Coreolis; the strength of this force is dependent on the latitude and flow velocity. Bottom slope affects flow velocities, and bottom topography and land boundaries are responsible for the fine structure of the flow.

- **Nontidal Oceanic Influence** - The flow at the mouth of the river is affected by waves that refract into the estuary and affect the sediment transport.

- **Tidal Oceanic Influence** - The tidal wave entering the mouth of the estuary is a major source of energy for the circulatory processes in the estuary. The effects of tides may be felt beyond the confines of the estuary in the form of rise and fall of the river water surface, flow reversals, and variations in flow with tidal frequency.

- **Atmospheric Interaction Processes** - Wind and barometric pressures may affect the flow in the estuary area where the water surface area is large.

These parameters are the driving forces that cause or directly affect the motion of the river water. A hydrodynamic flow model numerically defines these parameters, uses the bathymetric and flow data, and predicts 1) flow velocities, 2) circulation patterns, 3) river elevations, and 4) bottom shear, based on the driving forces.

Water quality at a point along the river depends upon the flow at that location and the constituent loading. Constituents under consideration may include dissolved chemicals, sediments, or suspended particles from outfalls. The river flow transports the dissolved and suspended particles downstream by way of advection and diffusion. Bottom shear and turbulence induces the motion of sediments which are carried downstream by way of bed load or suspended transport. A sediment transport model uses the flow data and the upstream sediment loading to compute the sediment movement. Similarly, a contaminant transport model predicts the pollutant concentration downstream using the flow and pollutant loading data. These processes can be simplified by a simple conceptual model (Figure 2.3-1). The results of pollutant and sediment transport models may be used to study: 1) shoaling characteristics of the river, 2) concentration of toxic elements, 3) biological oxygen demand (BOD) and dissolved oxygen (DO) concentrations, and 4) fate of settleable particles. Thus, simulation of river water quality requires

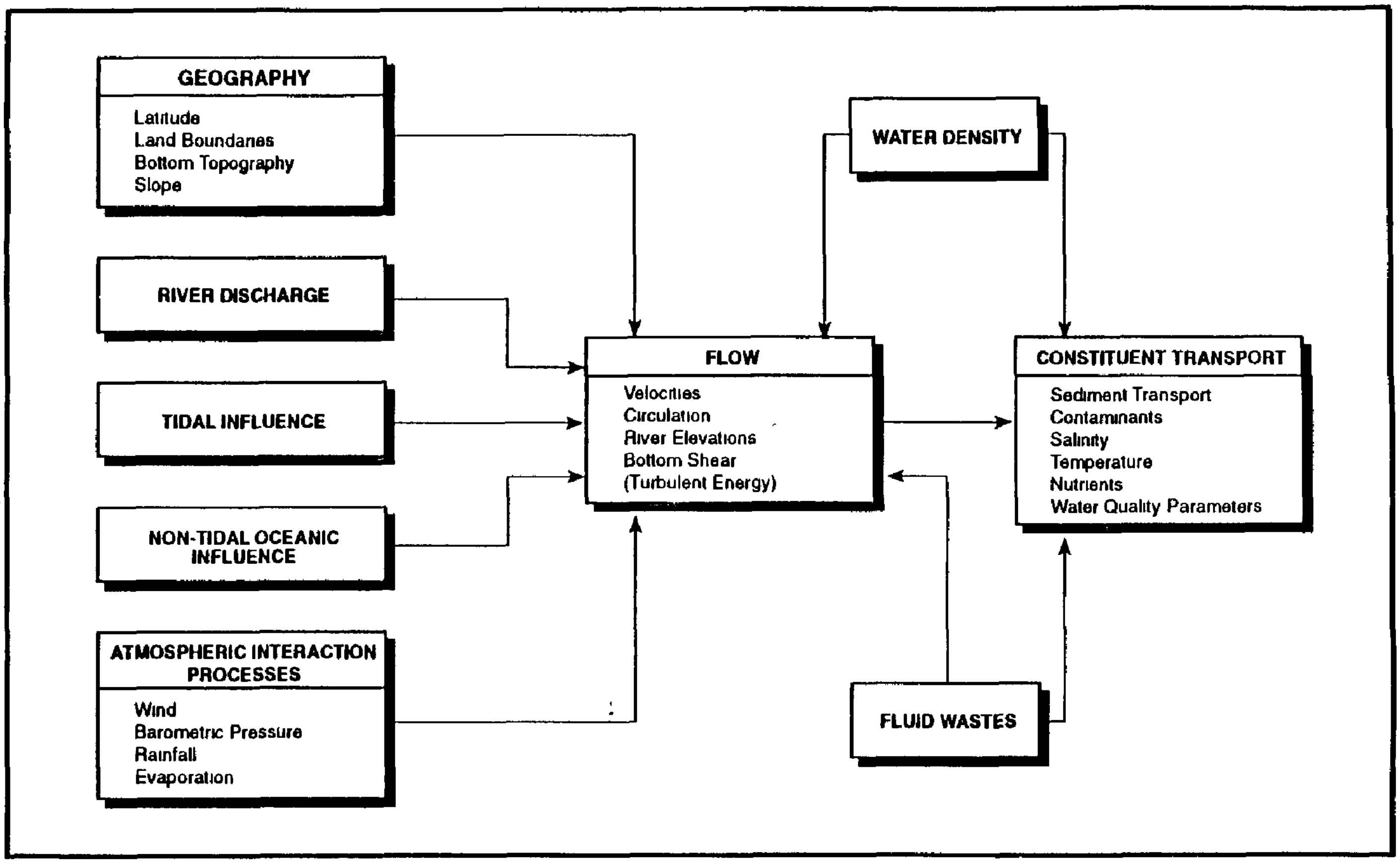


Figure 2 3-1. General Conceptual Model Framework for Physical Processes simulating river flow, which can be related to constituent transport for determination of fate of contaminants and transport of any other conservative substances.

River Hydrodynamics–Accurate flow simulation is essential for determining the temporal and spatial characteristics of constituent transport with reasonable accuracy. Logically, the most sophisticated models should be applied for flow simulation and constituent transport. However, selection of a model depends upon the appropriateness of the model and the costs of applying the model to a particular river reach. Due to geometric variations, bathymetric effects, and tidal and river flow influence, there is not one ideal model for the entire lower Columbia River from Bonneville Dam to the river mouth. Based on hydrodynamic flow behavior, the river is divided into 1) estuary region, 2) intermediate region, and 3) riverine region.

Estuary Region: RM 0 to RM 37 Hydrodynamically, the estuary region is the most complex reach of the river. The estuary has a wide mouth (about two miles in width) which is open to salt wedge intrusions. Freshwater river flow averages about 260,000 cfs and is highly modified by the tides. The flow structure depends on the bathymetry, which is diverse and includes shoals and small islands. The vertical flow structure is also affected by salinity-induced stratification. Due to the dominance of river flow, more mixing occurs during the ebb than the flood tide, which affects salt water and fresh water stratification. Salt transport in and out of the estuary occurs along different paths. These hydrodynamic characteristics, which indicate a strong three-dimensional flow structure, support application of a fully three-dimensional model in the estuary region.

Intermediate Region: RM 37 to RM 54 The intermediate region of the lower Columbia region is the transition region, where the flow changes from riverine to tidal. The flow is affected by the tides, and flow reversals have been observed. However, there is no salinity in this region; therefore, no vertical stratification exists. Throughout the region, there exists a number of multiple channel reaches, and the flow is split between them. The main channel, often referred to as the navigational channel, supports most of the flow. Due to a lack of vertical stratification, the flow can be assumed to be uniform in the vertical direction, but the islands and navigational channel induce a lateral variation that cannot be ignored. This region requires a vertically averaged, horizontal two-dimensional model to obtain sufficient accuracy in numerical simulation.

River Flow Region: RM 54 to RM 146 In this region, the river exhibits dynamic open channel flow for the most part. The channel bed slope is negligible and the flow is governed by upstream discharge from the Bonneville Dam and inflow from the tributaries. The variations in flow and transport parameters are much higher along the river than in the vertical or the lateral directions, and the simplest approach is to assume one-dimensional, quasi-steady-state conditions, assuming steady state conditions over short durations. However, the lower Columbia River shows tidal effects in the form of flow reversals as high as RM 95; therefore, a dynamic (time dependent) model is recommended. While most of the flow is in the navigational channel, localized areas with sloughs and islands create a lateral variation. This would require a two-dimensional model for simulation. Thus, this reach of river may be modeled using an open-channel, unsteady one-dimensional model, with additional localized analysis using two-dimensional models where necessary

Pollutant Modeling--River contamination results from three principal sources of pollution: 1) point sources, 2) non-point sources, and 3) in-place pollutants Point sources are defined as those discrete sources that discharge directly into the waters of Columbia River. They include domestic, industrial, and agricultural facilities that discharge effluent directly into the river via pipelines. Non-point sources include general run-off, urban stormwater discharges, combined sewer overflows, and atmospheric inputs, although some of these sources may also be ultimately delivered to the river by a discrete pipe or point source. In-place pollutants are those contaminants from hazardous waste sites and landfills that may enter the river through groundwater or surface water drainage.

The primary factors influencing water quality include 1) quantity of effluent discharge, 2) water depth, and 3) flow. These factors influence temperature, pH, turbidity, BOD, DO, conductivity, trace metals, radionuclides, and other toxic compounds or minerals. Since many toxic contaminants tend to be associated with fine particles, turbidity or suspended solids can affect total water levels of contaminants.

The transport of contaminants via the river flow occurs in three phases: 1) dissolved phase, 2) suspended phase, and 3) sediment phase. The portion of the contaminants that are dissolved into water are carried downstream with the river flow by the process of advection and diffusion. Suspended particles of waste are carried downstream mainly by advection with the flow and to certain extent by dispersion. Part of the effluent dissolved phase is adsorbed into fine-grained bottom sediments and becomes part of the suspended sediments that are transported downstream via river fluvial transport.

Thus, pollutant modeling requires three models: 1) a hydrodynamic flow model, 2) a contaminant transport model, and 3) a sediment transport model. The flow directly carries the dissolved component by way of mass transport and diffusion, so a numerical model is required that solves the advection-diffusion equation using the flow results of the hydrodynamic model. Similarly, the sediment transport model requires input from the hydrodynamic model to compute the transport of bed sediment as a combination of bed load and suspended load.

Numerical Models of Flow and Transport–Modeling techniques, aided by advances in the computational power of the new generation of computers, have reached a high level of sophistication and accuracy. The simplest models are the one-dimensional models that assume a completely mixed flow. Callaway et al. (1970) used such a model to simulate the flow in the Columbia River from Bonneville Dam to the river mouth. The next level of sophistication consists of two-dimensional models that assume uniformity in one direction and variability in the other direction. The Columbia River Hybrid System (McAnally 1983) uses a two-dimensional flow and sediment transport model, calibrated by using a physical scale model of the estuary to study flows and sand movement in the estuary. A quasi-three-dimensional model of the estuary has been constructed by Hamilton (1984), who uses a combination of a two-dimensional model in the vertical direction and a network of branched channels to model the hydrodynamics of the estuary.

A number of new hydrodynamic models have appeared in the market, which consider full three dimensional variations of flow with minimum approximations. Similarly, three-dimensional models of pollutant dispersion and sediment transport are now available. These models have been reviewed by Tetra Tech (1992f) in a report on numerical modeling. The task of producing a state-of-the-art, three-dimensional numerical modeling package for rivers and estuaries is being pursued by the Waterways Experiment Station in Vicksburg, Massachusetts (Robey and Lower 1991).

Modeling Recommendations–A number of models with different levels of sophistication exist. Considering the computational costs and degree of sophistication required, a two-case approach for numerical modeling is recommended for consideration.

Case 1. Conservative Approach. The conservative approach is used where results of the modeling study are required in a relatively short time frame with limited resources. It is recommended that models that have already been used on the Columbia River be used. These models have already been verified and are reliable. The following models are proposed for application to the lower Columbia River:

1. Estuary Region - Hamilton's Model (1984)

2. Intermediate Region - TABS-2 (Thomas & McAnally 1985)

3. River Channel Flow Region - Callaway's Model (Callaway et al. 1970) Site Specific Application- TABS 2 model

Case 2. State of the Art Approach. If the ultimate goal of the study is to obtain the best possible simulation and if resources exist for data collection and verification of an untested model on the lower Columbia River, then this approach can be followed:

1. Estuary Region - CH3D (Sheng 1986)

2. Intermediate Region - TABS-2 (Thomas & McAnally 1985)

3. River Channel Flow Region - SEDICOUP (Holly & Rahuel 1990) Site Specific Application- TABS 2 model.

The models recommended in the above two sections primarily address the flow simulation. Most of them carry their own subroutines for simulations of sediment or contaminant transport. Suitable transport models will have to be selected (Tetra Tech 1992f) and coupled to these flow models, depending on the modeling study requirements.

2.3.3 Data Gaps

The identification of data gaps is an important component of scoping future studies on the Columbia River. Data gaps are identified by evaluating the existing data and determining what additional data are required to characterize the river, develop a better understanding of the physical processes, and perform numerical modeling studies. Sufficient data exists for a qualitative understanding of the river behavior. Available information is summarized in the Task 3 report, *Hydraulic, hydrologic, sediment transport and geomorphic characteristics of the lower Columbia River* (Tetra Tech 1992e).

Data needs for numerical modeling purposes depend upon the modeling sophistication desired. Two potential modeling approaches are discussed in Section 4 0, a conservative approach and a state-of-the-art approach. The data needs will depend upon the approach selected. As a result, this discussion of data gaps has been developed assuming a generic modeling approach.

To develop a numerical model that is capable of simulating the hydrodynamics, sediment transport, and contaminant transport, the modeler must have sufficient knowledge of the following:

- Bathymetry
- Tides
- Flow from Bonneville Dam and major tributaries
- Sediment transport and dredging records
- Salinity and temperature data.

2.3.3.1 Bathymetry. Water depth as a function of location is a requirement for any type of model Bathymetry of the lower Columbia River is complex, with a number of mid-channel islands and sand shoals which vary in size, location and shape

The bathymetry data can be obtained through the USACOE surveys of the navigation channel and the Vancouver to the Dalles navigation projects. The surveys are in the form of transects across the channel at 500 ft intervals. Data are needed for the regions beyond the navigated channel, which are not covered by the surveys (USACOE 1987,1991), but which often tend to accumulate contaminants and so are important for water quality purposes.

Although flow from Bonneville Dam and tributaries from RM 146 to RM 54 is mostly supported by the navigational channel, predominant settlement of fine grain sediments is outside the main channel in backwater and secondary channels. The fine grain sediments are of concern because of contaminant affinity to these particles. Modeling of backwater flow and sedimentation conditions are therefore of primary interest, requiring additional bathymetry data.

In the estuary, the navigational channel is the predominant flow channel, but is only one of the many channels that support flow. Detailed bathymetry covering the entire estuary, including the sand shoals and the periphery of the small island, would be required for hydrodynamic simulation of the estuarine tidal circulation. These data are available through the bathymetric atlas of the Columbia River estuary (CREDDP 1983), and from USACOE surveys of the estuary.

2.3.3.2 Tides. Tidal data is an important forcing parameter for a tidally influenced river such as the lower Columbia River The mouth of the river forms an open water boundary, so free surface elevations as a function of time are required as boundary conditions for forcing the tidal circulation in the estuary. Irrespective of the model type, water surface elevations at the boundaries of the model domain are required; e.g., the estuary mouth and any chosen upstream boundary. USGS and USACOE have many years of continuous measurements at various locations including Warrendale, Portland (Willamette River), Astoria, Vancouver, and Longview. In addition, tides can be predicted along the river using models developed to assist Columbia River shipping Tidal data necessary for modeling purposes are available

2.3.3.3 Flow from Bonneville Dam and Major Tributaries. Accurate flow releases from Bonneville Dam are available on an hourly basis from USACOE within their CROMS database system. Mean daily flows are available for major tributaries such as the Willamette and Sandy Rivers in Oregon, and the Washougal, Kalama, Lewis and Cowlitz Rivers in Washington, through the USGS WATSTORE database. These data are sufficient for running one-dimensional flow models in the upper river However application of two dimensional models is recommended in the intermediate region (RM 37 to RM 54), and also other locations in the upper river where multiple channels and mid-channel islands exist. The hydrodynamic models are used to predict the water particle velocities, and require current meter records for verification.

A major data gap is identified regarding flow meter data on the river. There are limited USGS tide stations on the main Columbia River and only some of them include current meter records. Considering the long length of river from RM 146 at the Dam to RM 37 at Tenasillahe Island, additional current stations are required to obtain sufficient spatial distribution for verification of two-dimensional hydrodynamic models. On the other hand, current meter records have been collected at several locations in the estuary, and at several depths. The National Oceanic Survey field program conducted in 1981 and the CREDDP field study program conducted in 1980 are excellent sources of current and tidal data. These data will be valuable for the verification of a three-dimensional model in the estuary.

2.3.3.4 Sediment Transport and Dredging Records. Sediment transport data is required to verify a model subject to sediment budget and sediment movement. The principal data required is grain size distribution, sediment density and physical characteristics, and quantitative estimates of the sources and sinks of sediments. Data on grain size and other sediment physical characteristics are available mostly from dredging records of USACOE (1980, 1991). This information is required for running the sediment transport model and predicting sediment quantities moved by the river flow. While sediment characteristic data are available, the field data on site-specific sediment transport measurements, which are required for model verifications, are limited. Sediment transport measurements exist near Vancouver and are available from USGS, and USACOE records near Sauvie and Puget Islands (USACOE 1986 and 1988, respectively).

The available sediment characteristic data are primarily from the navigational channel. These data are predominantly for sand-sediment deposition. The majority of depositional areas for fine-grain, silt-sized sediment are located in the backwaters and sloughs where sediment data are lacking. The available data and studies allow a basis for qualified estimates of fluvial bedload supply in and out of specific river reaches. A specific study to measure bedload from the river into the estuary has not been conducted. Measurements of suspended loads have been conducted using turbidimeters in the estuary, but not in the upper river. For sediment transport verification, data are needed on actual sand or suspended sediment transport, measured across several transects as a function of time and location on the river.

2.3.3.5 Salinity - Temperature Data. Salinity data are required primarily for the purpose of modeling the estuarine processes that are influenced by salinity stratification. This information has been developed through the USACOE physical model study and the CREDDP report on circulatory processes by Jay (1984).

2.3.3.6 Summary - Data Availability. In conclusion, relatively good data availability exists in the estuary, primarily as a result of the CREDDP efforts. Three large data gaps have been identified:

1. Lack of sufficient current meter data or flow data at specific transects on the main Columbia River above the estuary.

2. Lack of sufficient sediment bed load and suspended load data as time histories at specific transects on the river upstream of the estuary.

3. Lack of sediment characterization in secondary channels and backwater areas in the river upstream of the estuary

A minimum database required for the development of simple hydrodynamic and sediment transport models is available but has not been compiled. Data availability and gaps related to contaminant transport are addressed in the Task 2 reports on pollutant characterization.

2.3.4 Conclusions

Through a review of the physical characteristics of the lower Columbia River and the evaluation of the conceptual and numerical models available, the following conclusions and recommendations can be made.

Hydraulic, Hydrologic, Sediment Transport, and Geomorphic Characteristics:

1. Two distinct hydrodynamic zones can be identified. The river system from RM 0 to RM 37 is the estuary region. This region shows the influence of tidal flows, salt intrusion and the presence of tidal and residual circulation patterns which typify three-dimensional variations. The estuary is also the sink or deposition zone for most of the sediments transported from the upper river

2. The second zone is the remaining stretch of the river from RM 37 to RM 146. The river demonstrates consistent dynamic open-channel unidirectional flow. The channel bed slope is small and the flow is forced by discharges from the upstream tributary inflows and the releases from the Bonneville Dam. The region between RM 37 to RM 54 can

be considered as a region of transition between the estuary and the riverine region because of flow reversals of significance during low river discharge.

3. The Columbia River drains about 258,000 square miles of terrain. Average discharge is about 260,000 cfs, varying from a low of about 100,000 cfs in the months of August to November to a regulated high of about 500,000 cfs in the months of April to July. The influence of tides can be measured upstream to the Bonneville Dam. The duration and locations of flow reversals depend upon river discharge and tidal amplitudes. Flow reversals as far upstream as RM 95 have been noted, but as more typical below RM 75. The influence of salinity intrusion can be felt up to RM 27 during low flows and neap tides.

4. Columbia River flows transport large volumes of sediments as suspended load and bed load. The sediment transported in suspension is estimated at 10 million tons/yr, and the sediment transported as bed load is estimated at about 1 to 2 million tons/yr. About 20-30 percent of sediments entering the estuary is deposited within the estuary and the rest is transported out of the river mouth into the Pacific Ocean. Maintenance of navigational channels is a major concern, requiring a reported average of 8,000,000 cubic yards of sand to be dredged from the Columbia River annually for this purpose.

5. Pollutants enter the river through outfalls of domestic and industrial wastes, from sewage and storm water runoff, and from other nonpoint sources. While dissolved contaminants are transported with the river flow, some contaminants attach to suspended and settleable sediments and are transported downstream via sediment transport. Generally, dissolved solid concentrations are less than 175 mg/L, water hardness is between 40 to 100 mg/L, and the suspended sediment concentration in the water column is about 20 to 200 mg/L.

Numerical Modeling of The Lower Columbia River:

1. Numerical modeling of the lower Columbia River involves three major components: 1) a flow model that is driven by the tidal and river free surface elevation, slopes and upstream flow; 2) a sediment transport model; and 3) a contaminant transport model.

The flow model provides the necessary input, namely fluid particle velocity as a function of time and space, to the sediment and contaminant transport models. The transport models then predict the concentration of pollutants and sediments with respect to time and downstream distance. Based on geomorphic complexity and modeling considerations, the river has been divided into 1) estuary region, 2) intermediate region, and 3) riverine region.

2. For performing numerical simulations with reasonable accuracy, a three-dimensional model in the estuary, a two-dimensional model in the intermediate region, and a one-dimensional branched model with two-dimensional modeling for site-specific reaches in the riverine region is recommended

2.4 TASK 4: BIOLOGICAL INDICATORS

2.4.1 Objectives

There were two objectives for Task 4: The first was to review and summarize data about the benthic taxa and contaminants identified in sediments collected during the reconnaissance survey. The second objective was to provide recommendations on the biological indicators that would be most useful in a long-term monitoring program for the lower Columbia River. The recommendations were based on a synthesis of information from the literature, historical studies, discussions with regional and national experts, and the results of the reconnaissance survey (Tetra Tech 1993) The following steps were taken to develop bioindicator recommendations for monitoring the water quality of the lower Columbia River:

- Reviewed the pertinent literature and interviewed scientists with experience and expertise in the development and use of biological indicators.

- Reviewed the distribution and abundance of species in the lower Columbia River identified in historical studies and during the reconnaissance survey.

- Reviewed the distribution of contaminants in sediments and biological tissues collected from the lower Columbia River during the reconnaissance survey.

- Analyzed and synthesized the information collected to date with respect to potential use in a biological monitoring program.

- Provided final recommendations of biological indicators that would be most useful and applicable for long-term water quality monitoring in the lower Columbia River.

Products of this task included:

- *Reconnaissance Survey of the lower Columbia River. Task 4: Review of biological indicators to support recommendations on a biological monitoring approach* (Tetra Tech 1992h).

- *Reconnaissance Survey of the lower Columbia River. Task 4: Recommended biological indicators for the lower Columbia River* (Tetra Tech 1992i).

2.4.2 Results

2.4.2.1 Summary of Initial Recommendations. An in-depth discussion on the theory and use of biological indicators was presented in the initial Task 4 report. A number of organisms and measured endpoints were discussed as exposure or response indicators for potential inclusion in a lower Columbia River monitoring program. A set of candidate biological indicators applicable for use in a Columbia River monitoring program was synthesized from information in the literature and review of historical data and presented in the Task 4 Report as initial recommendations (Tetra Tech 1992h).

In the initial recommendations report, use of a suite of biological indicators was identified as the optimum approach for monitoring water quality in the lower Columbia River. Biological indicators were drawn from both fish and benthic invertebrate taxa known to be resident in the lower Columbia River or commonly used in environmental monitoring programs in other areas. Recommended test approaches included use of resident species and communities, and surrogate (i.e., non-resident) species under laboratory or *in situ* field conditions. Many species of fish (including starry flounder, sturgeon, sculpins, salmonids, perch, carp, and peamouth) were recommended as both exposure and response indicators for elevated concentrations of metals and selected organic compounds (e.g., chlorinated hydrocarbons, PCBs, and pesticides). Salmonid laboratory bioassays were proposed for measuring site-specific, point-source effects in the lower Columbia River

The initial recommendations report discussed the use of benthic invertebrates as potential indicators of both exposure and response The sessile nature of many invertebrate taxa can provide site-specific information about exposure not possible with more motile organisms. Polychaetes (worms) and bivalves (mussels and clams) were specifically identified for use in bioaccumulation studies involving metals, PCBs, pesticides, and other chlorinated organic compounds. Laboratory tests of growth and reproductive impairment in mysid shrimp and polychaete species were presented as viable alternatives for assessing the overall water quality in the lower Columbia River

Algal and bacterial populations were believed to have limited use as contaminant exposure or response indicators in a long-term monitoring program for the lower Columbia River. While it was recommended that these organisms not be used as biological indicators for the overall monitoring program, it was recognized that these organisms, particularly bacteria, may be appropriate for assessing impacts to beneficial uses in the river.

2.4.2.2 Summary of the Reconnaissance Survey Results. Water, sediment, and biota samples were collected during the fall 1991 reconnaissance survey to characterize benthic community structure, and determine the extent and magnitude of contamination in various environmental matrices in the lower Columbia River. Data collected as a result of the survey were previously presented in the Task 6 Reconnaissance Survey Report (Tetra Tech 1993) and are summarized in more detail in Section 2.6 of this report.

Biological communities in the lower Columbia River tend to be structured by gradients of salinity, and habitat stability as represented by sediment grain size. Two major ecological zones were identified within the lower river based on salinity and species composition. the estuarine and riverine zones. There was some evidence that a transitional zone existed between the saline and freshwater portions of the river, but too few stations were sampled to clearly identify the characteristics of the transitional zone.

Benthic community composition shifted with decreasing salinity, and numbers of individuals and species richness tended to decrease with increasing distance from the mouth of the river. This phenomena was due, in part, to the increase in coarser sediments in the upper reaches of the river. Coarse-grained sands tended to be indicative of unstable substrates and supported fewer benthic organisms.

Contaminant distribution varied widely in sediments. Contaminants tended to be found in areas near industrial discharges or major urban areas along the river. In areas of higher contaminant concentrations, statistical tests examining the relationship between contaminant concentrations and benthic invertebrate community response did not show a negative association between chemical and biological variables. However, evaluation of fish and crayfish tissue from resident organisms indicated that many contaminants are present and are bioavailable. More contaminants were detected in fish and crayfish tissues than were found in water or sediment during the reconnaissance survey. The contaminants of concern were those that were detected frequently in tissues and sediments or represented a potential threat to human or ecological health. Contaminants of concern included metals, pesticides, PCBs, dioxins and furans, PAHs, and organotins.

2.4.2.3 Final Recommendations for Biological Indicators. Criteria used to select biological indicators included relevance to the lower Columbia River based on reconnaissance survey results, reported sensitivity to substances of concern, availability of established test procedures, ease of performance, and ease of interpretation of results. Recommended biological indicators included both exposure and response indicators. Exposure indicators consist of bioaccumulation and physiological measurements (e.g., detoxification enzyme production). These indicators provide information regarding the bioavailability of specific contaminants present within the river and the potential for magnification of these contaminants in the food chain. However, they do not provide information regarding subsequent biological or ecological effects because some contaminants can be accumulated without invoking adverse effects. Response indicators are used to address the effects associated with exposure. The recommended response indicators consisted of reduced survival, impaired growth, and physiological measurements (i.e., fish health index and changes in normal enzyme production). Although reduced survival, impaired growth, and the fish health index are not contaminant-specific responses, they can be used to demonstrate that effects are occurring because of exposure to a substance or condition. Decreased production of key enzymes can be used to demonstrate the effects associated with exposure to specific contaminants.

Some of the biological endpoints commonly used as exposure and response indicators include the following:

EXPOSURE INDICATORS

- Biochemical Level
  - Bioaccumulation
  - Enzyme induction

RESPONSE INDICATORS

- Individual Level
  - Reproductive impairment
  - Genetic aberrations
  - Growth/development impairment
  - Pathological lesions and neoplasms
  - Morphological abnormalities
  - Reduced survival
  - Enzyme inhibition
- Population Level
  - Reduced abundance
  - Altered age structure
  - Reduced growth
- Community Level
  - Reduced diversity
  - Altered community composition
  - Reduced total abundance
  - Reduced colonization rates

Biological indicators were selected for both estuarine and freshwater environments because of the different ecological zones present in the lower Columbia River. Physical habitat characteristics and community composition were used to establish two major ecological zones in the lower Columbia River; estuarine and riverine ecological zone. Absolute physical boundaries of the zones were not identified because the physical characteristics are used to describe the zones are present as a continuum or gradient. For the purposes of this study, habitats upstream of RM 27 were characterized as freshwater and the first 27 miles of the river from the mouth was classified as the marine/estuarine zone. Although there was some evidence that a transitional zone may be present between the marine and freshwater zones, no boundaries were identified because too few stations were sampled.

The selection of indicator species for use in the biological monitoring program will not be dependent on the absolute river mile demarcation between freshwater and estuarine environments. First, the boundaries between freshwater and estuarine environments fluctuate; shifting up- and downriver in response to tidal and seasonal cycles. The portion of river between RM 20 and RM 30 probably experiences the greatest salinity changes. Second, interstitial salinities may have greater influence on benthic community composition than water column salinity (Chapman and Brinkhurst 1981). The selection of a particular test species for use within the portion of the river where salinities are neither truly freshwater or marine will be based on the exposure conditions (e.g , water column vs. sediment exposures) and the organism's ability to withstand the conditions characteristic of the monitoring site (e.g., capable of withstanding wide variations in osmotic pressure or salinity).

Exposure or response endpoints can be measured in either field studies with resident or transplanted organisms, or in laboratory tests. Resident organisms provide a direct assessment of environmental conditions. This approach is sometimes limited because a sufficient number of species to support a given test cannot always be found within the system, or because natural variability in the test species may substantially reduce the power of the indicator to demonstrate an exposure or effect. An indirect assessment of exposure and response can be obtained by transplanting either cultured or field-collected organisms from uncontaminated areas and conducting *in situ* studies. Use of *in situ* bioassays provides the advantage of environmental realism and experimental control combined and selected endpoints can be easily monitored. One limitation for using field collected organisms occurs if an insufficient number of organisms is available from clean source areas

The recommended biological indicators for monitoring the lower Columbia River will address contaminants in the water column as well as those associated with the sediments. These biological indicators can provide information regarding the overall water quality of the lower Columbia River as well as for specific contaminants. Several *in situ* and laboratory approaches were reviewed prior to finalizing the list of recommended biological indicators. The recommended monitoring approach was based on the use of field studies incorporating both resident and transplanted species. Although laboratory manipulations (e.g., sediment mixing, elutriate processing) and exposure conditions (e.g., static renewal, artificial light) can affect toxicity responses (Burton 1991), laboratory testing was also suggested to verify field measurements Two sediment laboratory bioassays with amphipods were recommended for evaluating sediments because of their proven utility and sensitivity to a number of contaminants.

Recommendations are presented for each major habitat type in the following section.

Freshwater Water Column

- Survival, growth, and bioaccumulation in transplanted bivalves (i.e., *Corbicula fluminea*)

- Bioaccumulation measurements in resident fish species [e.g., peamouth (*Mylocheilus caurinus*), bass (*Micropterus* spp), and crappie (*Pomoxis* spp.)]

- Physiological measurements (Fish Health Index and detoxification enzymes) in resident fish (same species used in bioaccumulation studies)

Freshwater Sediments

- Survival, growth, and bioaccumulation in transplanted bivalves (i.e., *Corbicula fluminea*)

- Survival of endemic amphipods (e g., *Corophium salmonis*)

- Bioaccumulation measurements in resident amphipods (e.g., *Corophium salmonis*), crayfish (e.g., *Pacifastacus leniusculus*), bivalves (e.g., *Corbicula fluminea*), and fish species [e.g , carp (*Cyprinius carpio*), largescale sucker (*Catostomas macrocheilus*), white sturgeon (*Acipenser transmontanus*)]

- Physiological measurements (Fish Health Index and detoxification enzymes) in resident fish (same species used in bioaccumulation studies)

Estuarine Water Column

- Survival, growth, and bioaccumulation in transplanted bivalves (i.e., *Mytilus* spp.)

- Bioaccumulation measurements in resident fish species [e.g., peamouth (*Mylocheilus caurinus*)]

- Physiological measurements (Fish Health Index and detoxification enzymes) in resident fish (same species used in bioaccumulation studies)

Estuarine Sediments

- Survival, growth, and bioaccumulation in transplanted bivalves (i.e., *Macoma balthica*)

- Survival of endemic amphipods (e.g., *Eohaustorius estuarius*)

- Bioaccumulation measurements in resident clams (e.g., *Macoma nasuta*) and fish [e.g., starry flounder (*Platichthys stellatus*)]

- Physiological measurements (Fish Health Index and detoxification enzymes) in resident fish (same species used in bioaccumulation studies).

Both resident and transplanted organisms can be effectively used in these studies. The decision to use one group of animals over the other will depend on several factors. The use of resident species in monitoring programs may be limited by the ability to collect sufficient numbers or appropriate size classes from the areas under evaluation. Animals for use in transplant studies can be obtained from clean field sources or commercial laboratory cultures. However, not all species are available from culture facilities.

It may be necessary to further characterize the lower Columbia River and identify "clean" areas as collection sources for animals to be used in transplant tests. Depending on the availability of "clean" wild animals, it may be more cost-efficient to use laboratory-reared individuals, if available.

All of the recommended biological indicators are based on biochemical and individual level measurements. These types of measurements have been selected over population and community level metrics because of the difficulties and complexities associated with population or community level responses. The discussion presented in the Task 4 Report stated that populations are not commonly used in environmental monitoring programs due to insufficient information on the population dynamics or degree of natural variability of most plant and animal species Green et al. (1985) state that population and community level responses to environmental stress are often very non-specific For example, an observed shift in species composition often appears straight-forward, but on closer examination, the response is less clear due to the complexities of other responses which have been integrated in the measured response The response of a natural population or community to environmental variation is usually complex and multivariate, difficult to describe, and, according to Green et al. (1985), even more difficult to analyze statistically.

Although U S. EPA's Environmental Monitoring and Assessment Program (EMAP; U S. EPA 1990) strongly recommends benthic community structure as a response indicator for both estuarine and freshwater environments, it is not a recommended approach for assessing the overall health of the lower Columbia River. The results of the reconnaissance survey demonstrate that benthic community structure was highly variable in both estuarine and freshwater portions of the river. Species distributions were strongly affected by habitat characteristics (i e., salinity, habitat stability as indicated by grain size) and did not show a clear correlation with sediment contamination concentrations.

This variability in benthic community structure was attributed to the high-energy nature of the lower Columbia River and the unstable substrates characterizing the majority of the lower river. This is particularly true of the freshwater portions of the river where sediments consist primarily of sands and gravel. In the lower Columbia River, sands and gravel are characteristic of unstable substrates that move and shift a great deal as currents pass over them There are very few organisms that can successfully inhabit this high-energy environment. The communities that often develop in these high-energy systems are most likely responding to the physical environment, and not chemical contaminant concentrations.

There may be some individual situations in the lower Columbia River where benthic community structure may be useful as a biological indicator For example, the substrate in the vicinity of a particular outfall might be stable enough to support a diverse community, which could be used to evaluate the effects of the contaminants associated with the outfall. However, in order for this to be an effective approach, additional qualitative surveys must be conducted to ensure diverse, abundant benthic organisms are found in similar "unimpacted" areas for comparison.

2.4.2.4 Monitoring Approach. The recommended monitoring program is structured to address contaminants associated with sediments as well as contaminants in the water column originating from point- and nonpoint-sources. It is an integrated approach that is based on field studies utilizing both transplanted and resident species, and both exposure and response indicators. Exposure indicators provide evidence of the occurrence or magnitude of exposure to a physical, or chemical stress; in most cases they cannot be used to identify impacts or adverse effects to the exposed individuals. Response indicators can provide evidence of an injury; however, there are very few response indicators that are chemical- or stressor-specific. Exposure indicators must be used in conjunction with response indicators in order to identify both contaminants of concern and whether contaminants are impacting the biota.

This multiple endpoint, field-oriented approach will provide environmental realism and permit experimental control. The resulting database of information will permit formation of rigorous ecological conclusions regarding the water quality of the lower Columbia River. Standardized laboratory tests using effluents and sediments collected from the lower Columbia River are possible monitoring program elements that should be considered to address specific concerns or sites.

The recommended biological monitoring program would be of greatest value if conducted at least twice yearly to address some of the seasonal variability in river conditions and contaminant inputs. Monitoring events should reflect extreme flow conditions in the river (i.e., high and low flow periods). The April to May period would be appropriate to monitor high flow conditions associated with spring rains and snow melt. Low flow conditions could be expected during August or September. The data would be evaluated after each monitoring event to determine the impact of extreme conditions on results. If the results indicate few seasonal differences in contaminant effects, then monitoring frequency should be reduced to once per year. It is recommended that annual sampling occur in the fall because this time period probably represents worst-case conditions, the majority of test organisms are available, and deployment of caged animals for exposure and survival studies is less subject to extreme flow conditions.

Although these are final recommendations for monitoring the water quality in the lower Columbia River, the acquisition of additional data and biological indicator techniques may result in modifications in a monitoring approach. In addition, the effectiveness of the monitoring program should be evaluated after a period of one year with respect to the performance and sensitivity of the tests to identify adverse environmental conditions within the lower Columbia River.

2.4.3 Data Gaps

The data gaps for biological indicators are discussed under Task 1 (Section 2.1 3).

2.4.4 Conclusions

It is recommended that both response and exposure indicators be incorporated in a long-term water quality monitoring program in the lower Columbia River The response indicators of survival and growth are recommended endpoints for evaluating overall water quality Bioaccumulation, detoxification enzyme activity, and the Fish Health Index are the recommended exposure indicators. *Corbicula fluminea* are recommended for both water column and sediment studies in the freshwater reaches of the river *Mytilus* spp. and *Macoma nasuta* are recommended for the water column and sediment studies in the marine portions of the river Bioaccumulation studies can be conducted with each of these bivalve species as well as resident invertebrate and fish species The overall water quality of the lower Columbia River will be evaluated with growth and survival studies in transplanted bivalves and the Fish Health Index in resident fish species. Bioaccumulation studies will be used to identify past or current exposures to contaminants of concern. Based on the data obtained during the reconnaissance survey, analysis of benthic community structure in the lower Columbia River does not appear to be of utility for assessing impacts of sediment contamination. Benthic communities in the study area reflect the dynamic nature of the aquatic environment in the lower Columbia River Physical elements (e.g., salinity, sediment grain size, and substrate stability) rather than chemical contaminants, appear to strongly influence community composition throughout the river.

The reconnaissance survey measured tissue residues of contaminants in several species with differing degrees of mobility and feeding strategies. Evaluation of these data indicated that the best organism for use in bioaccumulation studies depends on the pollutant being evaluated and the distribution of the organism within the river. For example, tissues of the peamouth fish contained the highest concentrations of dioxins measured during the reconnaissance survey, but they were difficult to catch in the upper river. Of all the species analyzed, largescale sucker was the best indicator of environmental concentrations of PCBs; in contrast, PCBs were absent in the tissues of crayfish. However, tissues from crayfish and carp contained elevated concentrations of trace metals which corresponded to the environmental concentrations. Carp may be one of the most promising candidate species because their tissues contained the largest number of detected pollutants.

2.5 TASK 5: BENEFICIAL USES

2.5.1 Objectives

The objective of Task 5 was to define, describe and locate in consistent terms the beneficial and characteristic uses and sensitive areas of Columbia river waters within the identified study area. Definitions were based on Oregon Administrative Rules (OAR Chapter 340, Division 41, Sections 202, 442 and 482 including proposed amendments under triennial review) for the North Coast-Lower Columbia River Basin, and proposed Washington Administrative Code (WAC Chapter 173-203) as established in Draft Surface Water Quality Standards. (Note: WAC 173-203 as proposed will replace WAC 173-201 as established in the Water Quality Standards.) Use descriptions and locations included identification of beneficial use occurrence, extent, frequency or concentration, user group involvement, seasonality, and sensitivity to water quality alterations. This detail of information was not available for all uses. The location of each beneficial use was mapped using a Geographic Information System (GIS). This task also provides a discussion of data gaps, data quality, and recommendations for additional data collection and analysis.

2.5.2 Results

Task 5 was composed of three reports:

- *Reconnaissance Survey of the lower Columbia River. Task 5: Definition of beneficial uses* (Tetra Tech 1991d).

- *Reconnaissance Survey of the lower Columbia River Task 5: Beneficial use descriptions and locations* (Tetra Tech 1992j)

- *Reconnaissance Survey of the lower Columbia River. Task 5 summary report: Beneficial uses and sensitive areas* (Tetra Tech 1992k).

The first report precisely identified the beneficial and characteristic uses along the lower Columbia River as defined by both Oregon and Washington. Based on these definitions, the defined uses from both states were quantified and grouped into five categories The identified beneficial uses provided the basis for the second report that described and mapped these uses based on literature review, as well as numerous agency and organization interviews.

The identification of beneficial uses is critical to the development of a comprehensive understanding of the lower Columbia River system. The surface waters of the river are used for many purposes, all of which require water quality appropriate to the use Provisions have been established in both Washington and Oregon to ensure the conformance of quality criteria with reasonable present and potential uses of surface waters.

For the Bi-State Program the beneficial/characteristic uses from both states were compiled and organized into the five main groupings: (1) Water Supply, (2) Agricultural, (3) Fish/Wildlife Habitat, (4) Recreation, and (5) Commercial. The specific uses comprising each of these five groupings are listed in Table 2.5-1. The analysis of these beneficial/characteristic uses formed the content of the second report of Task 5.

The goal of Task 5 was to identify and describe the beneficial uses along the lower Columbia River, location of the use, frequency and season of the use, who or what is involved in the use and how sensitive the use is to water quality alterations The beneficial uses of the lower Columbia River are sensitive to water quality alterations in different ways and in varying degrees. In order to document the current water quality of the Columbia River within the study area, the water, fish, sediment, and benthic invertebrates

TABLE 2.5-1. BENEFICIAL USE DESCRIPTIONS FOR THE LOWER COLUMBIA RIVER

1. **Water Supply:**

   - All domestic water supply systems including private wells, small private water systems, public utility districts and municipal public systems, withdrawal rights, and other surface water extractions used for domestic supply; and
   - Industrial supply including direct withdrawals for manufacturing, processing, or other industrial activity.

2. **Agriculture:**

   - All private or public withdrawals for the purpose of irrigating agricultural crops, orchards, or public lands;
   - All withdrawals for the purpose of supplying water to commercial livestock operations; and
   - Areas of concentrated withdrawals by private landowners to supply livestock.

3. **Fish/Wildlife:**

   - Areas supporting anadromous fish passage, salmonid fish rearing, salmonid fish spawning, resident fish, and aquatic wildlife use including national and state refuges;
   - Significant riparian habitats such as backwater marshes and island nesting areas; and
   - Unique marine or freshwater habitats, and Natural Heritage Sites.

4. **Recreation:**

   - Hunting, fishing, and boating;
   - Primary contact recreation, in general where contact with the water is submergence such as skin diving, swimming, water skiing, jet skiing, and wind surfing;
   - Secondary contact recreation, in general where water contact is limited, such as wading or fishing; and
   - Aesthetic quality where senses are involved (i.e., scenic overlooks, unique botanical areas, birdwatching areas, etc.).

5. **Commercial:**

   - Hydropower production;
   - Navigation and transportation;
   - Marinas and other commercial activities associated with the River; and
   - Commercial fisheries

were sampled in designated locations as prescribed in the Reconnaissance Survey Sampling Plan for the lower Columbia River. The data gathered in Task 5 led to recommendations concerning each of the beneficial uses and how they applied toward developing the reconnaissance survey sampling plan. The findings from Task 5 are presented below.

Under **water supply** the major users of the Columbia River for municipal, industrial, and domestic purposes were identified. The Cities of Vancouver (RM 105) and Camas (RM 120) use wells along the river for municipal water. ALCOA (RM 102) is the largest private user for domestic and heat exchange supply. Whenever water sources are used for drinking water and other municipal domestic uses there is concern for human health. The major concerns for drinking water are contamination by fecal coliform bacteria and other pathogens, nitrates, and toxic levels of metals and/or organic chemicals. Well water is less likely to be contaminated, because it is naturally filtered before being withdrawn for use. Two of the largest industrial users of both surface and well water are Weyerhaeuser (RM 63) and Reynolds (RM 62).

There are few agricultural lands along the lower Columbia River. The largest **agricultural** user of the lower river is the Bachelor Island Ranch (RM 87-88). Depending on the use of the water (for irrigation or livestock), diminished water quality could affect crop production rates and quality, soil chemistry, and potentially the health of livestock. Conversely, a large agricultural area has the potential to alter the quality of the river water by adding excess amounts of fertilizer, pesticide and herbicide residues, sediment, and fecal coliform.

Fish use occurs along the entire length of the lower Columbia River. Fish species are year-round residents or migratory. Several areas of the river provide prime habitat for fish and shellfish and are known as popular fishing and crabbing locations The mouth of the Columbia River (Buoy 10) contains large concentrations of fish and Dungeness crabs (RM 0-6). The Cowlitz River (RM 68), Kalama River (RM 73) and Sandy River (RM 120-122) are also popular places for recreational fishing. With increased opportunity for human and wildlife consumption of fish from these areas the quality of the water and bottom sediment becomes a concern. Toxic substances are known to accumulate in sediment and fatty tissue. Since fish contain a large percentage of fatty tissue per body weight, they have the ability to bioaccumulate toxins. These pollutants can cause disease and cancerous lesions in the fish and, in turn, these diseased fish can contaminate consumers Pollutants of major concern are metals and organic chemicals.

Wildlife use is prevalent throughout the river but particular locations (refuges and river mouths) support large concentrations of a wide range of species. Sampling has focused on known bald eagle/osprey/raptor and sensitive amphibian usage areas. Because their main food staple comes from the lower river, these species are susceptible to alterations in water and sediment quality. Bald eagles and other raptors primarily feed on fish from the river. The U S. Fish and Wildlife Service has indicated that peamouth are a common prey species of the bald eagle. Several sensitive amphibians (i.e., red-legged frog and Olympic salamander) reside at the mouth of the Sandy River (RM 120-122). Because they absorb toxins through their skin they are vulnerable to water quality and sediment degradation, especially high levels of metals and phosphorus. Not only can these substances be fatal to the amphibian, but also can cause problems to the predators who consume them. Amphibians, like fish, can store excess toxins in their fatty tissue. This can lead to bioaccumulation of toxins in the food chain and ultimately affect many creatures.

Many **recreational uses** occur in and along the lower Columbia River. Primary contact sports are of particular concern because humans come in direct contact with the water. Swimming, wind surfing, water skiing, and fishing areas are locations important to monitor for water quality problems. Areas that are heavily used are Jones Beach (RM 45) for wind surfing, Youngs Bay (RM 12) for primary contact activities, and Skamokawa (RM 33) for primary contact activities and fishing. Degradation of water quality could potentially affect waterfowl and fish populations which would directly affect hunting and fishing activities. Excess nutrients can produce algae blooms which would hamper boating and contact activities. Pathogens and toxic chemicals that come in contact with the skin, or are ingested by humans, can cause skin irritations or gastrointestinal illness. Accumulations of oil and grease on the water surface, unpleasant odors due to anaerobic conditions, discoloration of the water due to excess suspended sediments and a spill or a discharge plume can affect the visual appearance of the river and diminish the aesthetic qualities normally associated with a healthy riparian system.

Of all the commercial uses along the lower Columbia River, commercial fishing is by far the most sensitive to water quality alterations. The open season for **commercial fishing** is regulated by the number of days, season, location and species caught. Most of the commercial fishing takes place from the mouth to RM 40 and especially between RM 25 to 35. Tongue Point, Youngs Bay and the Cowlitz River are also regularly fished for certain species Fish species that are of economic importance are salmon, steelhead, sturgeon, smelt and shad. If water quality is altered to intolerable levels for fish, then mortality and disease increase, and fish runs are reduced. Fewer fish directly affects the commercial fishing industry because fishing seasons are shortened and the allowable catch is reduced. Fish are highly sensitive to alterations in water temperature, dissolved oxygen, dissolved gas saturation, sediment loading, and concentrations of metals and organic compounds.

2.5.3 Data Gaps

A large volume of literature exists on the Columbia River However, most of the literature reviewed is not specific to beneficial uses, and few references address the relationship of beneficial uses to alterations in water quality The following comments describe the data that was available, as well as the data gaps that were discovered in preparing Task 5 reports.

- There was a lack of precise information on water supply permits for withdrawals and discharges on both sides of the Columbia River It was often difficult to determine the number of withdrawals, the exact location, the permitted rate, and the type of use.

- No information was found on use trends of water withdrawal for agriculture. There was also no information on the types of crops grown or chemicals used specifically along the Columbia River study area.

- There was a tremendous amount of data on fish, wildlife, plants, and invertebrate species that use or inhabit the lower Columbia River. However, there was little scientific data on these same species' sensitivity to alterations in water quality.

- There was a general lack of scientific water quality impact studies on migrating waterfowl and resident birds using the lower Columbia River. This type of information is essential since so many birds use this area for feeding, wintering and breeding activities.

- Very little scientific information was found which relates the sensitivity of recreational uses to alterations in water quality.

- Several studies exist on the relationship between hydropower dam operation and fish survival and migration. Both physical (e.g., fish passage) and chemical (e.g., nitrogen supersaturation) aspects of this relationship are addressed in these studies.

- Very little specific information was found relating commercial activities, except commercial fisheries, to alterations in water quality.

- Intensity of beneficial uses is difficult to determine without detailed study. A correlation between intensity of use and water quality cannot be made at this level of reconnaissance.

2.5.4 Conclusions

2.5.4.1 Water Supply. Major water withdrawals are made from the lower Columbia River for a variety of municipal, industrial and domestic purposes Lack of precise information on water supply permits made it difficult to determine actual water withdrawal rates and quantities (rather than permitted withdrawal), exact locations and type of use. Surface withdrawals for municipal and domestic drinking water supply and other domestic uses are particularly sensitive to alterations in water quality because of the concern for human health. Withdrawals from wells are less sensitive because of some limited filtering of ground water.

2.5.4.2 Agricultural Uses. Water withdrawal for agricultural purposes represents a low to moderately sensitive water use on the lower Columbia River, depending on whether the water is used for crop irrigation or livestock watering. Although no information on the types and sensitivity of crops grown or chemicals used for agricultural purposes along the river exists, it is generally recognized that the agricultural community can both affect and be affected by water quality alterations in the river.

2.5.4.3 ***Fish Use.*** Resident and migratory fish occur throughout the lower Columbia River and the river provides prime habitat for both fish and shellfish The ability of toxic substances to accumulate in sediment and fatty tissues of fish indicates that water quality is particularly important to fish and shellfish, their wildlife consumers, and their human consumers Unfortunately, there is little scientific data on fish sensitivity to alterations in water quality Health of fish populations in the river also has the potential to affect local and regional economies dependent on commercial and/or recreational fishing.

2.5.4.4 ***Wildlife Use.*** The lower Columbia River provides important habitat for and supports a wide range of wildlife species, particularly at refuges and river mouths. Several species (i.e., the Olympic salamander and red-legged frog) are considered rare, and are particularly sensitive to alterations in water quality. Others, such as the bald eagle, are top consumers in the food chain and fish represent the mainstay of their diet. Bioaccumulation of toxins in the food chain is a particularly important concern for wildlife resources along the river

2.5.4.5 ***Recreational Uses.*** The lower Columbia River is an important recreational resource. Many recreational uses, such as swimming, windsurfing and water skiing involve primary water contact and can be strongly affected by alterations in water quality Other recreational uses that are affected by water quality include boating, waterfowl hunting, fishing, and general enjoyment of the aesthetic qualities of the river

2.5.4.6 ***Commercial Fishing.*** Commercial fishing is the most sensitive of the commercial uses to water quality alterations. Fish species of economic importance include salmon, steelhead, sturgeon, smelt and shad. Fish are highly sensitive to alterations in various water quality parameters, including alterations in water temperature, dissolved oxygen, dissolved gas saturation, sediment loading, and concentrations of metals and organic compounds Reductions in fish runs can result in more stringent regulation of the duration and season of fishing, as well as regulation of the location and type of species taken.

2.6 TASK 6: RECONNAISSANCE SURVEY

The task of conducting a reconnaissance survey of the lower Columbia River was accomplished during September to November 1991 (Tetra Tech 1991e), following the guidance and protocols outlined in the final QA/QC (Tetra Tech 1991f) and sampling plans (Tetra Tech 1991g). The results of the reconnaissance survey are reported in detail in the final reconnaissance survey report (Tetra Tech 1993).

The primary objectives of the reconnaissance survey were:

- To provide a reconnaissance of levels of contaminants in water, sediments, and tissues of resident river biota.
- To fill data gaps identified from an evaluation of existing water quality data (Tetra Tech 1992a).
- To tentatively identify problem areas in the lower river.
- To provide recommendations for baseline studies to be conducted in subsequent years of the Bi-State Program.

The following sections summarize the results of the reconnaissance survey.

2.6.1 Objectives

2.6.1.1 Water. Assessment of water column characteristics has traditionally played a significant role in water quality studies for several reasons. First, contaminants are introduced into aquatic environments primarily through the water column. Second, most contaminant transport in aquatic environments occurs in the suspended, dissolved, and particulate phases (Bero and Gibbs 1990). Predictions of contaminant transport therefore require some knowledge of the levels and types of contaminants in the water column. Third, although some of the suspended contaminants will be deposited in sediments, a portion will remain suspended in dissolved or particulate form for some time. The dissolved contaminants may be available for uptake and accumulation (i.e., bioconcentration) by exposed biota depending on several factors, including hydrophobicity characteristics of the contaminants (Barron 1990). Fourth, the concentration and nature of the contaminants suspended in the water column influence the environmental behavior (e.g., sorption - desorption kinetics, partitioning coefficients) of sediment associated contaminants, thus potentially affecting bioavailability (Landrum and Robbins 1990; Farrington 1991).

Several broad-scale, conventional water quality studies of the lower Columbia River have been conducted prior to 1979 (e g , Lincoln and Foster 1943, Robeck et al 1954, Sylvester and Carlson 1961) The earliest water quality data available for the river were reported by Van Winkle (1914) Studies of the transport of sediment (Conomos 1968, Whetten et al 1969), nutrients (Haertel et al 1969; Park et al 1969, 1970, 1972) and phytoplankton (Haertel et al 1969, Williams and Scott 1962, Williams 1964, 1972) have also been reported Since 1979, however, water column studies in the lower Columbia River have been quite limited, both in frequency and scope (see Tetra Tech 1992a for a review of these studies) The exceptions are the long-term USGS water quality monitoring studies at Bradwood, Oregon (1973-1980); Warrendale, Oregon (1972-present), and Beaver Army Terminal (1990-present) Other recent studies have also described the nutrient and phytoplankton ecology of the Columbia River estuary (Lara-Lara et al 1990a,b) and organic carbon transport in the river (Dahm et al 1981, Hedges et al 1984) However, most water quality studies conducted in the lower river since 1979 have been sporadic and designed to characterize water quality conditions around specific point source discharges only

To gain a comprehensive assessment of current water quality conditions in the lower Columbia River, water-column characterization was included as part of the lower Columbia River reconnaissance survey The objectives of the water-column sampling were to

- Characterize levels of chemicals of concern in the water column, provide data for the development of conceptual models on contaminant transport in the river, and provide data for use in estimating pollutant loading to the river

- Characterize levels of indicator bacteria in water near beneficial use areas.

- Characterize levels of nutrients to address concerns about potential eutrophication of the river

- Characterize levels of conventional variables (e g , dissolved oxygen and temperature), metals, and organic compounds throughout the lower Columbia River and compare these levels with established criteria and standards to assess potential adverse effects to aquatic biota.

2.6.1.2 Sediment. Sediments in aquatic environments often represent a final repository for anthropogenic contaminants, and in many instances a significant source of these contaminants to the food chain (Landrum and Robbins 1990) Contaminants introduced into the lower Columbia River from various sources enter both as dissolved and particulate forms. Many of the dissolved contaminants adsorb preferentially onto fine-grained, suspended sediment particles as a result of physiochemical interactions and the larger surface area of the fine-grained materials. These suspended particles are either flushed into the Pacific Ocean or deposited in low-energy regions (e.g., backwaters, sloughs, and wetlands) of the river.

Deposition and accumulation of contaminated sediments can result in exposure of river biota to potentially toxic chemicals, and significantly affect the health of the entire river ecosystem For example, several studies in aquatic environments have shown altered benthic communities, accumulation of chemical residues in tissues, and increased prevalence of diseases in biota in areas with contaminated sediments (Myers et al. 1987, Nalepa and Landrum 1988, Weston 1990, Ferraro et al 1991).

Although a number of earlier studies have assessed sediment contamination in the lower Columbia River, reliability of the data from many of these studies is uncertain (see Tetra Tech 1992a for a review of these studies) Assessment of the current state of sediment contamination in the lower river, using the relatively few studies with reliable data, was difficult for several reasons. First, the studies were conducted between 1980 and 1990 These historical data may not accurately reflect current conditions given the dynamic nature of the sediments in rivers. Second, the studies were conducted sporadically, and designed to address objectives other than the overall sediment quality in the lower river Third, there is inconsistency in the analytical variables measured and the methods used in the different studies, making comparisons among regions of the river difficult Finally, the spatial distribution of historical sampling locations for sediment contamination does not permit an assessment of the entire lower Columbia River

Because no previous studies have systematically surveyed sediment contamination in the entire lower river (i e., lack of comprehensive broad-scale studies), the characterization of sediment quality was included as part of the reconnaissance survey The objectives of sediment survey were to:

- Determine the occurrence of selected, potentially toxic contaminants in sediments in the lower Columbia River

- Characterize major spatial trends in the distribution of contaminants in the sediments.

- Identify potential problem and reference areas in the lower river.

2.6.1.3 Tissue. The concentration of anthropogenic chemicals in aquatic organisms is of great environmental concern. First, there is concern among federal and state agencies and the public about the potential human health risks from consuming chemically contaminated fish and shellfish. A 1989 survey of 50 states and the District of Columbia showed that 37 states reported having waterbodies under some type of advisory restricting fish or shellfish consumption due to elevated tissue levels of pesticides, PCBs, or metals (Reinert et al. 1991). Secondly, there is concern about the potential for adverse impacts to wildlife populations resulting from the consumption of prey containing chemical contaminants. Henny et al. (1981) found elevated levels of PCBs and organopesticides in mink (*Mustela vison*) and otters (*Lutra canadensis*) collected along the lower Columbia river and suggested that population declines of these species might be attributed to reproductive failure due to the consumption of PCB-contaminated fish Impairment of reproductive success of predatory birds such as the bald eagle (*Haliaetus leucocephalus*) and osprey (*Pandion haliaetus*) due to the biomagnification of organochlorine pesticides (McGarigal et al. 1991) has been documented in many areas of the United States. Within the lower Columbia River Basin, the U.S. Fish and Wildlife Service (USFWS) has detected dioxin in the eggs of bald eagles nesting near the river (USFWS 1991, unpublished data). Finally, there is concern that physiological or behavioral responses of aquatic species may be impaired by the exposure and accumulation of toxic chemicals in tissues.

The objectives of the fish and crayfish tissue survey were to:

- Characterize the distribution and levels of contaminants of concern in representative aquatic animals that live in the lower Columbia River.

- Collect tissue contaminant data that would provide the basis for an assessment of human health and ecological risks.

- Provide tissue contaminant data from locations sampled simultaneously for sediment contaminants to evaluate possible relationships between contaminant levels in sediments and fish tissue

The main objective of the tissue component of the lower Columbia river reconnaissance survey was to characterize the distribution and levels of contaminants of concern in representative aquatic biota. Five species were selected for analysis in this study Crayfish were selected as an indicator organism because they are a food source for aquatic and terrestrial wildlife, they are commercially harvested from the lower Columbia river for human consumption, and they are assumed to have relatively limited ranges Carp were selected because they are a bottom feeding fish with a relatively high lipid content and have been documented to readily bioaccumulate hydrophobic organic pollutants (Schmitt et al 1990) Peamouth were selected because they feed both on the bottom and in the water column, because their diet and feeding habits differ from carp, and they occur throughout the study area. They are also a component of the diet of bald eagles, other wildlife, and game species of fish. Largescale sucker were not originally selected for sampling, but due to difficulties encountered in obtaining carp and peamouth in the field, largescale sucker were selected as an additional target species Although the diet and feeding habits of the largescale sucker are generally similar to the carp, these fish are also a component of the diet of piscivorous birds and fish White sturgeon were selected for analysis because they are harvested commercially and recreationally from the lower Columbia River and are consumed by humans These fish are also long-lived and therefore have the potential to accumulate high levels of tissue contaminants

2.6.1.4 Benthos. Benthic communities have been widely used in pollution impact studies and as part of long-term environmental monitoring programs Decreases in the number of taxa, shifts in community composition, and changes in abundance have all been documented responses to physical and chemical stresses in aquatic environments. While benthic communities exhibit a high degree of natural variability, comparison with communities from reference or control areas can assist in clarifying the types of impacts a benthic community may be experiencing at a given point in time.

Historical studies evaluating benthic communities in the lower Columbia River have been confined primarily to the estuary portions of the river (see Tetra Tech 1992a for a review of studies conducted in the lower river) A series of ecological investigations were sponsored by the Columbia River Estuary Data Development Program (CREDDP) in the early 1980's Studies included examination of the productivity of benthic and epibenthic organisms in response to changes in physical features (salinity, current velocity, sediment type) of the estuary, community composition of salmonid prey species, and food web structure No other program has matched the scope of the CREDDP sponsored investigations Studies within the freshwater portions of the river have been very limited in scope and areal extent Benthic communities have been used as part of investigations of localized impacts from specific activities or to examine prey species for target fisheries resources In most of these investigations in both the estuary and the river, the sampling design was not adequate to evaluate the overall character of benthic communities in the lower river

Because of the lack of broad-scale, comprehensive data on benthic communities in the lower river (primarily the freshwater portion), a benthic invertebrate sampling program was included in the reconnaissance survey The objectives of the benthic community investigations within the reconnaissance survey were to:

- Provide a broad characterization of benthic invertebrate communities in the lower Columbia River.
- Establish benthic invertebrate ecological zones
- Evaluate the relationship between benthic community structure and sediment chemical concentrations
- Assess the utility of benthic communities as indicators of environmental health in specific ecological zones.

Sampling locations, field and laboratory methods were described in detail in the reconnaissance survey report (Tetra Tech 1993) Differences in benthic community structure among stations or between stations and reference locations were identified on the basis of specific community attributes (i.e., species abundance, major taxa abundance, species richness) or habitat characteristics (e.g., sediment grain size, salinity).

Benthic community attributes (i.e., richness and abundance) for all stations were compared with reference values which were derived from the Columbia River reconnaissance survey data to identify areas of concern. Stations with richness and abundance less than or equal to 50 percent of the reference values were considered potentially impacted communities This approach followed guidelines for identifying biological impacts developed as part of the Washington State Sediment Management Standards (WAC 173-204).

2.6.2 Locations and Parameters Sampled

This section provides a brief summary of the locations at which water, sediment, tissue, and benthos samples were collected, and of the chemicals and other parameters that were measured for each of these media. More detailed rationale for the selection of sampling locations and chemicals/parameters can be found in the sampling plan and quality assurance/quality control (QA/QC) plan for the reconnaissance survey, and in the reconnaissance survey report. These reports also describe sampling methods, laboratory analytical methods, QA/QC procedures, and statistical methods used.

In order to maximize the number of sampling stations to achieve the broad geographic coverage objective of the reconnaissance survey, single samples were collected at each station. For water, sediment and tissue, the sample sent to the laboratory was a composite of several individual samples collected at a given station. A single benthos sample was analyzed for each station.

2.6.2.1 Sampling Locations. The locations from which samples were collected and analyzed as part of the reconnaissance survey are shown in Figures 2 6-1 through 2.6-4. The following number of locations (stations), by medium, were samples:

Water - 45 stations
Sediment - 54 stations
Tissue - 20 stations (various species)
Benthos - 54 stations

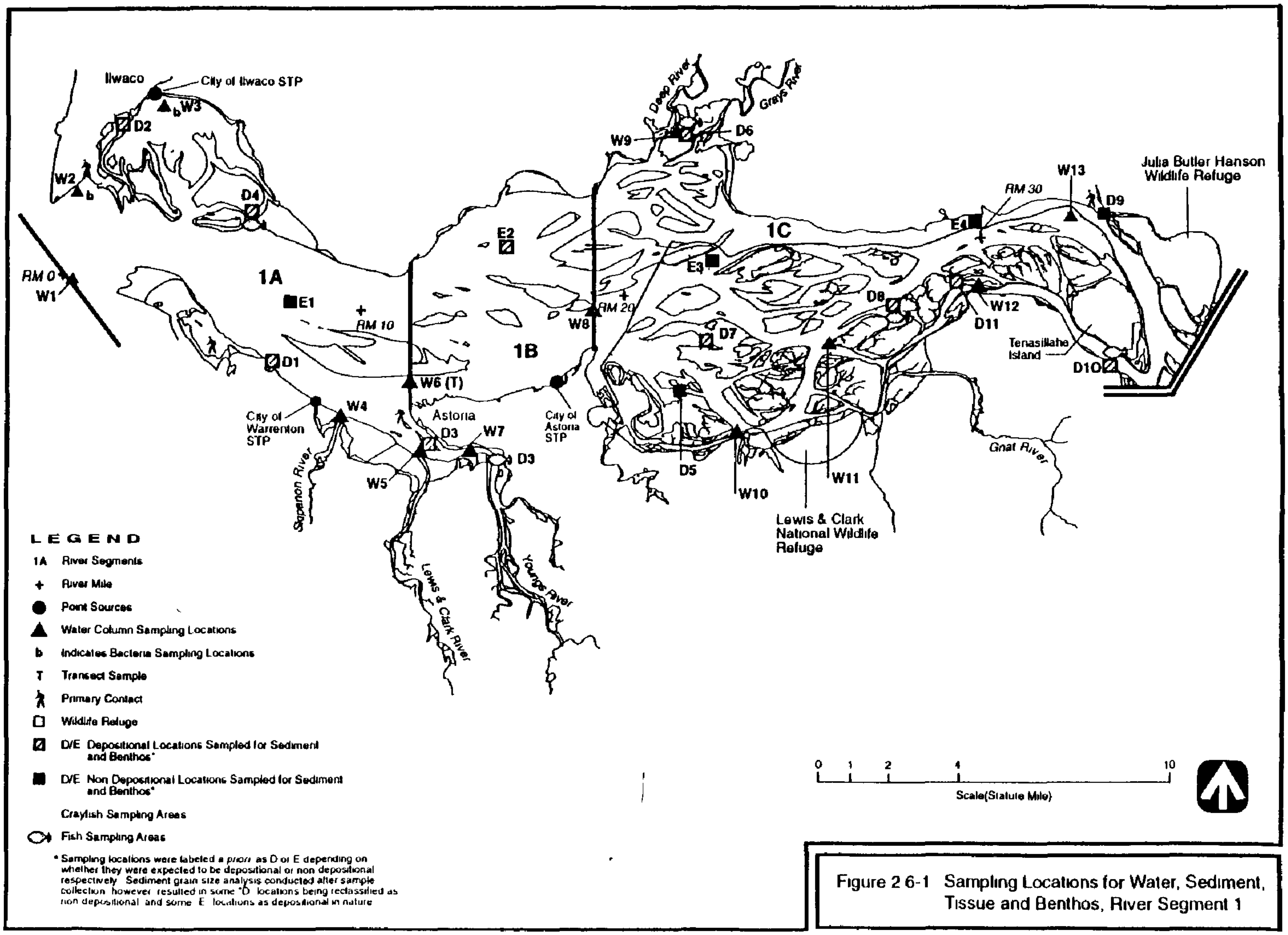


Figure 2 6-1 Sampling Locations for Water, Sediment, Tissue and Benthos, River Segment 1

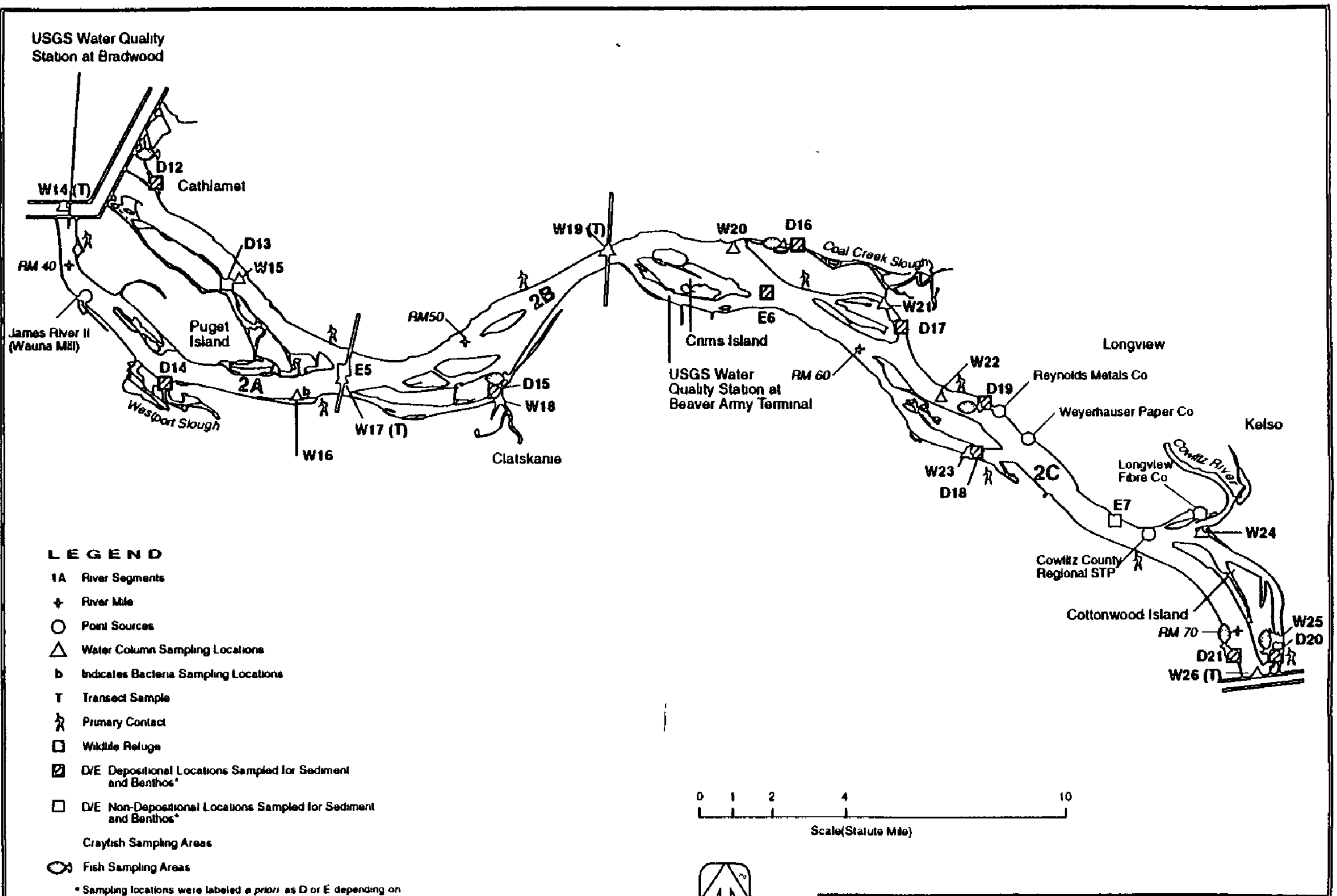


Figure 2 6-2 Sampling Locations for Water, Sediment Tissue and Benthos, River Segment 2

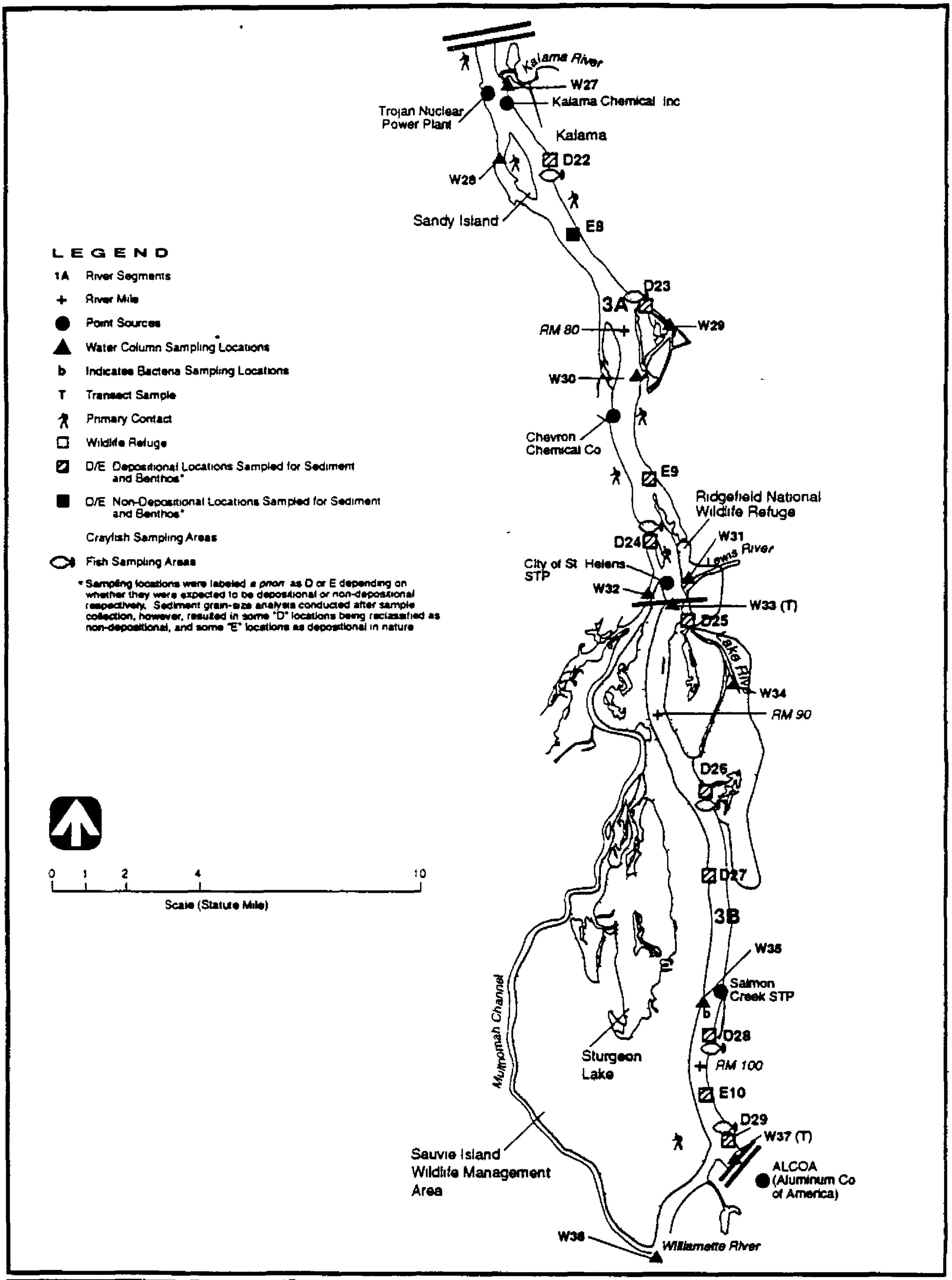


Figure 2 6-3. Sampling Locations for Water, Sediment, Tissue and Benthos, River Segment 3

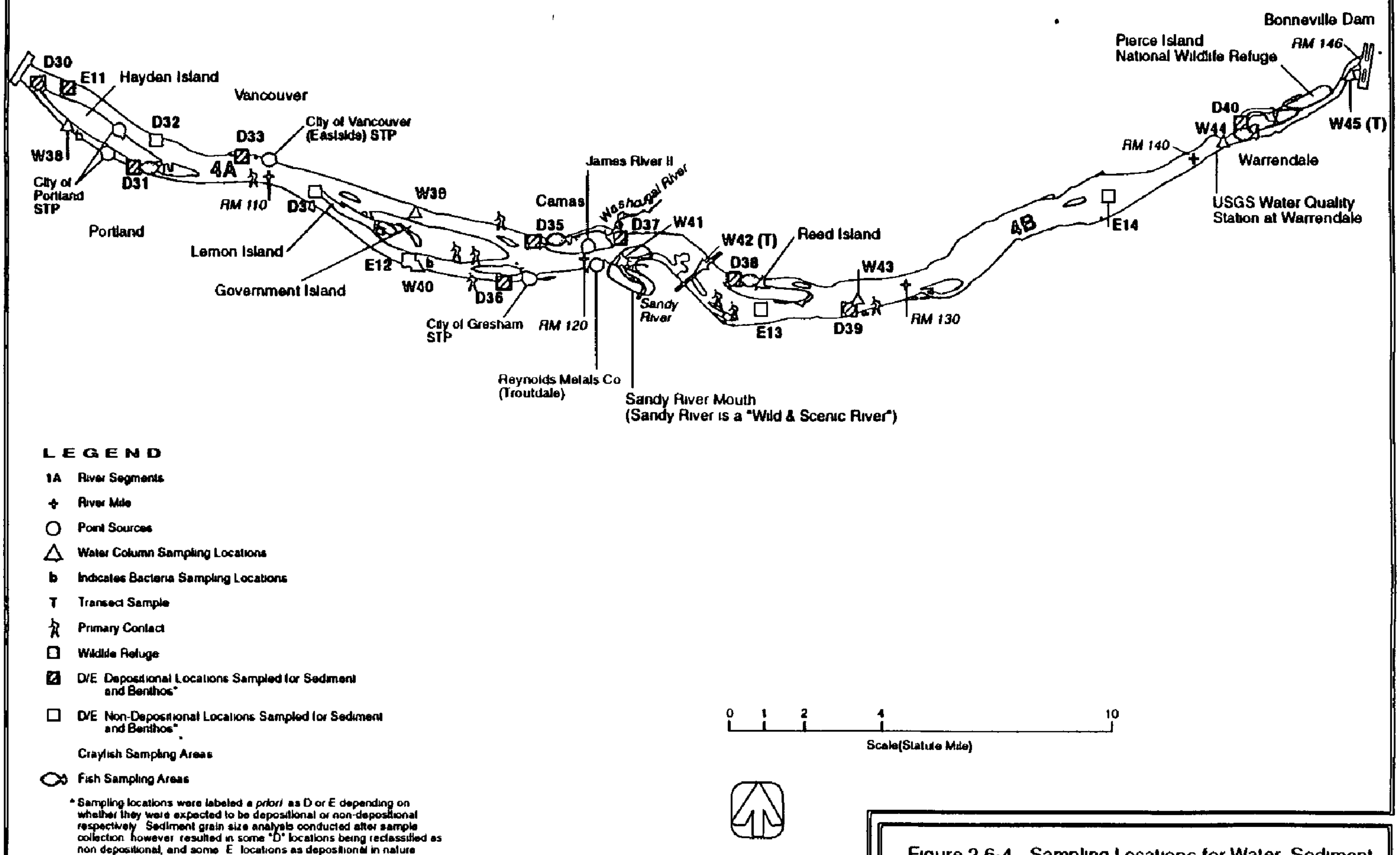


Figure 2 6-4 Sampling Locations for Water, Sediment, Tissue and Benthos, River Segment 4

The strategy and rationale for siting sampling stations are summarized below by medium.

Water–The following survey needs were considered in selecting the water column sampling stations:

- Obtaining broad-scale coverage of the entire lower Columbia River.
- Obtaining data that could be used to develop conceptual models for contaminant transport in the lower river.
- Estimating pollutant contributions from the major tributaries entering the lower river
- Assessing water quality near and its potential impacts on beneficial use areas.
- Assessing the impacts of point sources and major industrial areas on surrounding water column characteristics.

Sediments–Selection of the sediment sampling stations was based on the following considerations

- The need to obtain broad-scale, even coverage of the entire lower Columbia River.
- The necessity of sampling depositional areas in order to obtain a worst-case measure of the accumulation of contaminants in the river's sediments.
- The need to assess the effects of major industrial areas on sediment quality (e.g., the ports and urban areas of Longview, Vancouver, Portland).
- The need to identify reference areas as well as any problem areas in the river that could be focused on in future studies.
- The need to fill data gaps and confirm "hot spots" identified from a review of previous studies.

- The need to assess sediment contamination and its potential impacts in beneficial use areas, including wildlife habitats.

- Prevention of duplicate efforts in cases where recent (or ongoing) studies have provided useful data.

Tissue--The following general considerations were used to choose sampling locations for crayfish, carp, peamouth, and largescale sucker.

- Achieving broad-scale coverage to gain an overall characterization of tissue chemical burdens in the lower Columbia River.

- Obtaining data on tissue chemical burdens in biota inhabiting wildlife refuges, areas around known point source discharges, and putative reference areas

- Assessing tissue chemical burdens of relatively immobile species in relation to chemical contamination in the surrounding sediments

- Preventing duplication of effort in areas where recent tissue bioaccumulation studies had been conducted by the Oregon Department of Environmental Quality (ODEQ).

- Taking into account the known distributions of the various target species in the study area.

Benthos--Benthos samples were collected at all 54 of the sediment sampling stations, in order to investigate the relationship between the benthic community and sediment quality. The sediment stations were located partly to sample the various habitats in the river and to provide a broad characterization of benthic communities in the river.

2.6.2.2 Chemicals/Parameters Measured. The chemicals and parameters measured in the samples collected are listed in Table 2 6-1 by medium. This table also shows the number of samples for which each chemical/parameter was measured Not all chemicals were measured at all stations.

2.6.3 Results

2.6.3.1 Water. The water column data collected for the reconnaissance survey has characterized conventional water quality (e g , dissolved oxygen and temperature), nutrients and phytoplankton levels, bacterial indicators of pathogens, and levels of chemicals of concern in the lower Columbia River Levels of adsorbable organic halogens (AOX) were also studied to evaluate the influence of bleached kraft pulp and paper mill discharges to the river

Conventional Water Quality--Dissolved oxygen (DO) concentrations were greater than the Washington standards for both fresh (8 0 mg/L) and marine (6.0 mg/L) waters at 40 of the 45 stations. DO fell below these standards at five stations Lake River (W34), the mid-channel station below Skamokawa Creek (W13), Grays Bay (W9), and in the estuary at the mid-channel station W6 off Astoria and in the Skipanon River (W4). The DO percent saturation was below the Oregon DO percent saturation standard of 90 percent at 11 of the 37 stations classified as freshwater stations However, DO percent saturation at 8 of these stations was greater than 85 percent. The stations where DO percent saturation was lower than 85 percent were the stations where the DO concentration was also below the 8 mg/L standard (i e., station W9, W13, and W34)

Water temperatures measured during the survey were below the Washington established criterion (20° C) At several stations below Bonneville Dam, temperatures were above 19° C Review of historical data indicate chronic exceedances of the 20° C standard in the upper river from July to September which may have implications primarily for the river's cold-water anadromous fish species and warm-water resident species.

Phytoplankton and Nutrients--The nutrient data collected as part of the reconnaissance survey were excluded from consideration in this report due to unacceptably high quantitation limits reported by the analytical laboratory The phytoplankton data and recent nutrient data provided by Washington Department of Ecology (Johnson, A., and B Hopkins, 30 April 1990, personal communication) indicate

TABLE 2.6-1. CHEMICALS OF CONCERN ANALYZED IN VARIOUS MEDIA DURING THE LOWER COLUMBIA RECONNAISSANCE SURVEY
(Page 1 of 7)

Compound	Number of Samples (Excluding Duplicates)		
	Water	Sediments	Tissues
METALS AND CYANIDE			
Aluminum	45	54	
Antimony[a]	45	54	72
Arsenic[a,b]	45	54	72
Barium	45	54	72
Beryllium[a]	45	54	
Cadmium[a,b]	45	54	72
Chromium[a]	45	54	
Copper[a,b]	45	54	72
Iron	45	54	
Lead[a,b]	45	54	72
Mercury[a,b,d]	45	54	72
Nickel[a]	45	54	72
Selenium[a,b,d]	45	54	72
Silver[a]	45	54	72
Thallium[a]	45	54	
Zinc[a,b,d]	45	54	72
Cyanide[a]	45	54	
ORGANOTINS		10	
VOLATILES			
Vinyl chloride[a]	5		
Methylene chloride[a]	5		
1,1-Dichloroethane[a]	5		
Chloroform[a]	5		
1,1,1-Trichloroethane[a]	5		
Bromodichloromethane	5		
trans-1,3-Dichloropropene	5		
Dibromochloromethane[a]	5		
Benzene[a]	5		
Bromoform[a]	5		

TABLE 2.6-1 CHEMICALS OF CONCERN ANALYZED IN VARIOUS MEDIA
DURING THE LOWER COLUMBIA RECONNAISSANCE SURVEY
(Page 2 of 7)

Compound	Number of Samples (Excluding Duplicates)		
	Water	Sediments	Tissues
Tetrachloroethene[a]	5		
Chlorobenzene[a]	5		
Total xylenes	5		
Chloroethane[a]	5		
1,1-Dichloroethene	5		
trans-1,2-Dichloroethene[a]	5		
1,2-Dichloroethane[a]	5		
Carbon tetrachloride[a]	5		
1,2-Dichloropropane[a]	5		
Trichloroethene[a]	5		
1,1,2-Trichloroethane[a]	5		
cis-1,3-Dichloropropene	5		
1,1,2,2-Tetrachloroethane[a]	5		
Toluene[a]	5		
Ethylbenzene[a]	5		
Methyl chloride[a]	5		
Methyl bromide[a]	5		
ADSORBABLE ORGANIC HALOGENS (AOX)	19		
ACID EXTRACTABLE ORGANICS (SEMIVOLATILES)			
Phenolic Compounds			
Phenol[a]	5	54	72
2-Methylphenol	5	54	
4-Methylphenol	5	54	
2,4-Dimethylphenol[a]	5	54	
Pentachlorophenol[a]	5	54	72
2-Chlorophenol[a]	5	54	72
2,4-Dichlorophenol[a]	5	54	72
2,4-Dinitrophenol[a]	5	54	72
2-Nitrophenol[a]	5	54	72

TABLE 2.6-1. CHEMICALS OF CONCERN ANALYZED IN VARIOUS MEDIA DURING THE LOWER COLUMBIA RECONNAISSANCE SURVEY
(Page 3 of 7)

Compound	Number of Samples (Excluding Duplicates)		
	Water	Sediments	Tissues
4-Nitrophenol[a]	5	54	
2,4,6-Trichlorophenol[a]	5	54	72
BASE/NEUTRAL EXTRACTABLE ORGANICS (SEMIVOLATILES)			
Halogenated Ethers (Other than those listed elsewhere)			
bis(2-chloroethyl)ether[a]	5	54	72
bis(2-chloroethoxy)methane[a]	5	54	72
bis(2-chloroisopropyl)ether[a]	5	54	72
4-Bromophenylphenylether[a]	5	54	72
4-Chlorophenylphenylether[a]	5	54	72
Nitroaromatics			
2,4-Dinitrotoluene[a]	5	54	72
2,6-Dinitrotoluene[a]	5	54	72
Nitrobenzene[a]	5	54	72
Nitrosamines			
N-nitroso-di-n-propylamine[a]	5	54	72
N-nitrosodiphenylamine[a]	5	54	72
Chlorinated Naphthalene			
2-Chloronaphthalene[a]	5	54	72
Polynuclear Aromatics			
Acenaphthene[a]	5	54	72
Acenaphthylene[a]	5	54	72
Anthracene[a]	5	54	72
Benzo(a)anthracene[a]	5	54	72
Benzofluoranthenes(b,k)[a]	5	54	72
Benzo(a)pyrene[a]	5	54	72
Benzo(g,h,i)perylene[a]	5	54	72
Chrysene[a]	5	54	72
Dibenzo(a,h)anthracene[a]	5	54	72
Fluoranthene[a]	5	54	72
Fluorene[a]	5	54	72

TABLE 2.6-1. CHEMICALS OF CONCERN ANALYZED IN VARIOUS MEDIA DURING THE LOWER COLUMBIA RECONNAISSANCE SURVEY
(Page 4 of 7)

Compound	Number of Samples (Excluding Duplicates)		
	Water	Sediments	Tissues
Indeno(1,2,3-cd)pyrene[a]	5	54	72
Naphthalene[a]	5	54	72
Phenanthrene[a]	5	54	72
Pyrene[a]	5	54	72
Chlorinated Benzenes			
1,3-Dichlorobenzene[a]	5	54	72
1,2-Dichlorobenzene[a]	5	54	72
1,4-Dichlorobenzene[a]	5	54	72
1,2,4-Trichlorobenzene[a,d]	5	54	72
Hexachlorobenzene[a,d]	5	54	72
Hexachlorinated Organic Compounds			
Hexachlorobutadiene[a,d]	5	54	72
Hexachloroethane[a]	5	54	72
Hexachlorocyclopentadiene[a]	5	54	72
Benzidines			
3,3'-Dichlorobenzidine[a,e]	5	54	72
Phthalate Esters			
Dimethylphthalate[a]	5	54	72
Diethylphthalate[a]	5	54	72
Di-n-butylphthalate[a]	5	54	72
Butylbenzylphthalate[a]	5	54	72
bis-2-(ethylhexyl)phthalate[a,e]	5	54	72
Di-n-octylphthalate[a]	5	54	72
PESTICIDES/PCBs			
Pesticides			
o,p'-DDE	5	54	72
o,p'-DDD	5	54	72
o,p'-DDT	5	54	72
4,4'-DDT[a,b,c,e]	5	54	72

TABLE 2.6-1 CHEMICALS OF CONCERN ANALYZED IN VARIOUS MEDIA DURING THE LOWER COLUMBIA RECONNAISSANCE SURVEY

Compound	Number of Samples (Excluding Duplicates)		
	Water	Sediments	Tissues
4,4'-DDE[a,b,c,d,e]	5	54	72
4,4'-DDD[a,b,c,e]	5	54	72
Heptachlor[a,b,c,d,e]	5	54	72
Heptachlor epoxide[a,b,c,d,e]	5	54	72
Total chlordane[a,b,c,d,e]	5	54	72
Aldrin[a,b,e]	5	54	72
Dieldrin[a,b,c,d,e]	5	54	72
Mirex (dechlorane)[b]	5	54	72
Dacthal[b]	5	54	72
Dicofol	5	54	72
Methyl parathion	5	54	72
Parathion	5	54	72
Malathion	5	54	72
Toxaphene[a,b,e]	5	54	72
Isophorone[a]	5	54	72
Endosulfan I[a]	5	54	72
Endosulfan II[a]	5	54	72
Endosulfan sulfate[a]	5	54	72
Endrin[a,b,c,d]	5	54	72
Endrin aldehyde[a]	5	54	72
Methoxychlor	5	54	72
alpha-BHC[a,b,c,d,e]	5	54	72
beta-BHC[a,e]	5	54	72
delta-BHC[a]	5	54	72
gamma-BHC (Lindane)[a,b,c,d,e]	5	54	72
PCBs			
Aroclor 1016[a,c,e]	5	54	72
Aroclor 1221[a,c,e]	5	54	72
Aroclor 1232[a,c,e]	5	54	72

TABLE 2.6-1 CHEMICALS OF CONCERN ANALYZED IN VARIOUS MEDIA DURING THE LOWER COLUMBIA RECONNAISSANCE SURVEY
(Page 6 of 7)

Compound	Number of Samples (Excluding Duplicates)		
	Water	Sediments	Tissues
Aroclor 1242[a,b,c,e]	5	54	72
Aroclor 1248[a,b,c,e]	5	54	72
Aroclor 1254[a,b,c,e]	5	54	72
Aroclor 1260[a,b,c,e]	5	54	72
DIOXINS AND FURANS			
2,3,7,8-TCDD[a,c,d,e]		20	44
1,2,3,7,8-PeCDD[c,d]		20	44
1,2,3,4,7,8-HxCDD[d]		20	44
1,2,3,6,7,8-HxCDD[c,d]		20	44
1,2,3,7,8,9-HxCDD[d]		20	44
1,2,3,4,6,7,8-HpCDD[c,d]		20	44
Octachlorodibenzo-p-dioxin[c]		20	44
2,3,7,8-TCDF[c,d]		20	44
1,2,3,7,8-PeCDF[c,d]		20	44
2,3,4,7,8-PeCDF[d]		20	44
1,2,3,4,7,8-HxCDF[d]		20	44
1,2,3,7,8,9-HxCDF[d]		20	44
1,2,3,6,7,8-HxCDF[d]		20	44
2,3,4,6,7,8-HXCDF[d]		20	44
1,2,3,4,6,7,8-HpCDF[d]		20	44
1,2,3,4,7,8,9-HpCDF[d]		20	44
Octachlorodibenzofuran		20	44
RADIONUCLIDES			
Americium-241		6	
Cesium 137		6	
Cobalt-60		6	
Europium-152		6	
Europium-155		6	

TABLE 2.6-1 CHEMICALS OF CONCERN ANALYZED IN VARIOUS MEDIA DURING THE LOWER COLUMBIA RECONNAISSANCE SURVEY
(Page 7 of 7)

Compound	Number of Samples (Excluding Duplicates)		
	Water	Sediments	Tissues
Plutonium-238		6	
Plutonium-239/240		6	
CONVENTIONALS[f]			
Nitrogen (TKN, NO_3, NO_2, NH_4)	45		
Phosphorus	45		
Total suspended solids	45		
Hardness	45		
Total organic carbon	5	54	
Grain size		54	
Acid volatile sulfides		54	
Total solids		54	
Lipids			72
BACTERIA[g]			
Fecal coliform	30		
Enterococcus	30		

[a] Priority pollutants.

[b] Target compounds of U S. Fish and Wildlife Service bioconcentration study (Schmitt and Brumbaugh 1990, Schmitt et al. 1990)

[c] Currently monitored by Oregon Department of Environmental Quality

[d] Bioconcentrating compounds monitored in the National Bioaccumulation Study (U S EPA 1991a)

[e] Chemicals of highest concern listed by U S EPA (1991b)

[f] The following measurements were taken at each station in the field. pH, dissolved oxygen, conductivity, water temperature, and turbidity

[g] Six shore-based bacteria stations were sampled five times over a 30-day period.

that although nutrients are available for phytoplankton growth during the low-flow period, phytoplankton abundance and biomass were relatively low. Nuisance levels of phytoplankton, especially the blue-green algae (cyanobacteria) were not observed during the survey.

Bacteria--Indicator bacteria concentrations (fecal coliform and enterococcus bacteria) were measured to assess sanitary quality of river water at six beneficial use areas. Fecal coliform counts at three of the stations exceeded state standards on at least one sampling date which violates the standard that 10 percent of the samples collected at a location (over a 30-day period) should not exceed the standard. For the most part, fecal coliform counts were below standards throughout the 30-day sampling period, except at station W3 in Ilwaco where the geometric mean concentration exceeded the standard for shellfish harvesting waters. Enterococcus counts were generally higher than those for fecal coliforms, and exceeded federal standards at all stations sampled.

Metals and Cyanide--Metals were detected in a number of the samples collected during the survey. Cyanide was not detected. Based on comparison with available chronic marine and freshwater criteria, many of the concentrations of metals detected in the survey exceeded established criteria. Exceedances of the freshwater chronic criteria were noted for aluminum, cadmium, copper, iron, lead, selenium, and zinc. However, the laboratory detection limits (DLs) at several stations for some metals were higher than the available criteria. The freshwater criteria for aluminum, mercury, and silver; and the marine chronic criteria for lead, mercury, nickel, and selenium at many of the stations were lower than the DLs achieved in this study. The available freshwater chronic criteria were not exceeded in any sample from a freshwater station for cyanide or the metals antimony, arsenic, beryllium, mercury, chromium, nickel, silver, and thallium.

Although the water column metals data indicate potential adverse effects to aquatic biota (especially for the metals aluminum, cadmium, copper, iron, lead, selenium, and zinc); these metals data should be viewed with caution for several reasons. The water column metals data have been qualified as estimates due to the lack of supporting calibration check standard data. Laboratory blank contamination was also noted for the metals aluminum and iron which resulted in the qualification of many of the reported values as undetected. Furthermore, a recent (1990) survey of the metals cadmium, copper, lead, mercury, and zinc in the lower Columbia River by WDOE indicated that the water column concentrations of cadmium, copper, lead, mercury, and zinc may be much lower than the concentrations reported for these metals for the reconnaissance survey (Johnson, A. and B Hopkins, 30 April 1990, personal communication) These data suggest that the reconnaissance survey water column metals data may have been positively biased by contamination of the samples either in the field or in the laboratory

Organics--All of the organic chemicals of concern were undetected in the samples collected during the survey, except for the phthalate ester bis(2-ethylhexyl)phthalate This compound was reported from two stations: the Portland/Vancouver area (W37) and below the confluence of the Kalama and Columbia rivers (W26). Although this chemical is a common laboratory contaminant, neither field nor laboratory method blanks showed evidence of contamination from this compound. The reported concentrations at both stations exceeded the freshwater chronic criterion of 3 µg/L.

In several instances, the DLs for the organic compounds not detected in the water column during this survey were greater than the established marine and freshwater chronic criteria. These compounds include pentachlorophenol, hexachlorocyclopentadiene, forms of DDT and their metabolites, heptachlor, alpha-chlordane, aldrin, dieldrin, mirex, parathion, toxaphene, endrin, methoxychlor, and PCBs. It is possible that many of these compounds were present in the water column, but at concentrations below the detection limits of the conventional analytical methods used in this study

AOX--AOX concentrations in the upper river above the influence of the bleached kraft pulp and paper mills ranged from 10 to 15 µg Cl^-/L These concentrations increased to 40 to 60 µg Cl^-/L in samples collected below the bleached kraft pulp and paper mill outfalls near Longview. In the estuary, concentrations of 250 to 255 µg Cl/L were reported, although such levels are likely due to analytical interferences in the laboratory method used. Bleached kraft pulp and paper mill discharges from Camas, St. Helens, and Wauna did not appear to have an appreciable effect on AOX concentrations downriver of these facilities. This result may be due to the relatively limited number of stations surveyed and possibly the relative quantity of AOX discharged by these facilities.

*2.6.3.2 **Sediment.*** Sampling locations and analytical methods used to accomplish this task are described in the reconnaissance survey report (Tetra Tech 1993) Areas and contaminants of concern were determined on the basis of analyses that identified stations where there was evidence of potential anthropogenic enrichment of chemical substances, as well as comparisons of the concentrations observed in the river to effects-based sediment quality guidelines

The following section summarizes the chemical results for 54 sediment surface (0-2 cm) samples collected at 54 stations in the Columbia River below Bonneville Dam Samples were analyzed for sediment grain size, total organic carbon content (TOC), 17 inorganic substances, and 122 organic compounds, including polycyclic aromatic hydrocarbons (PAHs), pesticides, polychlorinated biphenyls (PCBs), polychlorinated dibenzodioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs) (i.e , dioxins and furans), and organotin compounds Seven radionuclides were also measured at six sediment sampling stations lisaum

Physical Characteristics and Conventional Chemistry--In the lower Columbia River, the sediments collected ranged from silts to coarse grained sand (Figure 2 6-5) Because the sample collection was biased toward locations with finer-grained sediments, fine sands (63-125 μm) often were a major fraction of the sediments Silts dominated the sediment composition at the station nearest the mouth of the river, D2, where it constituted over 90 percent of the sediments, and at station D22, with 52 percent silt. Clay-sized sediments did not constitute a major component of the sediments at any station There were no apparent consistent spatial trends in the composition of the sediments, with sediments of similar composition being collected from all segments of the river The one exception may be the possible trend toward finer-grained sediments near the mouth of the river, but that trend was not well established.

Within the higher energy areas of Columbia River system, sediment particles finer than 100 μm in size are transported as suspended material in the water column (Conomos and Gross 1972, Glenn 1973, Sherwood et al. 1984) Presence of these finer sediments was, therefore, considered to be indicative of more depositional areas within the river compared to those areas dominated by coarser-grained sediments Throughout the river, the percent of sediments finer than 100 μm (the sum of very fine sands, silts, and clays) ranged from < 1 to 98 percent (Figure 2 6-6) While no data were available to clearly use the grain-size data to distinguish actual depositional areas from less stable locations, it was considered reasonable to use these data to classify the location as either comparatively stable/depositional (finer-grained) and unstable/erosional (coarser grained) Based on reasonably conservative judgement, the presence of fine sediment size fraction in amounts greater than 20 percent of the total sample weight was therefore used to distinguish the two habitat types in the river A total of 41 fine-grained and 13 coarse-grained stations were sampled on the basis of this classification Although most of the samples collected in areas of the river predicted to be coarse-grained prior to the reconnaissance survey had less than 20 percent fines, nine stations had to be reclassified Stations D5, D32, D34, and D38 were reclassified as

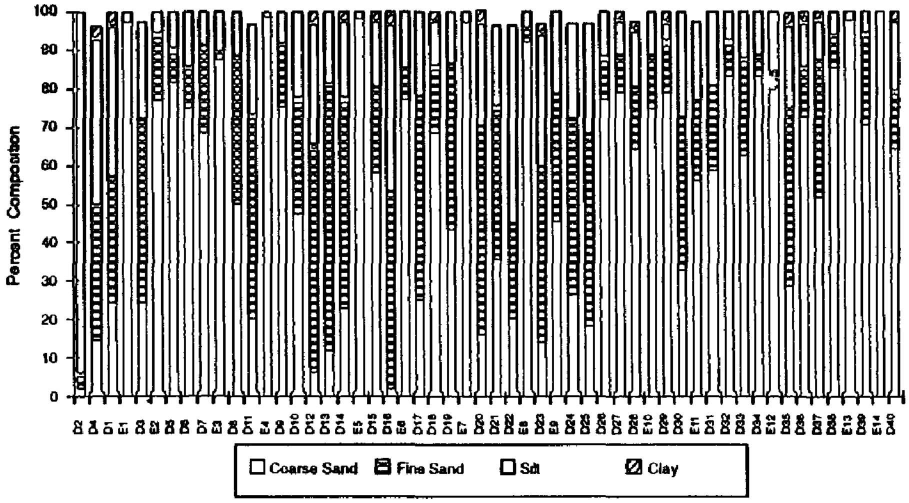


Figure 2.6-5. Composition of sediments at 54 stations in the Columbia River below Bonneville Dam (RM 146).

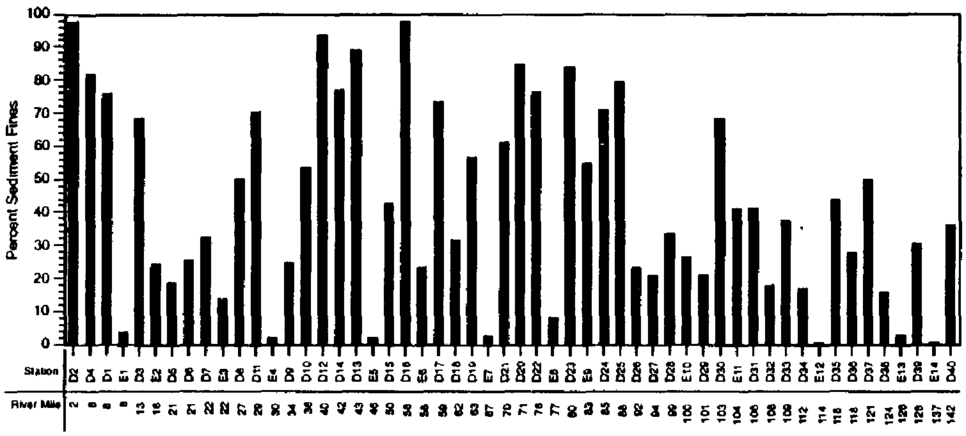


Figure 2 6-6 Percent sediment fines (percent finer than 100 µm - sum of fine sands, silts, and clays) at 54 stations in the Columbia River below Bonneville Dam (RM 146) coarse-grained sediments; stations E2, E6, E9, E10, and E11 were reclassified as fine-grained sediments. These changes will be noted in the text by using a superscript "^{D}" or "^{E}" (e.g., E2^{D}).

Total Organic Carbon--Total organic carbon (TOC) is known to affect the bioavailability and toxicity of some substances, tends to discriminate location of deposition and erosion, and influences the composition and abundances of benthic communities. The TOC content of the sediments was low (less than 1.6 percent) at all but one station (D35, 4.1 percent) in the lower Columbia River, and showed no obvious spatial trends. The sediment TOC data are presented in Figure 2.6-7.

Chemical Occurrence and Distribution--

Metals. Ten of the 17 metals were detected at more than 95 percent of the stations. Antimony and thallium were never found at concentrations above their detection limits, while beryllium and selenium were detected in one and two samples, respectively. Mercury and silver were each present at concentrations that exceeded their detection limits at 10 stations. All of the metals are natural components of soils and sediments, and therefore, even the undetected substances were probably present in the sediments, but at concentrations below their detection limits.

Concentrations of individual metals varied by as much as 2 orders of magnitude among the samples from the lower Columbia River, but limited spatial patterns were evident. The concentrations of those metals detected in the sediments are presented in Figure 2.6-8a through 2.6-8f. Overall, a number of metals (barium, cadmium, chromium, lead, and zinc) appeared to be present at slightly lower concentrations in most of segments 1 and 2 (downstream of the Cowlitz River mouth) compared to segments 3 and 4 (Cowlitz River to Bonneville Dam). Conversely, silver was detected in segments 1 and 2. Anomalously high concentrations of a number of metals were found at station D6 (arsenic, lead, nickel, silver, and zinc) and cadmium was also relatively high at station D9. Differences in chemical concentrations between the estuarine and freshwater portions of the river were not apparent.

Radionuclides. Of the seven long-lived radionuclides that were analyzed in sediment from the six stations selected for radioanalysis, only cesium-137 was consistently detected. All of the sediment stations sampled for radionuclides were classified as fine-grained sediments. Concentrations of other radionuclides were at or below their respective detection limits with the exception of europium-152 and

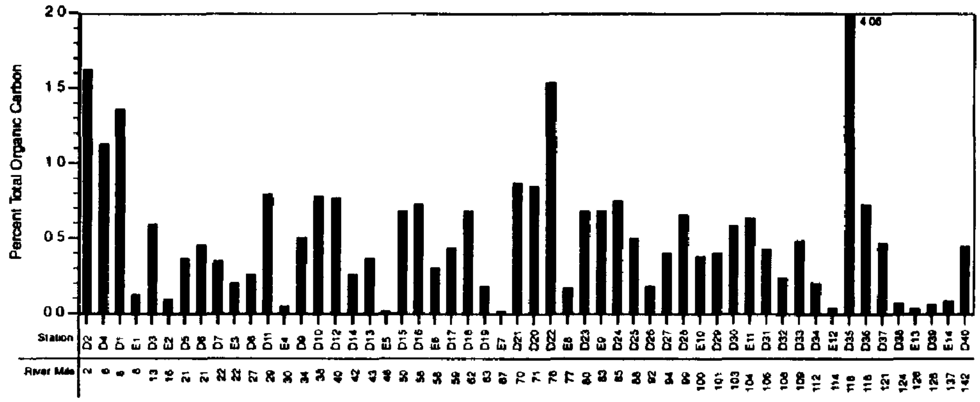


Figure 2 6-7 Percent total organic carbon (TOC) at 54 stations in the Columbia River below Bonneville Dam (RM 146)

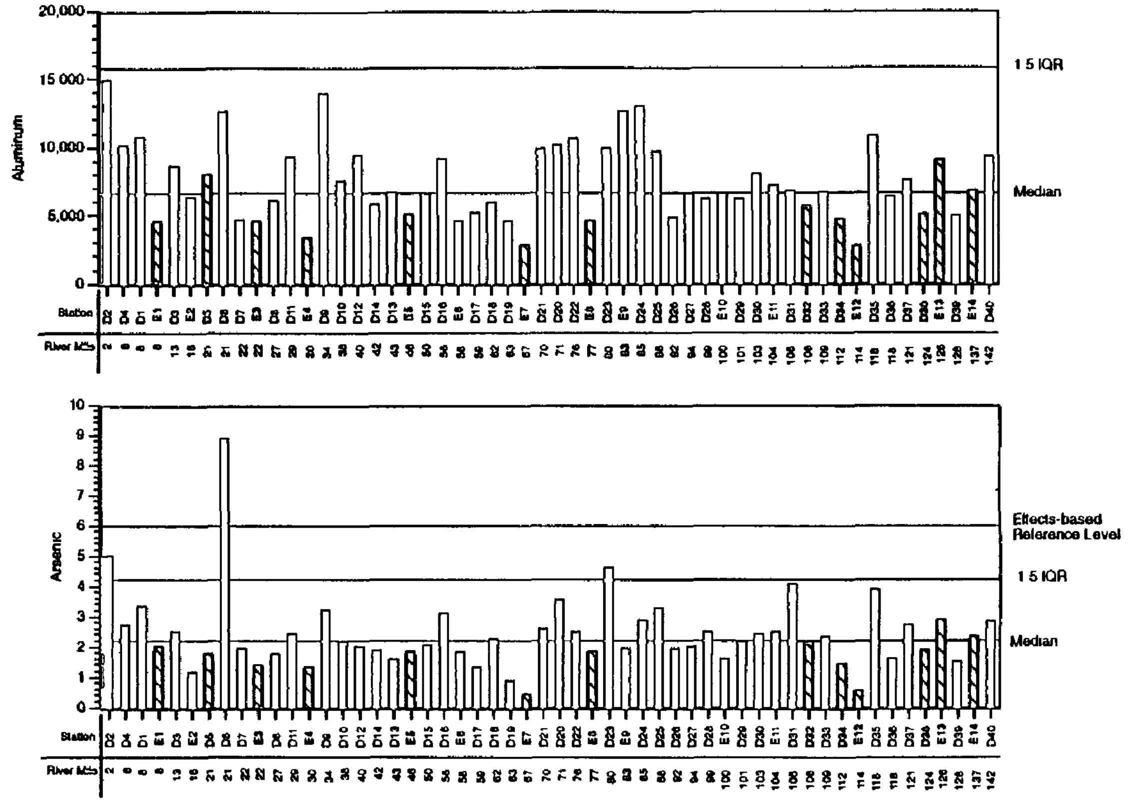


Figure 2 6-8a Concentrations of aluminum and arsenic (mg/kg dry wt) at 54 stations in the Columbia River below Bonneville Dam (RM 146) Hatched bars indicate coarse-grained stations; solid bars indicate fine-grained stations; stippled bars indicate one-half detection limit 1.5 IQR indicates the concentration that is 1 5 times the Inter-Quartile Range.

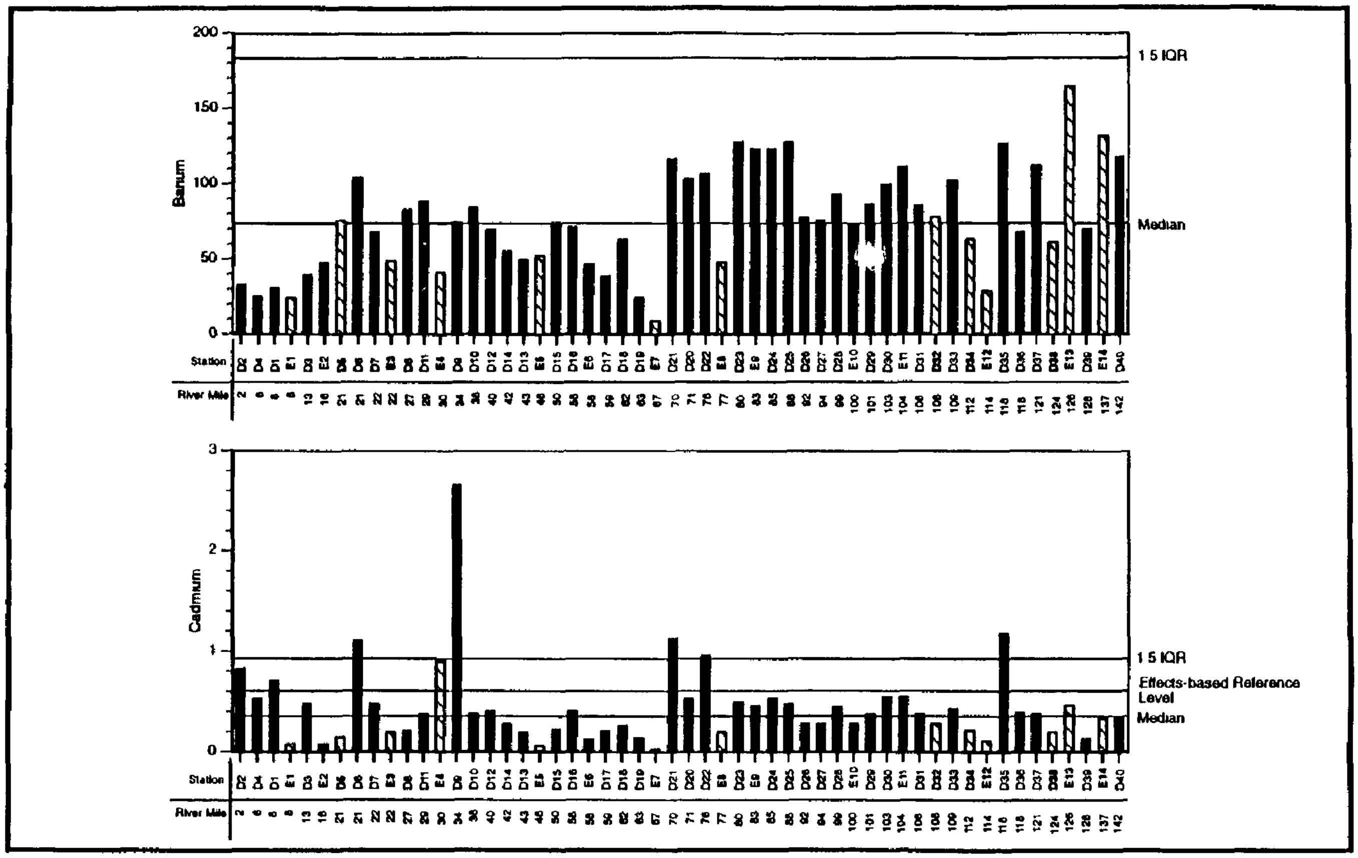


Figure 2 6-8b Concentrations of barium and cadmium (mg/kg dry wt) at 54 stations in the Columbia River below Bonneville Dam (RM 146) Hatched bars indicate coarse-grained stations; solid bars indicate fine-grained stations; stippled bars indicate one-half detection limit. 1 5 IQR indicates the concentration that is 1 5 times the Inter-Quartile Range

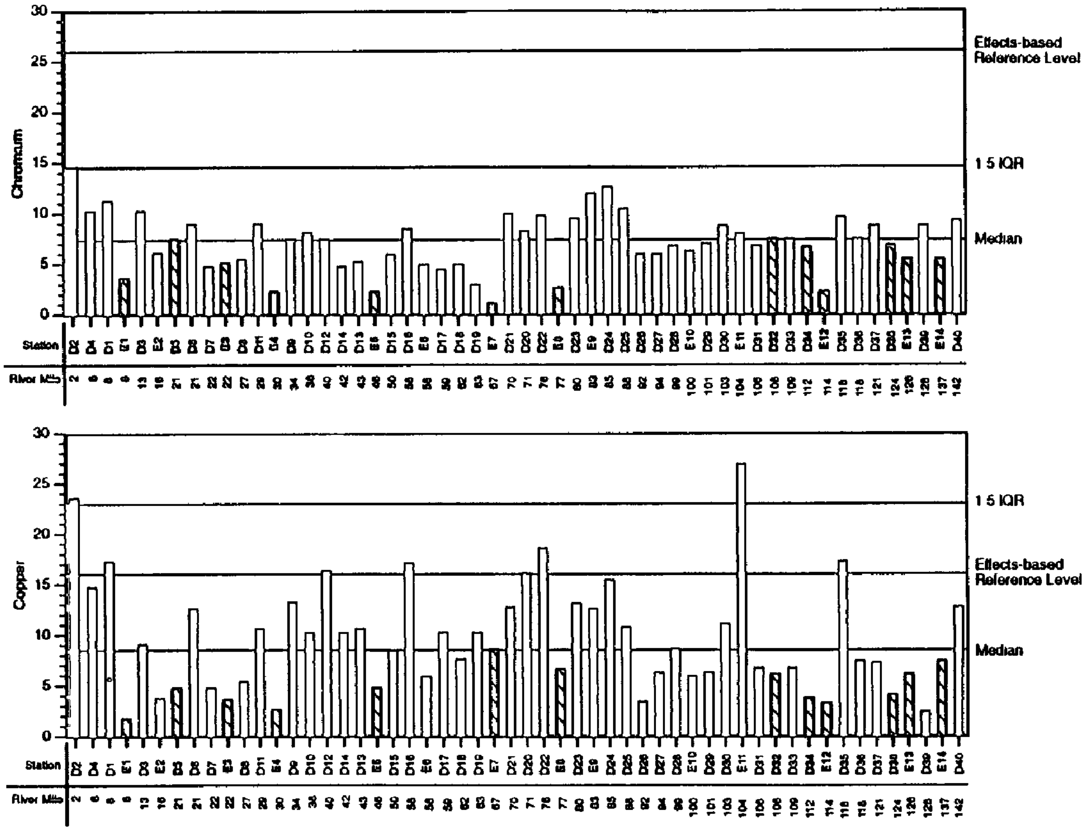


Figure 2.6-8c. Concentrations of chromium and copper (mg/kg dry wt) at 54 stations in the Columbia River below Bonneville Dam (RM 146) Hatched bars indicate coarse-grained stations; solid bars indicate fine-grained stations, stippled bars indicate one-half detection limit 1.5 IQR indicates the concentration that is 1 5 times the Inter-Quartile Range.

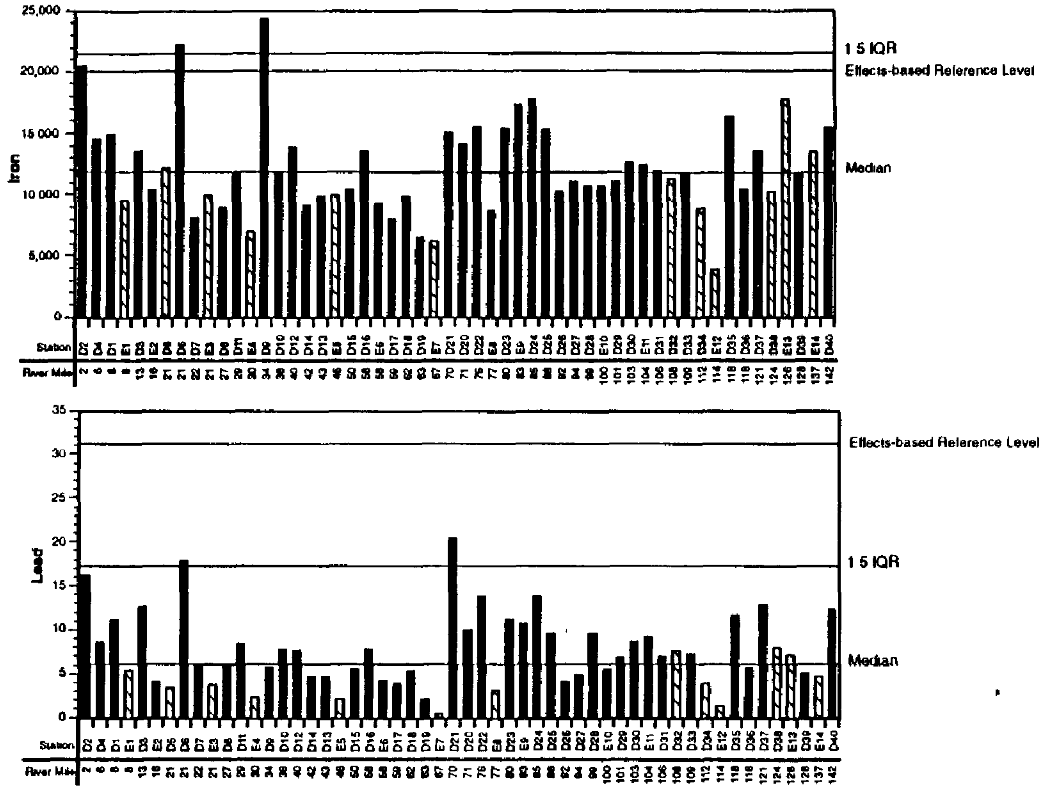


Figure 2 6-8d Concentrations of iron and lead (mg/kg dry wt) at 54 stations in the Columbia River below Bonneville Dam (RM 146). Hatched bars indicate coarse-grained stations; solid bars indicate fine-grained stations, stippled bars indicate one-half detection limit. 1.5 IQR indicates the concentration that is 1 5 times the Inter-Quartile Range

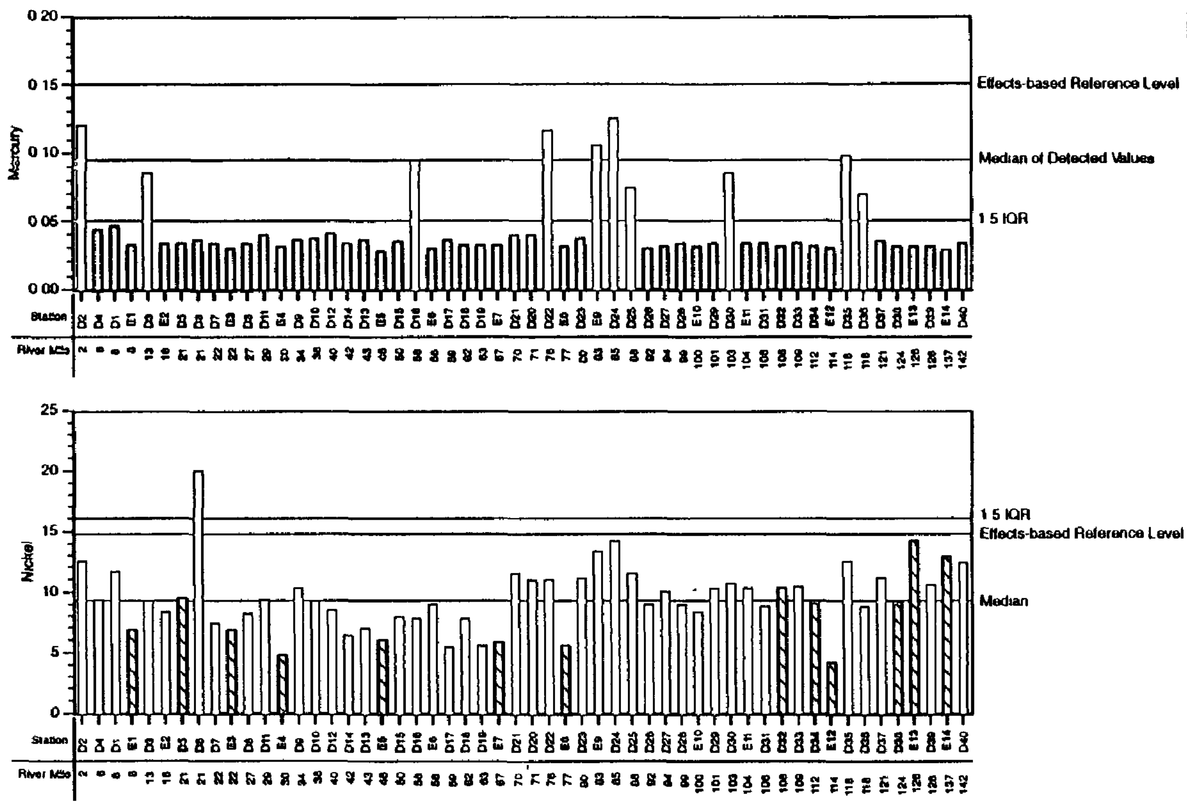


Figure 2 6-8e. Concentrations of mercury and nickel (mg/kg dry wt) at 54 stations in the Columbia River below Bonneville Dam (RM 146). Hatched bars indicate coarse-grained stations, solid bars indicate fine-grained stations; stippled bars indicate one-half detection limit. 1.5 IQR indicates the concentration that is 1 5 times the Inter-Quartile Range

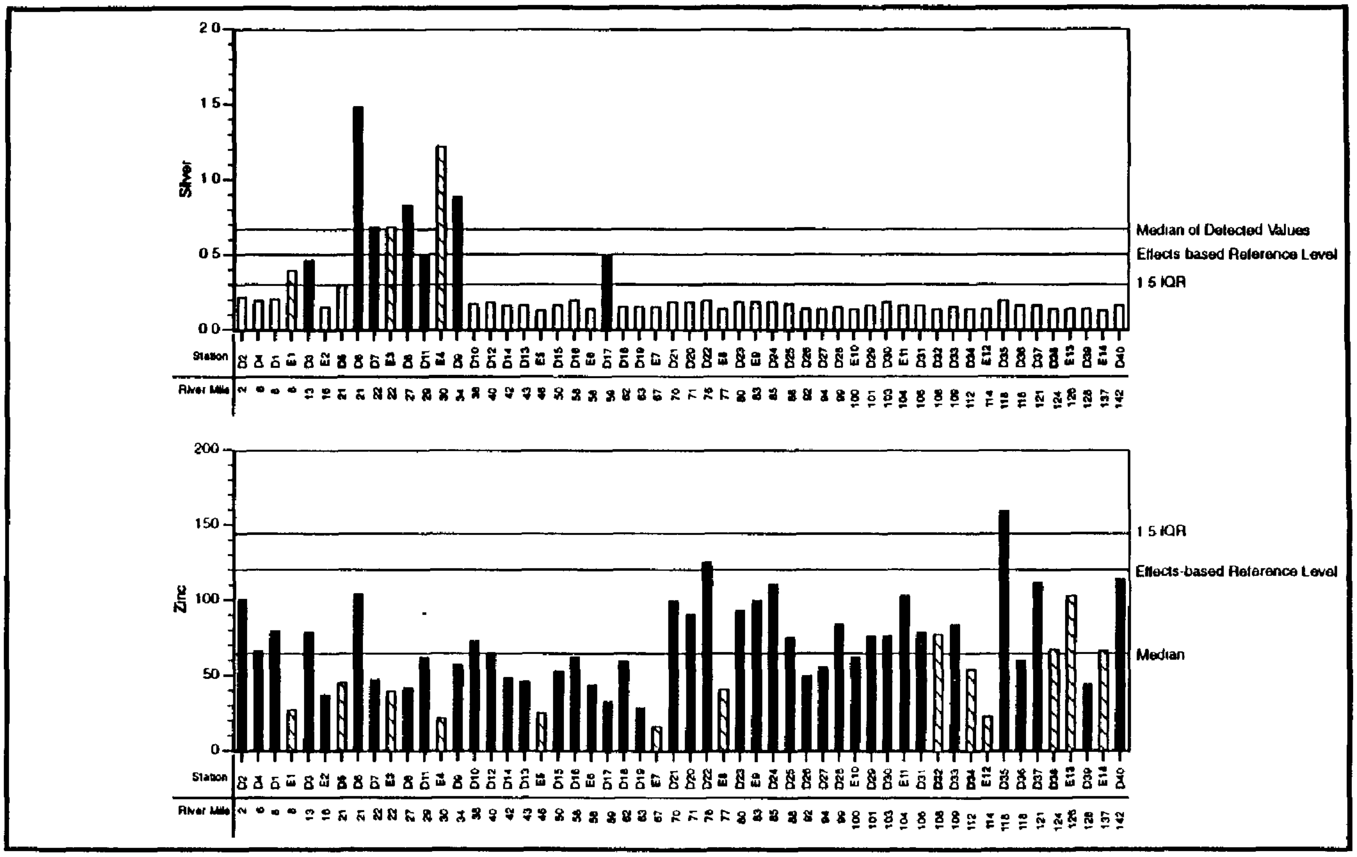


Figure 2 6-8f Concentrations of silver and zinc (mg/kg dry wt) at 54 stations in the Columbia River below Bonneville Dam (RM 146) Hatched bars indicate coarse-grained stations, solid bars indicate fine-grained stations, stippled bars indicate one-half detection limit 1 5 IQR indicates the concentration that is 1 5 times the Inter-Quartile Range plutonium-239/240. The limited sampling for radionuclides did not allow for comparison of the results among station sediment types.

Organic Compounds. Organic compounds were more rarely detected than the metals, except for dioxins, furans, and organotins. Forty-nine organic compounds were detected at least once.

PAHs were detected in five samples in the entire river at stations D19, D24, E8, E9[D], and station D32[E]. There are several possible sources of PAHs, including forest fires, combustion of fossil fuels, petroleum contamination, wood treatment facilities using creosote, and urban runoff (Hoffman et al. 1984, Menzie et al. 1992, Christensen and Zhang 1993). Most of the PAHs are ubiquitous in urban runoff and also have a substantial source from forest and range fires (Menzie et al. 1992). Aluminum smelting also represents another source of PAHs (e.g., Năf et al. 1992). Therefore it would be expected that PAHs are present in many areas of the river. The PAHs were generally found in sediments near urban areas and they were most frequently detected at the highest concentrations at station D19, immediately downstream of the aluminum smelter in Longview

PCBs (as Aroclor 1254) were detected only at station D19. PCBs have been used as insulators and lubricants in transformers, capacitors, and other electrical equipment. Although the production and importation of PCBs has been prohibited for some time in the United States, transformers manufactured or imported prior to the ban are still in use and continue to be a potential source of these compounds. Therefore, it is likely that PCBs are present in depositional areas near many urban developments, near former PCB production facilities, and near areas that contain or have historically contained power transformers.

Pesticides were detected throughout the river and included DDT compounds, heptachlor, aldrin, dieldrin, mirex, dacthal, methyl parathion, parathion, malathion, endrin, and lindane compounds (i.e., alpha-, delta-, and gamma-BHC). The occurrence of pesticide residues in the sediments may be due to agricultural usage or pesticide handling facilities in the Columbia River basin. Most of the chlorinated pesticides are no longer used in the United States, and their presence in the sediments may therefore, represent residual concentrations from past usage rather than from recent applications. This residual, however, may be present over large areas of the Columbia River basin above Bonneville Dam (and in lower river tributary basins), and may continue to act as a source to the lower river. No source could be identified to explain the particular distribution of high concentrations of pesticides near the coarse-grained sediment station E8, although a chemical manufacturer of fertilizers is located near this site.

One phthalate ester [bis(2-ethylhexyl)phthalate] was detected at concentrations exceeding 5 times the blank contamination concentration in 18 samples. This compound is commonly used as a plasticizer and as a replacement for PCBs in dielectric fluids for electrical capacitors. It is present in many plastics (especially vinyls), paints, flexible tubing, plastic bags, and medical supplies. Potential sources of bis(2-ethylhexyl)phthalate include industrial and municipal effluents, landfill leachate, incineration of plastics, and nonpoint storm runoff from urban, industrial, and residential uses. However, this compound is also a common laboratory contaminant, and therefore, the possibility that the unqualified detected concentrations were the result of laboratory contamination (detected in 2 of 7 analytical blanks) should also be considered.

Dioxins and furans were found in the majority of the samples analyzed, but only 20 of the 54 stations were sampled for analysis of these compounds The spatial distributions of the sediment dioxin and furan compounds are presented in Figures 2.6-9 and 2.6-10. The concentrations of most of the dioxins were relatively higher at stations D10 (Wauna) and D24 (St. Helens) compared to the concentrations at the other stations. 2,3,7,8-TCDD (2,3,7,8-tetrachloro-dibenzo-*p*-dioxin) was present in greatest concentration at station D16 (Coal Creek Slough) and was also elevated at station D35 (Camas Slough). 2,3,7,8-TCDF (2,3,7,8-tetrachloro-dibenzo-*p*-furan) was also elevated at station D16, but most of the furans were detected in greatest concentrations at stations D10, D18 (across from Longview behind Lord Island), D24, and D35.

Organotin compounds were detected in 7 of the 10 samples collected and the concentrations did not vary substantially among the samples (Figure 2.6-11). The one exception was a relatively higher concentration of triethyl butyltin measured in the sediment from station D19.

Correlation with Habitat Characteristics--Differences in chemical concentrations for trace elements and organic compounds between the estuarine and freshwater portions of the river were not apparent. However significant differences in concentrations between sediments types (coarse vs. fine-grained sediments) were found.

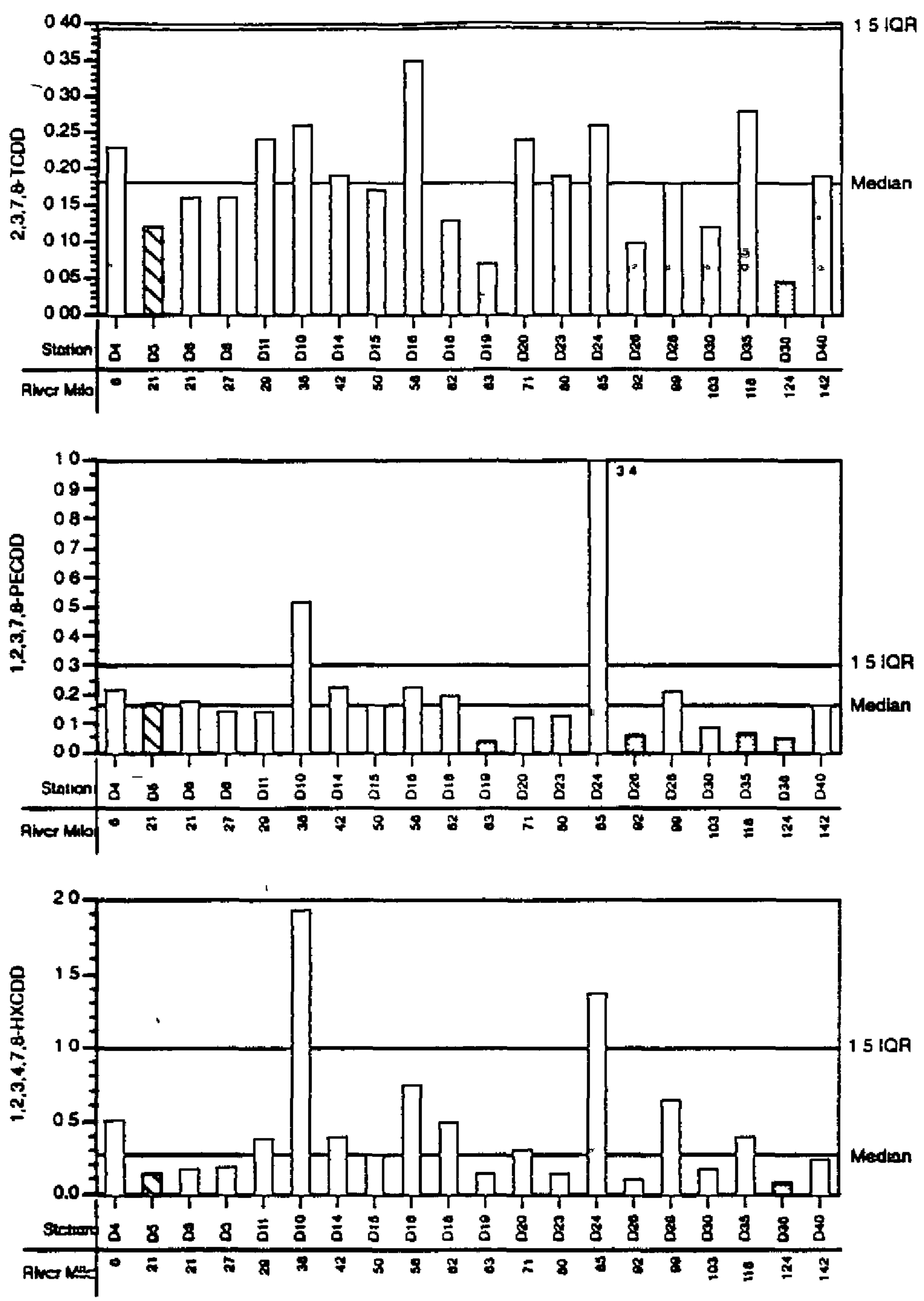


Figure 2-6.9. Concentrations (pg/g dry wt) of dioxin congeners in sediments from 20 stations in the Columbia River below Bonneville Dam (RM 146). *Hatched bars indicate coarse-grained stations; solid bars indicate fine-grained stations, stippled bars indicate one-half detection limit. 1 5 IQR indicates the concentration that is 1 5 times the Inter-Quartile Range.*

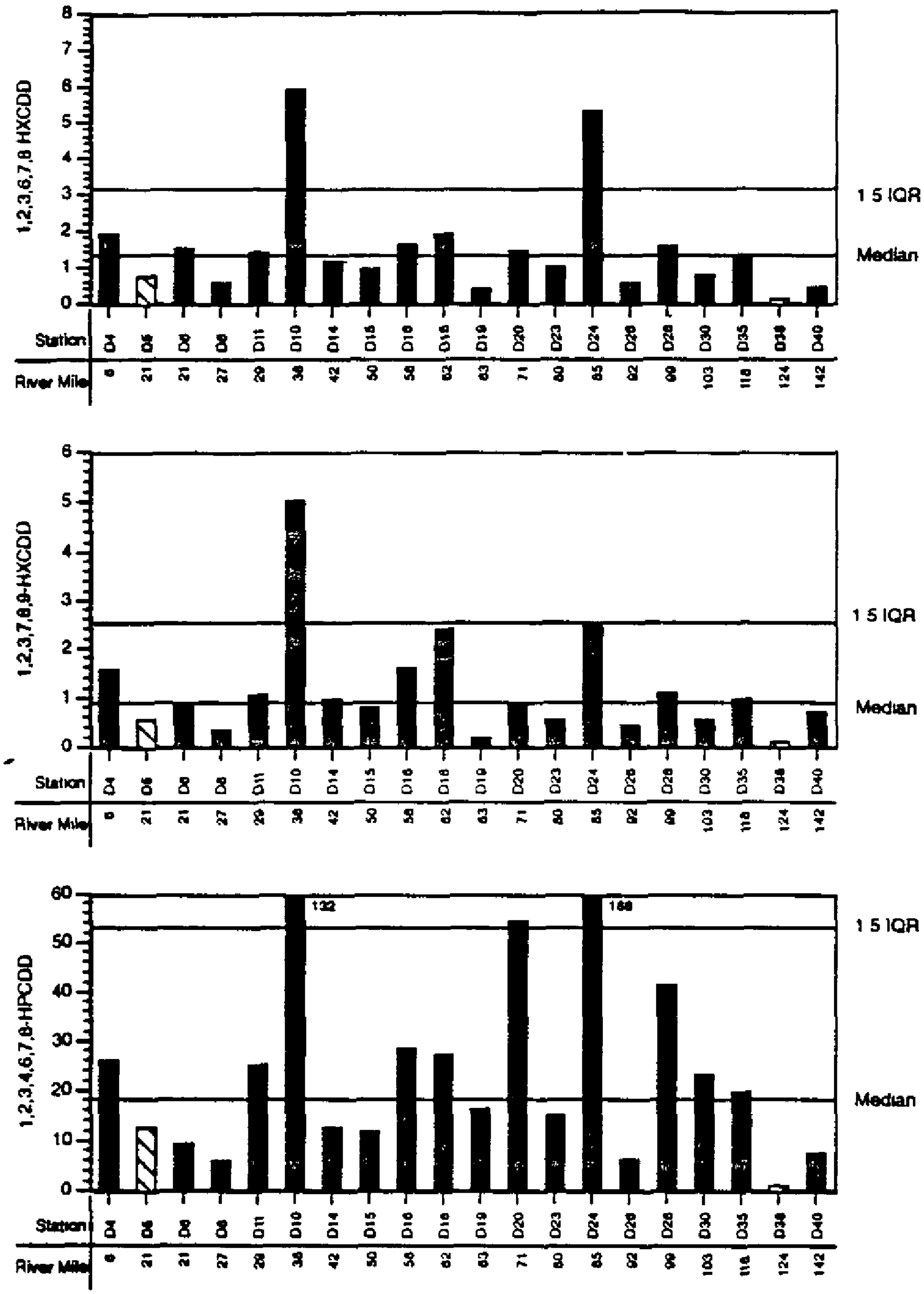


Figure 2-6.9. Concentrations (pg/g dry wt) of dioxin congeners in sediments from 20 stations in the Columbia River below Bonneville Dam (RM 146). *Hatched bars indicate coarse-grained stations, solid bars indicate fine-grained stations, stippled bars indicate one-half detection limit. 1.5 IQR indicates the concentration that is 1.5 times the Inter-Quartile Range*

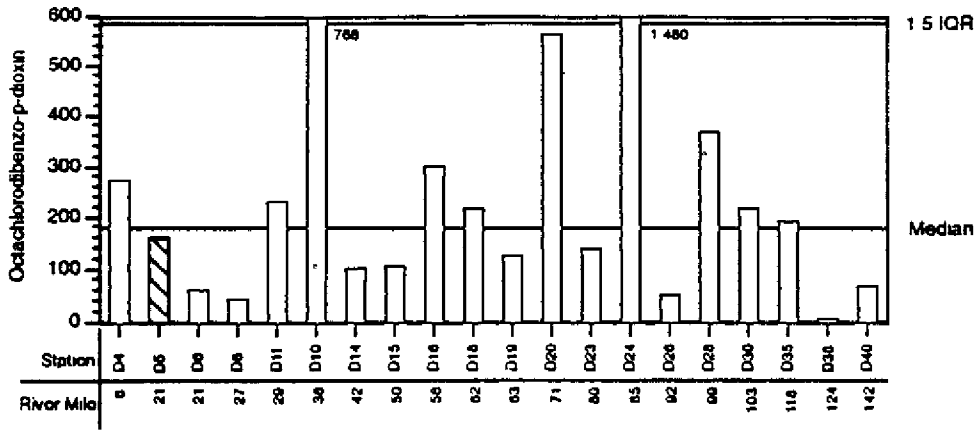


Figure 2.6-9. Concentrations (pg/g dry wt) of dioxin congeners in sediments from 20 stations in the Columbia River below Bonneville Dam (RM 146). *Hatched bars indicate coarse-grained stations, solid bars indicate fine-grained stations, stippled bars indicate one-half detection limit. 1 5 IQR indicates the concentration that is 1 5 times the Inter-Quartile Range*

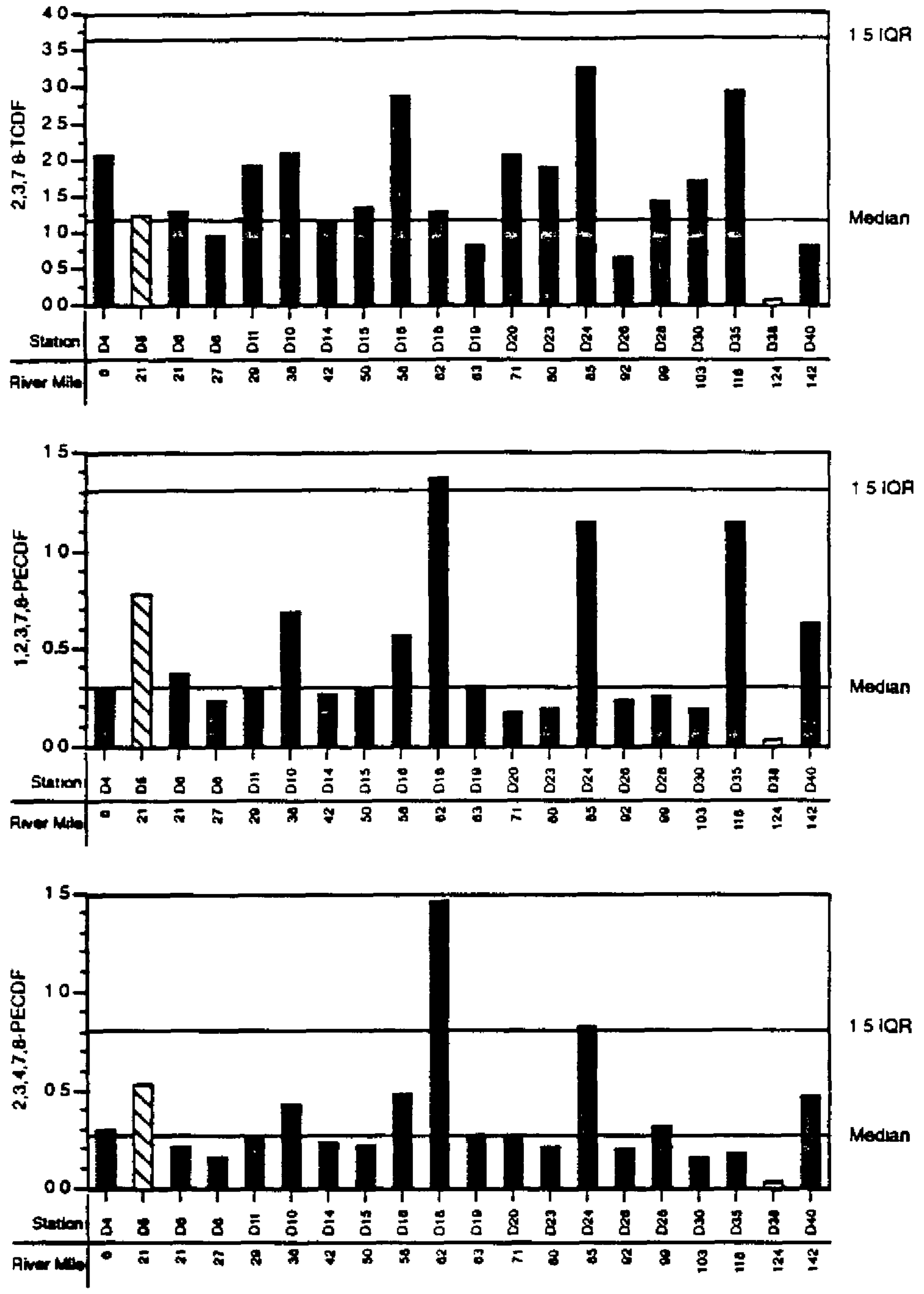


Figure 2.6-10. Concentrations (pg/g dry wt) of furan congeners in sediments from 20 stations in the Columbia River below Bonneville Dam (RM 146). *Hatched bars indicate coarse-grained stations, solid bars indicate fine-grained stations; stippled bars indicate one-half detection limit. 1 5 IQR indicates the concentration that is 1 5 times the Inter-Quartile Range*

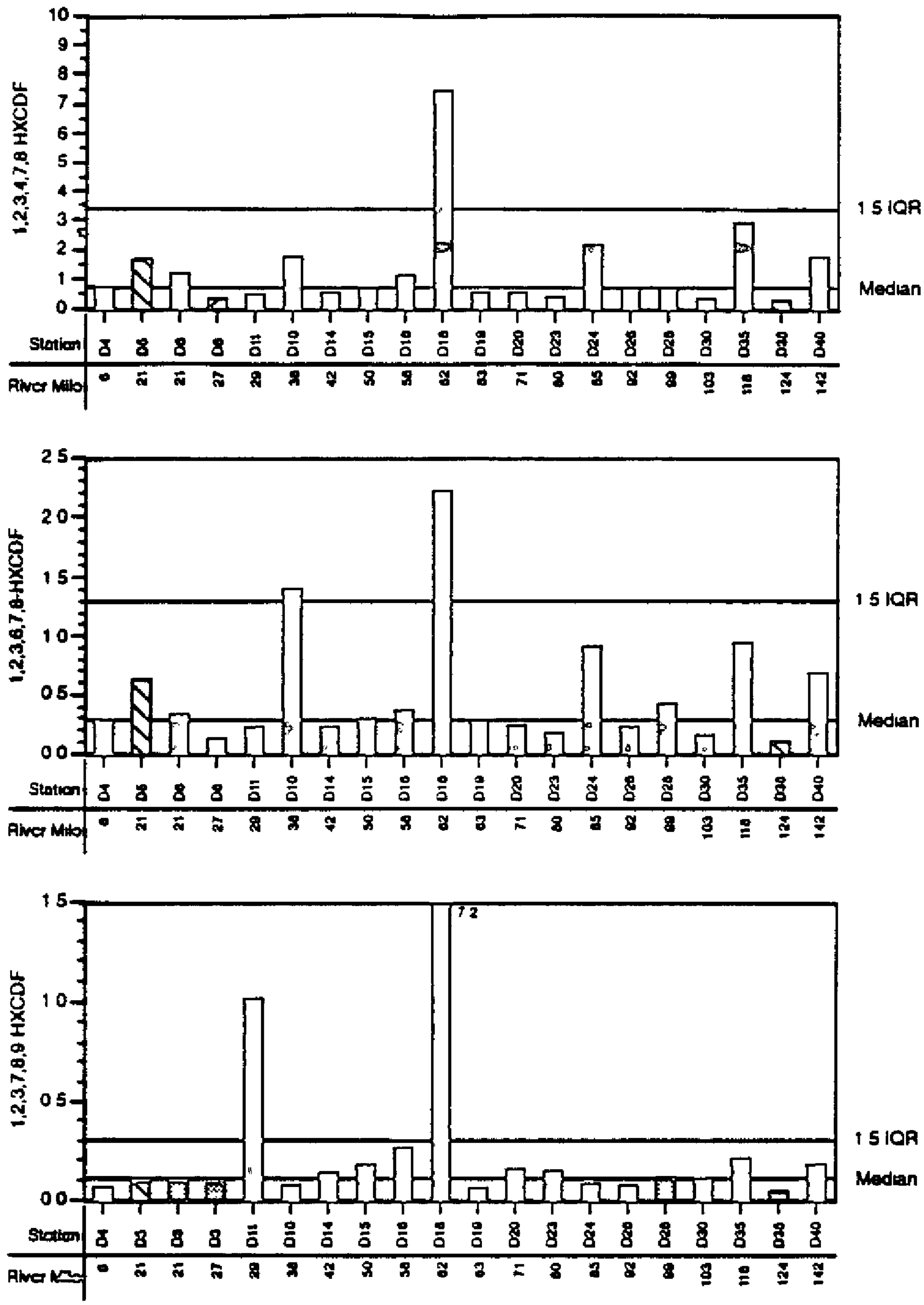


Figure 2.6-10. Concentrations (pg/g dry wt) of furan congeners in sediments from 20 stations in the Columbia River below Bonneville Dam (RM 146). *Hatched bars indicate coarse-grained stations, solid bars indicate fine-grained stations; stippled bars indicate one-half detection limit 1 5 IQR indicates the concentration that is 1 5 times the Inter-Quartile Range*

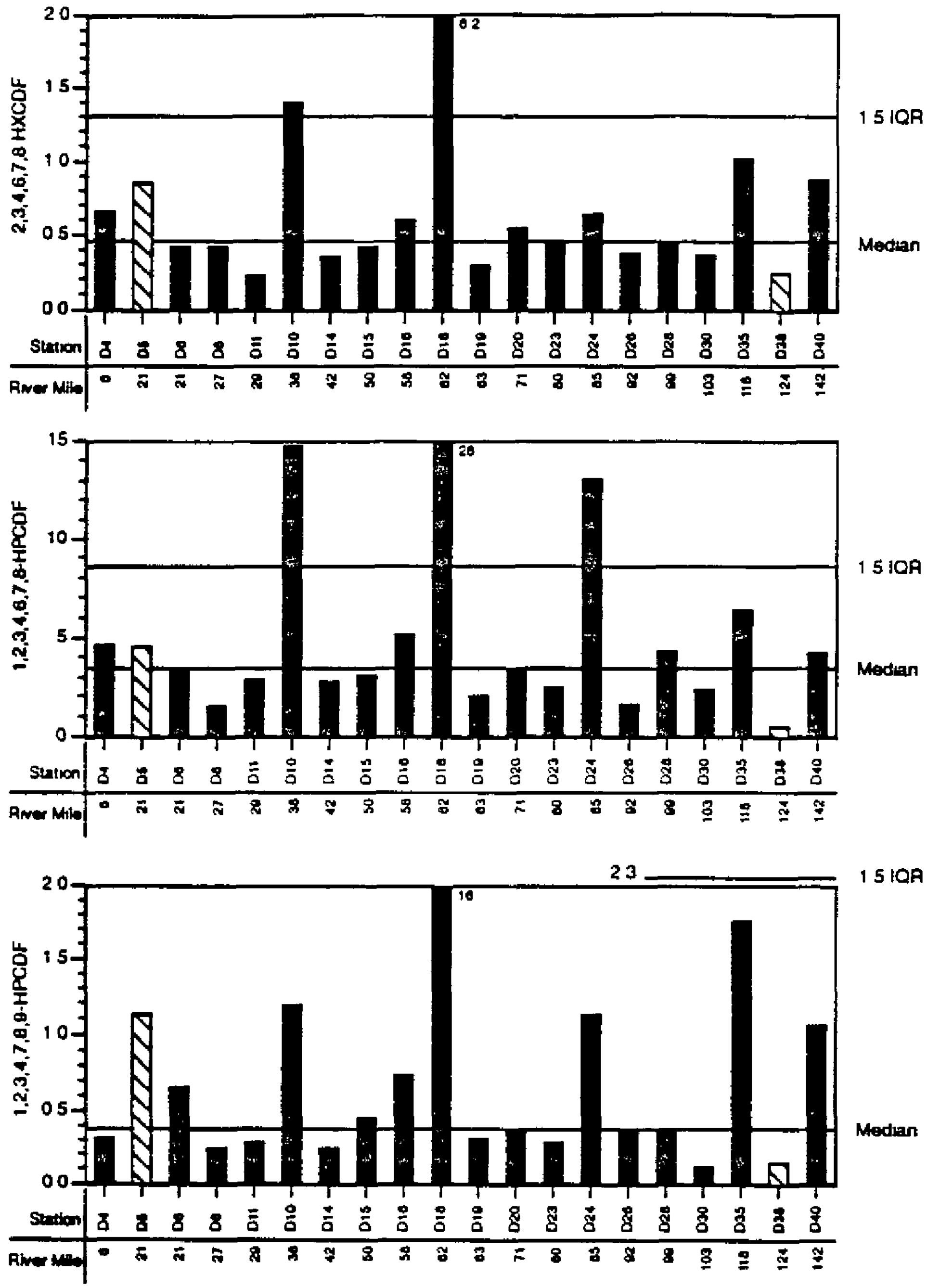


Figure 2.6-10. Concentrations (pg/g dry wt) of furan congeners in sediments from 20 stations in the Columbia River below Bonneville Dam (RM 146). *Hatched bars indicate coarse-grained stations; solid bars indicate fine-grained stations, stippled bars indicate one-half detection limit. 1 5 IQR indicates the concentration that is 1 5 times the Inter-Quartile Range*

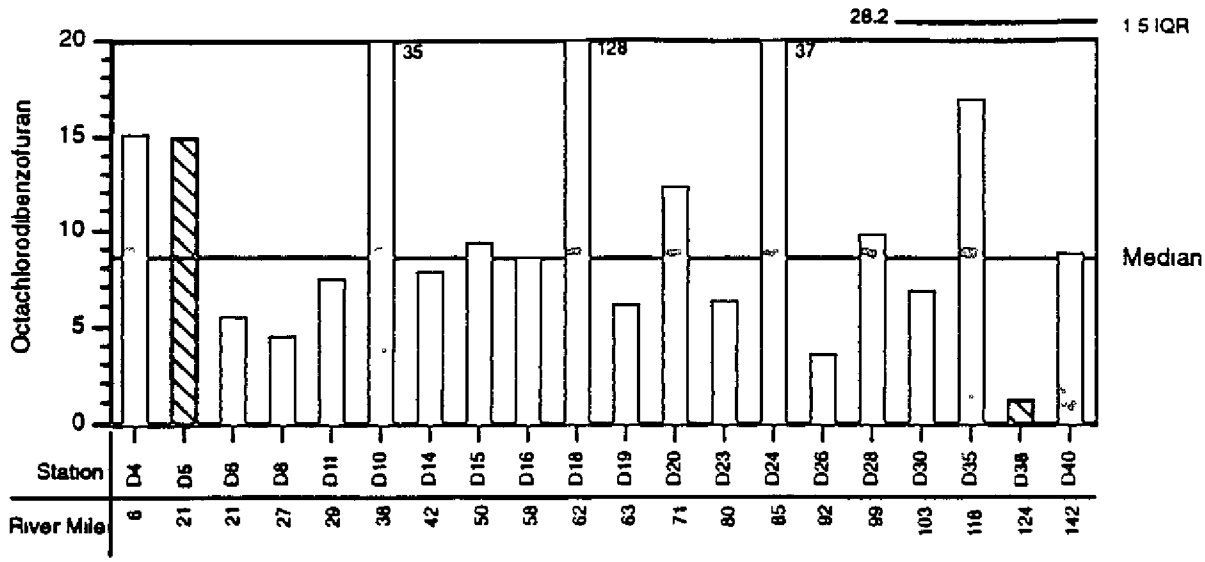


Figure 2.6-10. Concentrations (pg/g dry wt) of furan congeners in sediments from 20 stations in the Columbia River below Bonneville Dam (RM 146). Hatched bars indicate coarse-grained stations; solid bars indicate fine-grained stations, stippled bars indicate one-half detection limit 1 5 IQR indicates the concentration that is 1 5 times the Inter-Quartile Range.

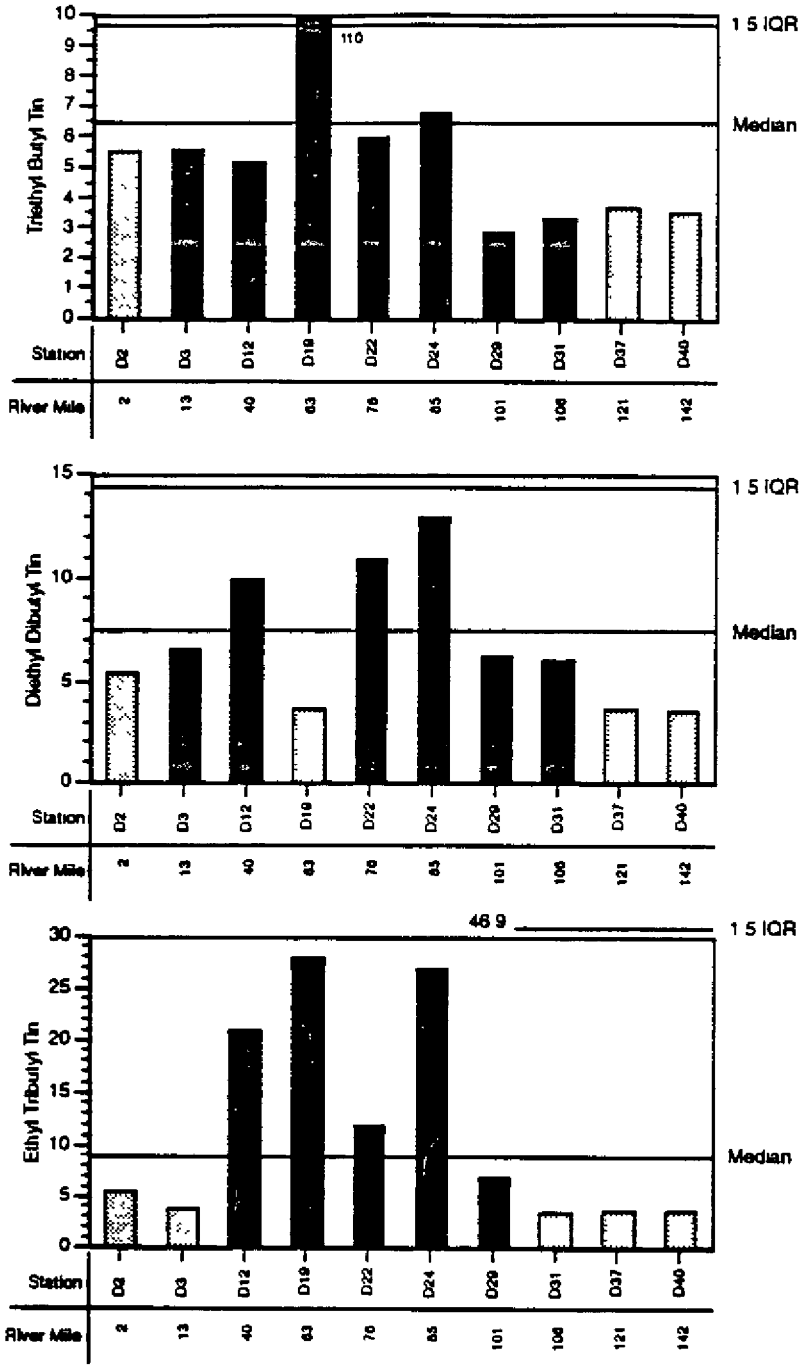


Figure 2.6-11. Concentrations (µg/kg dry wt) of organotins in sediments from 10 stations in the Columbia River below Bonneville Dam (RM 146). Stippled bars indicate one-half detection limits. 1.5 IQR indicates the concentration that is 1.5 times the Inter-Quartile Range.

Metals Concentrations of all of the detected elements, except silver, were higher at the fine-grained stations in the river compared to the coarse-grained stations Similarly, differences in the total concentrations of all the metals between sediment types indicated that the concentrations of metals were significantly ($p \leq 0.05$) higher in fine-grained than in coarse-grained areas of the river. These differences appear to be driven by the differences in concentrations between sediment types within the freshwater reaches of the river No significant differences were found between sediment types in the estuary

As noted above, because the distribution of metals is affected by sediment grain size and TOC concentrations, the correlations between these variables and the concentrations of the elements were tested All of the metals except barium, nickel, and silver were significantly correlated ($P < 0$ 05) with either the TOC content of the sediments or the percentage of silt and clay Aluminum, arsenic, chromium, copper, lead, and mercury were significantly correlated with both variables

Organic Compounds Most organic compounds also accumulate in sediments to higher concentrations in finer, organic-rich sediments However, the low number of detected organic compounds precluded precise testing of the relationship between these compounds and grain size In addition, organotins, dioxins, and furans were measured primarily in fine-grained areas in the freshwater reaches of the river Therefore the distribution of these compounds by sediment type could not be examined.

Limited testing showed that 2,3,7,8-TCDF was significantly correlated ($P < 0.05$) with the total organic carbon concentrations in the sediment. The other dioxin and furan congeners appeared to show some relationship, but were not highly correlated with either habitat variable. No correlation between organotins and habitat variables was found. Visual examination of the sediment characteristics associated with the stations where PAHs, PCBs, and pesticides were found did not indicate that either grain-size or TOC was related to those measurements, except perhaps for station D35, which had very high TOC concentrations, as well as numerous pesticides and high concentrations of 2,3,7,8-TCDD and some furans. Organotin compounds were not analyzed for at station D35

Identification of Potential Areas of Concern--As part of the reconnaissance survey, the data were used to delineate areas of concern within the river on the basis of potentially elevated concentrations due to anthropogenic inputs (for metals), the detection of organic compounds of anthropogenic origins, or where concentrations of metals or organic compounds exceeded reference levels adopted for this study which are associated with deleterious biological effects.

Identification of Potentially Anthropogenically Enriched Sediments–

Metals Regression analyses, using iron as the independent variable, were used to identify sediments that might be anthropogenically enriched with metals Those concentrations that lay within or below the 95 percent confidence envelope for the regression were considered to be sediments that were negligibly influenced by point or nonpoint pollutant sources. Those outlying concentrations that exceeded the confidence level were therefore considered to indicate possible anthropogenic sources of that metal at those stations. This approach is only valid when the data support a sufficiently robust correlation between the variables For the data set from the lower Columbia River, the correlations for aluminum, arsenic, barium, cadmium, chromium, copper, nickel, lead, and zinc were significantly correlated with iron. Outliers that exceeded the ranges of frequency distributions were used to identify anomalously high concentrations for the metals that were not significantly correlated with the sediment iron content. Stations with concentrations of metals identified as potentially influenced by anthropogenic inputs by either method are summarized in Table 2 6-2

Radionuclides. All of the sediment radionuclides analyzed for in the reconnaissance survey are the direct or indirect result of human activities Radioactive cesium, plutonium, and europium detected in the reconnaissance survey sediment samples are the result of fallout from historical above-ground nuclear weapons testing, nuclear power facility accidents (e.g., the Chernobyl accident in the former Soviet Union), current and historical release from the Hanford site located in the upper river, and possibly from historical activities at the Trojan nuclear power plant.

Organic Compounds. All of the organic compounds that were measured were considered to have no or very low (e.g., PAHs) natural concentrations As a result, all locations where the compounds were detected were considered to have been influenced by anthropogenic inputs. However, where the data supported the evaluation, the extent of contamination at the different stations was compared to identify those areas with particularly high concentrations.

TABLE 2.6-2. IDENTIFICATION OF SEDIMENTS THAT MAY POTENTIALLY BE ELEVATED IN THE INDICATED METAL DUE TO INPUT FROM ANTHROPOGENIC SOURCES
(Page 1 of 2)

Station[a]	Aluminum	Arsenic	Barium	Cadmium	Chromium	Copper	Lead	Mercury	Nickel	Silver	Zinc
D1	X				X	X					
D2		+			+	X+		+			
D3					X		X	+		+	
D4	X				X	X					
D5[E]	X									+	
D6		X+		+			+		X+	+	
D7		X	X	X			X			+	
D8	X		X				X			+	
D9				X+						+	
D10					X					+	X
D11	X				X						
D12	X					X					
D13	X					X					
D14	X	X				X					
D15											
D16	X	X						+			
D17	X					X				+	
D18		X									X
D19	X					X					
D20	X	X									
D21			X	X+			X+				
D22	X			X+		X	X	+			X
D23		X+	X								
D24	X							+			
D25			X		X			+			
D26			X						X		
D27									X		
D28		X	X				X				X
D29			X						X		X
D30			X		X			+			
D31		X	X								X
D32[E]					X		X		X		X
D33			X						X		X

TABLE 2 6-2 IDENTIFICATION OF SEDIMENTS THAT MAY POTENTIALLY BE ELEVATED IN THE INDICATED METAL DUE TO INPUT FROM ANTHROPOGENIC SOURCES
(Page 2 of 2)

Station[a]	Aluminum	Arsenic	Barium	Cadmium	Chromium	Copper	Lead	Mercury	Nickel	Silver	Zinc
$D34^E$			X		X				X		X
D35		X		X+		X		+			X+
D36					X			+			
D37			X				X				X
$D38^E$					X		X		X		X
D39					X				X		
D40			X				X				X
E1		X								+	
$E2^D$											
E3										+	
E4				X						+	
$E6^D$									X		
E7						X					
E8		X									
$E9^D$	X							+			
$E10^D$											
E11			X			X+	X				X
E12	X										
E13			X								
E14			X						X		

X = Enrichments identified by regression analyses

+ = Potential enrichments identified by frequency distribution analyses.

[a] Station number prefix "D" and "E" were assigned prior to sampling to stations expected to be fine-grained and coarse-grained, respectively. Following sampling, some stations were reclassified based on the grain size analysis [>20% fines (<100 um effective diameter) was considered a fine-grained sediment station]. Reclassified stations are identified by superscript "E" or "D".

Dioxins, furans and organotins were detected frequently enough to support a distributional analysis to identify anomalously high concentrations. Dioxins and furans were detected at all 20 stations sampled, and the highest concentrations occurred at station D10, D11, D18, D20, and D24. One furan congener at station D11 and one dioxin congener at station D20 was identified as an outlier. Station D10 and D24 had the highest concentrations of six dioxin and several furan congeners. All outliers at station D18 were due to furan congeners.

Organotins were detected in 7 of the 10 samples collected (stations D2, D12, D19, D22, D24, D29, and D31). However, no concentrations were identified as anomalously high in comparison with concentrations at other stations except triethyl butyltin at station D19 This station was the only one used to help identify areas of concern.

Most PAH compounds were detected in sediments from five stations, including stations D19, D24, and E9^{D}. Several compounds were also detected at stations D32^{E} and E8. As a conservative screening approach, all of these stations were used in the identification of areas of concern.

PCBs were detected at station D19, and this finding was used in the identification of areas of concern.

Numerous pesticides were detected in Columbia River sediments distributed over 22 stations. One or two compounds were detected at 16 of the 22 stations, but three or more pesticides were detected in the sediments at 6 stations (D22, E8, D23, E9^{D}, D24, and D35); the greatest number of pesticides were detected at station E8. Too few data were available to statistically identify outliers; therefore, these six stations were included in the delineation of problem areas in the lower Columbia River.

Effects-Level Comparisons--As a second independent approach for identifying areas of concern within the lower river, concentrations observed in the sediments were compared with existing freshwater sediment quality guidelines developed by the Ontario Ministry of the Environment (Persaud et al. 1991), the lower 10th percentile (the ER-L) of the concentrations associated with adverse effects in laboratory and field studies compiled by Long and Morgan (1990), and the U.S. Environmental Protection Agency freshwater sediment criteria (corrected for sediment organic carbon content) available for five organic compounds (U.S. EPA 1991c,d,e,f,g). These comparisons are summarized in Tables 2.6-3 and 2.6.4.

TAB[illegible]6-3. SUMMARY OF SEDIMENT METALS AND CYANIDE [illegible] FROM THE LOWER COLUMBIA RIVER RECONNAISSANC[illegible]RVEY

Parameter	Frequency of Detection[a]	Detection Limit(s)	Coarse-Grained[b] (n=13)		Fine-Grained[c] (n=41)		Reference Levels	
			Range	Median	Range	Median	ER-L[d] (marine)	Ontario[e] (freshwater)
			Units in mg/kg Dry Sediment					
Aluminum	54/54	- -	2,794 - 9,032	4,747	4,605 - 15,060	7,650		
Antimony	0/54	4 3 - 11 1	4 3U - 10 2U	- -	4.6U - 11 1U	- -	2 0	
Arsenic	54/54	- -	0 46 - 2 9	1 8	0 95 - 8 92	2 4	33	6
Barium	54/54	- -	8 5 - 164 5	51 4	23 7 - 127 7	77 4		
Beryllium	1/54	2 9 - 8 0	2 8U - 3 5U	- -	3 2U - 4 0	- -		
Cadmium	53/54	0 06	0 06U - 0.9	0 19	0 07 - 2 66	0 41	5	0 6
Chromium	52/54	2 3 - 4 5	2 3U - 7 5	5 18	2 9 - 14 6	7 9	80	26
Copper	54/54	- -	1 8 - 8 5	4 8	2 4 - 26 9	10 3	70	16
Iron	54/54	- -	3,906 - 17,742	9,988	6,579 - 24,408	12,414		20,000
Lead	54/54	- -	0 6 - 8 0	3 87	2 2 - 20 5	7 33	35	31
Mercury	10/54	0 06 - 0 09	0 06U - 0 07U	- -	0 06U - 0 125	0 096	0 15	0.2
Nickel	54/54	- -	4 2 - 14 2	6 92	5 0 - 20 1	9 4	30	16
Selenium	2/54	0 3 - 0 8	0 3U - 0 7U	- -	0 3U - 0 8	0 55		
Silver	10/54	0 3 - 0 6	0 3U - 1 22	0 69	0 3U - 1 49	0 68	1	0 5
Thallium	0/54	10 3 - 24 4U	10 3U - 24 4U	- -	11.1U - 26 8U	- -		
Zinc	54/54	- -	16 4 - 103	40 8	28 3 - 161	72 7	120	120
Cyanide[f]	- -	- -	- -	- -	- -	- -	- -	0 1

U = Undetected above the laboratory detection limit

[a] The frequency of occurrence of detectable concentrations of the parameter at the 54 sediment metal sampling stations

[b] Coarse-grained sediments have been defined for this project as those sediments samples with less than or equal to 20 percent of the sample weight consisting of sediment grain sizes less than 100 μm

[c] Fine-grained sediments have been defined for this project as those sediments samples with greater than 20 percent of the sample weight consisting of sediment grain sizes less than 100 μm

[d] The Effects Range-Low of Long and Morgan (1990)

[e] Provincial Sediment Quality Guidelines, Lowest Effect (Persaud et al 1991)

[f] The sediment cyanide data were considered unuseable for this report

TABLE 2.6-4. SUMMARY OF SEDIMENT ORGANIC COMPOUNDS FROM THE LOWER COLUMBIA RIVER RECONNAISSANCE SURVEY
(Page 1 of 3)

Parameter	Frequency of Detection[a]	Detection Limit(s)	Coarse-Grained[b] (n=13)		Fine-Grained[c] (n=41)		Reference Levels		
			Range	Median	Range	Median	ER-L[d] (marine)	Ontario[e] (freshwater)	Draft EPA[f] (freshwater)
			Units in μg/kg dry sediment						$\mu g/g_{oc}$[d]
PAHs									
Benzo(a)anthracene	3/54	40-144	40U-94U	- -	42U-260	180	230	2,000[g]	
Benzo(b)fluoranthene	3/54	80-288	80U-188U	- -	84U-400	170		2,000[g]	
Benzo(k)fluoranthene	1/54	80-288	80U-188U	- -	84U-210	- -[h]		2,000[g]	
Benzo(a)pyrene	3/54	80-288	80U-188U	- -	84U-260	250	400	2,000[g]	
Benzo(g,h,i)perylene	2/54	80-288	80U-188U	- -	84U-200	150		2,000[g]	
Chrysene	4/54	40-144	40U-48	- -[h]	44U-630	280	400	2,000[g]	
Fluoranthene	5/54	40-144	40U-72	71	44U-280	250	600	2,000[g]	1020 (470-2190)
Indeno(1,2,3-cd)pyrene	3/54	80-288	80U-188U	- -	84U-170	140		2,000[g]	
Phenanthrene	4/54	40-144	40U-48	- -[h]	44U-210	110	225	2,000[g]	120 (56-260)
Pyrene	5/54	40-144	40U-110	77	44U-420	360	350	2,000[g]	
Phthalate Esters									
bis(2-ethylhexyl)phthalate	18/54	40-250	40U-500	58	42U-790	185			
PCBs									
Aroclor	1/54	25-250	25U	- -	25U-85	- -[h]	50[i]	70[i]	

TABLE 2.6-4. SUMMARY OF SEDIMENT ORGANIC COMPOUNDS FROM THE LOWER COLUMBIA RIVER RECONNAISSANCE SURVEY
(Page 2 of 3)

Parameter	Frequency of Detection[a]	Detection Limit(s)	Coarse-Grained[b] (n=13)		Fine-Grained[c] (n=41)		Reference Levels		
			Range	Median	Range	Median	ER-L[d] (marine)	Ontario[e] (freshwater)	Draft EPA[f] (freshwater)
			Units in µg/kg dry sediment						$\mu g/g_{oc}$[d]
Pesticides									
Aldrin	1/54	2-20	2U	- -	2U-3.1	- -[h]		2	
alpha-BHC	4/54	2-20	2U	- -	2U-4	3 0		3[j]	
delta-BHC	3/54	2-20	2U	- -	2U-7.9	5.5		3[j]	
gamma-BHC	1/54	2-20	2U	- -	2U-2.2	- -[h]		3[j]	
Dacthal	1/54	2-20	2U-9	- -[h]	2U-20U	- -			
o,p-DDD	1/54	2-20	2U-6 6	- -[h]	2U-20U	- -	1 - 3[k]	5-8[k]	
o,p-DDE	2/54	2-20	2U-3 6	- -[h]	2U-3 2	- -[h]	1 - 3[k]		
o,p-DDT	5/54	2-7	2U-8 3	7.0	2U-20	9 4	1 - 3[k]		
4,4'-DDE	3/54	2-20	2U	- -	2U-5.6	2 8	1 - 3[k]		
4,4'-DDT	2/54	2-20	2U-3 3	- -[h]	2U-100	- -[h]	1 - 3[k]		
Dieldrin	1/54	2-20	2U-3 3	- -[h]	2U-20U	- -	0 02	2	9.0 (4.2-19)
Endrin	1/54	2-20	2U-4 5	- -[h]	2U-20U	- -	0 02	3	4.0(1.9-8 6)
Heptachlor	3/54	2-20	2U	- -	2U-6.1	2 5			
Malathion	1/54	2-20	2U-2 3	- -[h]	2U-20U	- -			
Methyl parathion	13/54	2-20	2U-4.9	4.0	2U-68	5 9			
Mirex	2/54	2-20	2U-4 8	- -[h]	2U-5.2	- -[h]		7	
Parathion	2/54	2-20	2U-5 1	- -[h]	2U-4.4	- -[h]			

TABLE 2.6-4. SUMMARY OF SEDIMENT ORGANIC COMPOUNDS FROM THE LOWER COLUMBIA RIVER RECONNAISSANCE SURVEY
(Page 3 of 3)

Parameter	Frequency of Detection[a]	Detection Limit(s)	Coarse-Grained[b] (n=13)		Fine-Grained[c] (n=41)		Reference Levels		
			Range	Median	Range	Median	ER-L[d] (marine)	Ontario[e] (freshwater)	Draft EPA[f] (freshwater)
			Units in μg/kg dry sediment						$\mu g/g_{oc}$[d]

FOOTNOTES

U = Undetected above the laboratory detection limit.

[a] The frequency of occurrence of detectable concentrations of the parameter at the 54 sediment semivolatile, PCB and pesticide sampling stations.

[b] Coarse-grained sediments have been defined for this project as those sediments samples with less than or equal to 20 percent of the sample weight consisting of sediment grain sizes less than 100 μm.

[c] Fine-grained sediments have been defined for this project as those sediments samples with greater than 20 percent of the sample weight consisting of sediment grain sizes less than 100 μm.

[d] The Effects Range-Low of Long and Morgan (1990)

[e] Provincial Sediment Quality Guidelines; Lowest Effect (Persaud et al. 1991)

[f] Draft EPA freshwater sediment criteria are based on the concentration of contaminant relative to the sediment organic carbon concentration. Sources include U.S. EPA (1991c,d,e,f,g). Values in parentheses are the 95 percent confidence limits.

[g] Reference value for total PAHs

[h] Median not reported Parameter detected above the laboratory detection limit only once.

[i] Reference value for total PCBs

[j] Reference value for total BHC.

[k] Range for total DDT and individual compounds.

As a conservative screening approach, the lowest concentration reported among the three sources was used to identify the lower Columbia River sediments that may pose a threat to aquatic biota.

Metals. No effects-based comparison data were available for aluminum or barium. The concentrations chromium, lead, and mercury never exceeded effects concentrations. Arsenic, cadmium, copper, iron, nickel, silver, and zinc exceeded effects levels at 18 stations The stations at which several metals were present at concentrations exceeding one or more reference levels were stations D6 in Grays Bay (arsenic, cadmium, iron, nickel, and silver), D9 near Skamokawa (cadmium, iron, and silver), D22 near Kalama (cadmium, copper, and zinc), and D35 in Camas Slough (cadmium, copper, and zinc). Copper was present at stations throughout the river, and exceeded the lowest reference level at the most stations (D1, D2, D12, D16, D20, D22, E11[D], D35, and D40). Silver was not present over the same range in the river, but did exceed its effects-based reference level at six stations (D6, D9, D21, D22, and D35) were it was detected. Cadmium was also present at concentrations that exceeded its reference value at five stations that spanned most of the lower river (D6, D9, D21, D22, and D35). The remaining metals exceeded the lowest reference levels at three (iron at D2, D6, and D9) or fewer stations (zinc at D22 and D35; arsenic and nickel at D6).

Radionuclides No effects-based sediment guidelines or reference concentrations for radionuclides were identified or adopted for this study, and therefore, no problem areas were identified on the basis of comparison of the sediment radionuclide concentrations to effects-based reference concentrations.

Organic Compounds. Several PAH compounds and total PAHs (determined by summing he concentrations at each station of those PAH compounds that were detected) were measured at concentrations greater than the effects-based reference concentrations at four stations: D2, D19, D22, and D24. The concentrations of the PCBs detected at station D19 exceeded both the Long and Morgan (1990) ER-L and the Ontario freshwater sediment guidelines. In at least one case for each pesticide, the reported detection limits exceeded the effects-based reference values. Pesticides were measured in amounts greater than their effects-based reference levels at 12 stations. No sediment quality guidelines exist for the remaining constituents for which the lower Columbia River sediments were analyzed and these were not ranked using this approach.

Overall, the concentrations of chemical substances exceeded sediment quality guidelines at 23 stations. Stations with the three or more chemicals at concentrations above screening concentrations occurred near urbanized or industrial areas, including Camas, Kalama, Longview, Ilwaco (Washington), and St. Helens and Astoria (Oregon). Station D6 in Grays Bay had five metals at concentrations above the sediment quality guidelines adopted for this study

Areas of Concern--The stations that were identified as having sediments that were potentially influenced by anthropogenic sources or that had chemical concentrations exceeding sediment quality guidelines are summarized in Table 2.6-5. Because the dioxins and furans, the PAHs, and the PCBs generally consist of covariant groups of compounds, reflecting the commonality of their source, a single exceedance was assigned to those stations at which these compounds were found. Table 2.6-5 includes the actual numbers of individual compounds detected in each group, except for the PCBs which were reported as the Aroclor representative.

Sediments collected from five stations (E2^{D}, E3, E5, D15, E10^{D}) did not have any substances at concentrations that indicated potential anthropogenic influences. Stations D19 (Longview) and D24 (St. Helens) had the greatest numbers of different classes of compounds present at high concentrations. The stations with the greatest numbers of substances that indicated potential anthropogenic influence also generally had the greatest numbers of substances that exceeded the effects-based reference values. The stations with the greatest numbers of both potential anthropogenic influence and reference level exceedances included D1, D2, and D6 in the estuary (Segment 1); stations D16, D19, D22, E8, E9^{D}, and D24 in the reach between RM 58 (below Longview) and RM 83 (below St. Helens); and station D35 (Camas Slough). Comparatively high concentrations of dioxins and furans occurred at the stations downstream of St. Helens (D24) and Wauna (D10), and across from Longview at station D18 behind Lord Island. Organotins were comparatively high at station D19 (RM 62 below Longview), which was also the station where Aroclor 1254 (PCBs) was detected. PAHs were detected at five stations including station D32^{E} between Vancouver and Portland; stations D24 and E9^{D}, downstream from St. Helens; station E8 near Kalama, and station D19 below Longview. Pesticides were distributed somewhat differently and were primarily found between Kalama and St. Helens (RM 76 to RM 86), with station E8 having the greatest number of pesticides detected.

TABLE 2 6-5. THE IDENTIFICATION OF AREAS OF CONCERN FOR SEDIMENT QUALITY BASED ON AREAS IDENTIFIED AS POTENTIALLY ENRICHED DUE TO ANTHROPOGENIC SOURCES AND EXCEEDANCES OF SEDIMENT QUALITY GUIDELINES[a]

(Page 1 of 3)

Station[b]	River Mile	Potentially Enriched Chemicals							Total # of Effects Exceedances
		Metals	Organic Compounds					Total # of Enrichments	
			Dioxins/Furans	Organotins	PAHs	PCBs	Pesticides		
D1	8	3						3	2
D2	2	4						4	3
D3	13	4						4	
D4	6	3						3	
D5[E]	21	2						2	1
D6	21	5						5	5
D7	22	5						5	1
D8	27	5						5	1
D9	34	2						2	3
D10	38	2	1(10)					3	0[c]
D11	29	3	1(1)					4	0[c]
D12	40	2					2	4	2
D13	43	2						2	
D14	42	2						2	
D15	50								
D16	58	3					2	5	3
D17	59	3					1	4	1
D18	62	2	1(9)					3	0[c]
D19	63	2		1	1(8)	1		5	5
D20	71	3	1(1)					4	1[c]

TABLE 2.6-5. THE IDENTIFICATION OF AREAS OF CONCERN FOR SEDIMENT QUALITY BASED ON AREAS IDENTIFIED AS POTENTIALLY ENRICHED DUE TO ANTHROPOGENIC SOURCES AND EXCEEDANCES OF SEDIMENT QUALITY GUIDELINES[a]
(Page 2 of 3)

Station[b]	River Mile	Potentially Enriched Chemicals							Total # of Effects Exceedances
		Metals	Organic Compounds					Total # of Enrichments	
			Dioxins/Furans	Organotins	PAHs	PCBs	Pesticides		
D21	70	3						3	1
D22	76	6					3	9	3
D23	80	2					3	5	
D24	85	2	1(8)		1(10)		5	8	3[c]
D25	88	3						3	
D26	92	2						2	
D27	94	1						1	
D28	99	4						4	
D29	101	3						3	
D30	103	4						4	
D31	106	2						2	
D32[E]	108	4			1(4)			5	1
D33	109	3						3	
D34[E]	112	3						3	
D35	118	5					4	9	5
D36	118	2						2	
D37	121	3						3	
D38[E]	124	4						4	
D39	128	2						2	
D40	142	3					2	5	1

TABLE 2 6-5. THE IDENTIFICATION OF AREAS OF CONCERN FOR SEDIMENT QUALITY BASED ON AREAS IDENTIFIED AS POTENTIALLY ENRICHED DUE TO ANTHROPOGENIC SOURCES AND EXCEEDANCES OF SEDIMENT QUALITY GUIDELINES[a]

		Potentially Enriched Chemicals							
			Organic Compounds						
Station[b]	River Mile	Metals	Dioxins/Furans	Organotins	PAHs	PCBs	Pesticides	Total # of Enrichments	Total # of Effects Exceedances
E1	8	2						2	
E2[D]	16								
E3	22								1
E4	30	2						2	2
E5	46								
E6[D]	58	1						1	
E7	67	1						1	
E8	77	1			1(2)		6	8	4
E9[D]	83	2			1(9)		3	6	2
E10[D]	100								
E11[D]	104	4						4	1
E12	114	1						1	
E13	126	1						1	
E14	137	2						2	

[a] A value of 1 was assigned to each metal and each group of organic compounds that was considered to be potentially enriched or exceeded reference concentrations. The actual number of individual compounds is indicated in parentheses.

[b] Station number prefixed "D" and "E" were assigned prior to sampling to stations expected to have fine-grained and coarse-grained sediments, respectively Following sampling, some stations were reclassified based on the grain size analysis [>20% fines (<100 um effective diameter) was considered a fine-grained sediment station]. Reclassified stations are identified by superscript "E" or "D".

[c] No effects screening levels for dioxins and furans were available

2.6.3.3 Tissue. The reconnaissance survey analyzed crayfish, carp, largescale sucker, peamouth, and white sturgeon for the presence of 11 trace metals and 108 organic compounds. This section briefly describes the results of these analyses

Trace Metals--All trace metals except antimony and selenium were detected in fish and crayfish collected from the lower Columbia River (Figure 2 6-12) Overall, carp had the highest tissue concentration of total metals, with decreasing concentrations present in crayfish, peamouth, largescale sucker, and white sturgeon. Lead, mercury, and zinc were the metals most commonly detected metals

Patterns of metals accumulation in tissue varied between species. For example, arsenic was only detected in white sturgeon filets while, with the exception of a single sturgeon sample, silver was only detected in crayfish With few exceptions, barium, cadmium, copper, nickel, and silver were not detected in sturgeon filets. This result may be explained by the fact that tissue analyses of sturgeon consisted of filets, while analysis of whole bodies was conducted for all other species. The absence of some metals in sturgeon may indicate a tendency for these metals to accumulate in internal organs and bone rather than in muscle tissue.

Metals were detected in biota throughout the lower Columbia River, with no clear trend along the river A few stations, however, tended to show higher tissue metal concentrations D40 at Beacon Rock, $D38^{E}$ near Reed Island, D28 along Sauvie Island, and D6 in Grays Bay. High levels at the two most upriver tissue stations (D40 and $D38^{E}$) are interesting in that there are no known anthropogenic sources of metals immediately upstream from these stations within the study area However, it is acknowledged that pollution sources located above Bonneville Dam contribute contaminants to the lower river

Tissue metals concentrations measured in the lower Columbia River were compared to those measured at over 100 stations nationwide from 1976 to 1984 as part of U S. Fish and Wildlife Service's (USFWS) National Contaminant Biomonitoring Program (NCBP) (Schmitt and Brumbaugh 1990) Geometric mean tissue concentrations for arsenic, copper, and cadmium exceeded USFWS 1984 geometric means by factors of 1 7, 3 5, and 1 3, respectively (Table 2 6-6) Means calculated for the other five metals detected in tissue were below values reported in the USFWS-NCBP study (see Table 2.6-6)

TISSUE–METALS

Fish Species
C = Carp
Cy = Crayfish
P = Peamouth
ST = Sturgeon
Su = Largescale sucker

	Astoria OR	Astoria OR		Deep River	Marsh Island	Deep River Mouth	Grays Bay	Woody Island Channel	Clifton Channel	Elochoman Slough	Wallace Island	Wallace Slough	Coal Creek Slough	Longview WA	Rainier OR	Goble, OR	Carrolls Channel	Port of Kalama, WA	Kalama WA	Burke Slough	Martin Bluff WA	St Helens OR	Bachelor Point, WA	Sauvie Island	Willamette River Mouth		N Portland Harbor	Government Island	Camas Slough	Reed Island		Multnomah Falls OR	Beacon Rock
CHEMICAL CLASS	RM 15 ST	RM 15 5 D3	RM 18 5 ST	RM 20 ST	RM 20 D8	RM 21 ST	RM 22 5 D6	RM 27 ST	RM 38 D10	RM 40 D12	RM 49 ST	RM 49 5 D15	RM 57 D16	RM 63 D19	RM 67 ST	RM 71 D21	RM 71 1 D20	RM 75 D22	RM 75 ST	RM 79 5 D23	RM 80 ST	RM 85 5 D24	RM 92 5 D26	RM 98 D28	RM 101 D29	RM 103 ST	RM 107 5 D31	RM 115 ST	RM 118 5 D35	RM 125 5 D38	RM 127 ST	RM 136 ST	RM 141 5 D40
METALS																																	
Species Analyzed	ST	P	ST	ST	Cy Su	ST	Cy Su	ST	Cy Su P	Cy Su P	ST	Cy Su P	Cy Su P	Cy Su P	ST	P	Cy Su	Cy Su	ST	Cy Su P	ST	Cy C Su P	Cy C Su P	Cy C Su P	Cy C Su P	ST	Cy C Su	ST	Cy C Su	Cy C Su	ST	ST	Cy C Su
Arsenic	●							●			●				●																●	●	
Barium		●			●		●		●	●		●	●	●		●	●	●		●		●	●	●	●		●		●	●			●
Cadmium		●			●		●		●	●		●	●	●		●	●	●	●	●		●	●	●	●		●	●	●	●			●
Copper		●		●	●		●		●	●		●	●	●		●	●	●		●		●	●	●	●		●		●	●		●	●
Lead	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
Mercury		●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
Nickel					●		●		●	●		●	●	●			●	●		●		●	●	●	●		●		●	●			●
Silver					●		●		●	●	●	●	●				●	●		●		●		●	●		●		●	●			●
Zinc	●	●		●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●

Figure 2 6-12 Metals detected in fish and crayfish tissue samples collected for the lower Columbia River Reconnaissance Survey

TABLE 2 6-6 COMPARISON OF RECONNAISSANCE SURVEY TISSUE CONTAMINANT LEVELS WITH THOSE MEASURED NATIONWIDE IN THE NATIONAL BIOACCUMULATION STUDY AND NATIONAL CONTAMINANT BIOMONITORING PROGRAM

Chemical	Lower Columbia River Reconnaissance Survey 1991		National Bioaccumulation Study	National Contaminant Biomonitoring Program
	Median	Geometric Mean	(Median) (EPA 1991h)[a]	(Geometric Mean) (Schmitt & Brumbaugh 1990)[a]
METALS [mg/kg wet weight (ppm)]				
Arsenic[c]	0 22	0 24	--	0 14
Barium	2 19	0 95	--	--
Cadmium	0 04	0 04	--	0 03
Copper	1 20	2 30	--	0 65
Lead	0 04	0 05	--	0 11
Mercury	0 07	0 06	0 17	0 10
Nickel	0 39	0 48	--	--
Selenium	ND	ND	--	0 42
Zinc	23 35	19 95	--	21 7
PESTICIDES [mg/kg wet weight (ppm)]				
4,4'-DDT	0 0030	0 0033	-	0 030
4,4'-DDE	0 0190	0 0154	0 058	0 190
4,4'-DDD	0 0375	0 0049	-	0 060
Heptachlor	0 0015	0 0019	ND	0 010
Dieldrin	0 0015	0 0023	0 0042	0 040
Endrin	0 0015	0 0022	ND	ND(<0 01)
Methoxychlor	0 0150	0 0206	ND	--
alpha-BHC	0 0015	0 0020	0 00072	ND(<0 01)
gamma-BHC (Lindane)	0 0015	0 0021	ND	ND(<0 01)
PCBs [mg/kg (ppm)]				
Aroclor 1254	0 0250	0 0445	--	0 210
Aroclor 1260	0 0250	0 0352	--	0 150
DIOXINS AND FURANS [ng/kg wet weight (ppt)]				
2,3,7,8-TCDD	0.76	0 84	1 38	--
1,2,3,7,8-PeCDD	0 48	0 43	0 93	--
1,2,3,4,7,8-HxCDD	0 20	0 19	1 24	--
1,2,3,6,7,8-HxCDD	0 39	0 37	1 32	--
1,2,3,7,8,9-HxCDD	0 18	0 19	0 69	--
1,2,3,4,6,7,8-HpCDD	1 10	1 22	2 83	--
OCDD	4 21	4 66	--	--
2,3,7,8-TCDF	6 41	8 39	2 97	--
1,2,3,7,8-PeCDF	0 24	0 28	0 45	--
2,3,4,7,8-PeCDF	0 48	0 48	0 75	--
1,2,3,4,7,8-HxCDF	0 21	0 21	1 42	--
1,2,3,7,8,9-HxCDF	0 17	0 18	1 38	--
1,2,3,6,7,8-HxCDF	0 18	0 18	1 42	--
2,3,4,6,7,8-HxCDF	0 49	0 68	0 98	--
1,2,3,4,6,7,8-HpCDF	0 29	0 30	--	--
1,2,3,4,7,8,9-HpCDF	0 12	0 13	1 30	--
OCDF	0 41	0 49	-	--

ND = Not detected above the laboratory detection limit
[a] Geometric mean of 1984 data

[b] Statistics were calculated using one-half the detection limit for samples where analyte was undetected

[c] Arsenic was detected only in sturgeon tissue although calculated statistics include all species

Semivolatile Organics--Tissue samples were analyzed for 52 semivolatile compounds Fifteen of these compounds were detected (Figure 2 6-13) This group of chemicals was unique in that, with the exception of bis-2-ethylhexylphthalate, virtually all of the measured concentrations occurred for a single sample Carp tissue collected from station D29, located in a flushing channel connecting Vancouver Lake with the Columbia River, downstream of the mouth of the Willamette River, was the only site where the following chemicals were detected phenol, 2-chlorophenol, 4-chloro-3-methylphenol, 4-nitrophenol, 2,4-dinitrotoluene, n-nitroso-di-n-propylamine, acenapthene, pyrene, 1,4-dichlorobenzene, and 1,2,4-tri-chlorobenzene

The compounds detected in carp from station D29 could potentially be derived from a variety of sources The phenolic compounds and 2,4-dinitrotoluene are all chemical intermediates used in the production of other chemicals in a variety of industries The polycyclic aromatic hydrocarbons (PAHs), acenaphthene and pyrene, are formed by the combustion of hydrocarbon products, and may be released into the environment as a result of oil spills The chemical 1,4-dichlorobenzene is used as an insecticide, and 1,2,4-dichlorobenzene is used in the production of dyes, transformer dielectric fluid, and as a solvent in chemical manufacturing

Station D35, located in Camas Slough, was the only other site where PAHs were measured in fish tissue One potential source of the PAHs detected in tissue is oil spills that have occurred within the slough From 1989 through 1991 Camas Slough received several small accidental oil spills (Tetra Tech 1992c)

Pesticides--Tissue samples were analyzed for 20 pesticides and pesticide derivatives Twenty four of these compounds were detected in at least one tissue sample Figure 2 6-14 show the compounds detected in tissue Chemicals listed above the shaded divider in this figure are pesticides (and their degradation products) that have been banned and are no longer in use, while chemicals listed below this divider are still in use (although their use may be restricted) This division indicates that the most commonly detected pesticides are those that are no longer in use For example, derivatives of DDT were present in biota from almost 99 percent of the samples analyzed

Pesticides that are still in use were detected throughout the lower Columbia River, but the frequency with which these chemicals were detected was low -- less than 8 percent of the samples analyzed. The pesticides within this group include chemicals used in agriculture, forestry, and household applications

TISSUE–SEMIVOLATILE COMPOUNDS

Fish Species:
C = Carp
Cy = Crayfish
P = Peamouth
ST = Sturgeon
Su = Largescale sucker

CHEMICAL CLASS	Astoria, OR RM 15 ST	Astoria, OR RM 15.5 D3	RM 18.5 ST	Deep River RM 20 ST	Marsh Island RM 20 D8	Deep River Mouth RM 21 ST	Grays Bay RM 22.6 D6	Woody Island Channel RM 27 ST	Clifton Channel RM 38 D10	Elochoman Slough RM 40 D12	Wallace Island RM 48 ST	Wallace Slough RM 49.5 D15	Coal Creek Slough RM 57 D16	Longview, WA RM 63 D19	Rainier, OR RM 67 ST	Goble, OR RM 71 D21	Carrolls Channel RM 71.1 D20	Port of Kalama, WA RM 75 D22	Kalama, WA RM 75 ST	Burke Slough RM 79.5 D23	Martin Bluff WA RM 80 ST	St Helens, OR RM 85.5 D24	Bachelor Point, WA RM 92.5 D26	Sauvie Island RM 98 D28	Willamette River Mouth RM 101 D29	RM 103 ST	N Portland Harbor RM 107.6 D31	Government Island RM 115 ST	Camas Slough RM 118.5 D35	Reed Island RM 125.5 D38	RM 127 ST	Multnomah Falls, OR RM 136 ST	Beacon Rock RM 141.5 D40
SEMIVOLATILE COMPOUNDS																																	
Species Analyzed	ST	P	ST	ST	Cy Su	ST	Cy Su	ST	Cy Su P	Cy Su P	ST	Cy Su P	Cy Su P	Cy Su P	ST	P	Cy Su	Cy Su	ST	Cy C Su P	ST	Cy C Su P	Cy C Su	Cy C Su P	Cy C Su	ST	Cy C Su	ST	Cy C Su	Cy C Su	ST	ST	Cy C Su
PHENOLIC COMPOUNDS																																	
Phenol																									O								
2-Chlorophenol																									O								
4-Chloro-3-methylphenol																									O								
4-Nitrophenol																									O								
NITROAROMATICS																																	
2,4-Dinitrotoluene																									O								
NITROSAMINES																																	
N-Nitroso-di-n-propylamine																									O								
POLYNUCLEAR AROMATIC HYDROCARBONS																																	
Acenaphthene																									O								
Naphthalene																													O				
2-Methylnaphthalene																									O				O				
Pyrene																									O								
CHLORINATED BENZENES																																	
1,4-Dichlorobenzene																									O								
1,2,4-Trichlorobenzene																									O								
PHTHALATE ESTERS																																	
Di-n-butylphthalate			O								O								O	O				O						O	O		
Bis-2-(ethylhexyl)phthalate		O	O		O				O	O		O	O	O		O	O	O		O		O	O	O	O	O	O	O	O	O		O	O
Butylbenzylphthalate																			O														

Figure 2 6-13 Semivolatile compounds detected in tissue samples in the lower Columbia River Reconnaissance Survey

TISSUE–PESTICIDES

Fish Species
C = Carp
Cy = Crayfish
P = Peamouth
ST = Sturgeon
Su = Largescale sucker

CHEMICAL CLASS	Astoria, OR RM 15 ST	Astoria, OR RM 15.5 D3	RM 18.5 ST	Deep River RM 20 ST	Marsh Island RM 20 D8	Deep River Mouth RM 21 ST	Grays Bay RM 22.5 D6	Woody Island Channel RM 27 ST	Clifton Channel RM 38 D10	Elochoman Slough RM 40 D12	Wallace Island RM 49 ST
PESTICIDES											
Species Analyzed	ST	P	ST	ST	Cy Su	ST	Cy Su	ST	Cy Su P	Cy Su P	ST
o,p'-DDE		●									
o,p'-DDD		●									
o,p'-DDT											
p,p'-DDE	●	●	●	●	●	●	●	●	●	●	●
p,p'-DDD					●			●	●		
p,p'-DDT							●	●	●		●
Heptachlor											
Aldrin									●	●	
Dieldrin								●			
Endrin											
Endrin aldehyde										●	
Mirex											
Isophorone					●						
Dacthal											
Methyl parathion							●	●			
Parathion		●			●						
Malathion									●		
Endosulfan I		●						●	●		
Endosulfan II											
Endosulfan sulfate											
Methoxychlor								●			
alpha-BHC											
beta-BHC										●	
gamma-BHC											

CHEMICAL CLASS	Wallace Slough RM 49.5 D15	Coal Creek Slough RM 57 D16	Longview WA RM 63 D19	Rainier OR RM 67 ST	Goble OR RM 71 D21	Carrolls Channel RM 71.1 D20	Port of Kalama, WA RM 75 D22	Kalama WA RM 75 ST	Burke Slough RM 79.5 D23	Martin Bluff WA RM 80 ST	St Helens OR RM 85.5 D24
PESTICIDES											
Species Analyzed	Cy Su P	Cy Su P	Cy Su P	ST	P	Cy Su	Cy Su	ST	Cy C Su P	ST	Cy C Su P
o,p'-DDE	●	●	●				●	●	●		●
o,p'-DDD	●						●	●	●		
o,p'-DDT								●	●		
p,p'-DDE	●	●	●		●	●	●	●	●	●	●
p,p'-DDD	●	●	●			●	●		●		●
p,p'-DDT	●	●				●	●	●	●		●
Heptachlor											
Aldrin	●	●			●						
Dieldrin					●			●	●		
Endrin					●			●	●		
Endrin aldehyde								●			
Mirex											
Isophorone							●				●
Dacthal		●									
Methyl parathion		●									●
Parathion		●				●					
Malathion											●
Endosulfan I					●				●		
Endosulfan II											
Endosulfan sulfate		●						●			
Methoxychlor	●							●			●
alpha-BHC									●		
beta-BHC		●			●						
gamma-BHC	●	●	●								●

CHEMICAL CLASS	Bachelor Point, WA RM 92.5 D26	Sauvie Island RM 98 D28	Willamette River Mouth RM 101 D29	RM 103 ST	N Portland Harbor RM 107.5 D31	Government Island RM 115 ST	Camas Slough RM 118.5 D35	Reed Island RM 125.5 D38	RM 127 ST	Multnomah Falls, OR RM 136 ST	Beacon Rock RM 141.5 D40
PESTICIDES											
Species Analyzed	Cy C Su	Cy C Su P	Cy C Su P	ST	Cy C Su	ST	Cy C Su	Cy C Su	ST	ST	Cy C Su
o,p'-DDE	●	●	●		●						
o,p'-DDD			●		●		●			●	
o,p'-DDT		●									
p,p'-DDE	●	●	●	●	●	●	●	●	●	●	●
p,p'-DDD	●	●	●	●	●	●	●	●			●
p,p'-DDT	●	●	●	●	●	●	●	●	●	●	●
Heptachlor								●			
Aldrin			●								●
Dieldrin	●			●	●			●			
Endrin			●					●			
Endrin aldehyde											
Mirex	●										
Isophorone	●	●			●						
Dacthal											
Methyl parathion				●		●					
Parathion											
Malathion											
Endosulfan I											
Endosulfan II			●								
Endosulfan sulfate							●				
Methoxychlor										●	
alpha-BHC	●										
beta-BHC			●					●			
gamma-BHC	●										

Figure 2 6-14 Pesticides detected in fish and crayfish tissue samples collected for the lower Columbia River Reconnaissance Survey

The state of New York is currently using fish flesh reference values, originally proposed by Newell et al. (1987) as unofficial guidelines for the protection of piscivorous wildlife. Reference levels have been proposed by the state of New York for eight of the pesticides detected in fish tissue in the lower Columbia River (aldrin, dieldrin, mirex, heptachlor, DDT, DDE, DDD, and BHC). Exceedances of these reference levels were noted at four stations. Tissue concentrations of beta-BHC (hexachlorocyclohexane) in peamouth collected from station D21 near Goble, OR, exceeded the New York State (NYS) reference level of 100 μg/kg. DDE concentrations in peamouth collected from stations D3 near Astoria, D23 in Burke Slough, and D24 near St. Helens, exceeded the NYS reference level of 200 μg/kg.

PCBs--Tissue samples were analyzed for eight PCBs. Three of these PCBs were detected in tissue samples (Figure 2.6-15) Patterns of tissue contamination of PCBs differed among the five species analyzed. PCBs were not detected in any crayfish samples. Peamouth was the only species that had detectable levels of Aroclor 1242, and also had detectable levels of Aroclor 1260. The PCBs Aroclor 1254 and Aroclor 1260 were both detected in largescale sucker, although fish from a given location had only one or the other of these two PCBs. The only PCB detected in white sturgeon was Aroclor 1254.

PCB levels measured in fish can be compared with concentrations reported in biota sampled during the NCBP. The geometric mean concentrations of Aroclor 1260 in carp and peamouth collected during the reconnaissance survey were 41.5 and 162.7 μg/kg, respectively. The value for carp was approximately four times lower than the geometric mean for this PCB reported in the NCBP study (150 μg/kg), while the value for peamouth exceeds the NCBP geometric mean (see Table 2.6-6).

As indicated in Figure 2.6-15, PCBs were widely distributed throughout the lower Columbia River. Although information is limited, it appears that measured concentrations may be high enough to adversely affect piscivorous wildlife. The NYS reference value for the protection of piscivorous wildlife is 110 μg/kg. Eighty percent of peamouth, 67 percent of carp, and 61 percent of largescale sucker had tissue PCB concentrations that exceed NYS proposed guidelines. The maximum tissue concentration of PCB (520 μg/kg) was measured in peamouth collected near St. Helens, OR. This concentration approaches the dietary concentration of 640 μg/kg reported by Henny et al. (1981) to cause reproductive failure in mink.

TISSUE–PCBs, DIOXINS, AND FURANS

Fish Species
C = Carp
Cy = Crayfish
P = Peamouth
ST = Sturgeon
Su = Largescale sucker

CHEMICAL CLASS	Astoria, OR RM 15 ST	Astoria, OR RM 15.5 D3	RM 18.5 ST	Deep River RM 20 ST	Marsh Island RM 20 D8	Deep River Mouth RM 21 ST	Grays Bay RM 22.5 D6	Woody Island Channel RM 27 ST	Clifton Channel RM 38 D10	Elochoman Slough RM 40 D12	Wallace Island RM 49 ST	Wallace Slough RM 49.5 D15	Coal Creek Slough RM 57 D16	Longview, WA RM 63 D19	Rainier, OR RM 67 ST	Goble, OR RM 71 D21	Carrolls Channel RM 71.1 D20
PCBs, DIOXINS, AND FURANS																	
PCBs																	
Species Analyzed	ST	P	ST	ST	Cy Su	ST	Cy Su	ST	Cy Su P	Cy Su P	ST	Cy Su P	Cy Su P	Cy Su P	ST	P	Cy Su
Aroclor 1242		●															
Aroclor 1254					●		●		●	●		●	●	●			●
Aroclor 1260		●							●	●		●	●	●		●	
DIOXINS AND FURANS																	
Species Analyzed			ST		Cy Su		Cy Su	ST	Cy Su P		ST	Cy Su P		Cy Su P	ST	P	Cy Su
2,3,7,8-TCDD					●		●		●			●		●		●	●
1,2,3,7,8-PeCDD					●		●		●			●		●		●	●
1,2,3,4,7,8-HxCDD					●		●		●			●		●		●	●
1,2,3,6,7,8-HxCDD					●		●		●			●		●		●	●
1,2,3,7,8,9-HxCDD					●		●		●			●		●		●	●
1,2,3,4,6,7,8-HpCDD					●		●	●	●			●		●		●	●
OCDD					●		●	●	●		●	●		●	●	●	●
2,3,7,8-TCDF			●		●		●	●	●		●	●		●	●	●	●
1,2,3,7,8-PeCDF					●		●		●			●		●		●	●
2,3,4,7,8-PeCDF					●		●		●			●		●		●	●
1,2,3,4,7,8-HxCDF					●		●		●			●		●		●	
1,2,3,6,7,8-HxCDF					●		●		●			●		●		●	
2,3,4,6,7,8-HxCDF					●		●		●			●		●		●	●
1,2,3,7,8,9-HxCDF					●		●		●			●		●			●
1,2,3,4,6,7,8-HpCDF					●		●		●			●		●		●	●
1,2,3,4,7,8,9-HpCDF					●		●		●			●		●		●	●
OCDF									●			●		●		●	●

CHEMICAL CLASS	Port of Kalama, WA RM 75 D22	Kalama, WA RM 75 ST	Burke Slough RM 79.5 D23	Martin Bluff, WA RM 80 ST	St Helens, OR RM 85.5 D24	Bachelor Point, WA RM 92.5 D26	Sauvie Island RM 98 D28	Willamette River Mouth RM 101 D29	RM 103 ST	N Portland Harbor RM 107.5 D31	Government Island RM 115 ST	Camas Slough RM 118.5 D35	Reed Island RM 125.5 D38	RM 127 ST	Multnomah Falls, OR RM 136 ST	Beacon Rock RM 141.5 D40
PCBs, DIOXINS, AND FURANS																
PCBs																
Species Analyzed	Cy Su	ST	C Cy Su P	ST	Cy C Su P	Cy C Su	Cy C Su P	Cy C Su P	ST	Cy C Su	ST	Cy C Su	Cy C Su	ST	ST	Cy C Su
Aroclor 1242							●									
Aroclor 1254	●	●	●	●	●	●	●	●		●		●	●			
Aroclor 1260			●		●	●										●
DIOXINS AND FURANS																
Species Analyzed		ST	Cy Su P		Cy C Su P		Cy C Su P				ST	Cy C Su	Cy C Su	ST		Cy C Su
2,3,7,8-TCDD		●	●		●		●					●	●			●
1,2,3,7,8-PeCDD			●		●		●					●	●			●
1,2,3,4,7,8-HxCDD			●		●		●					●	●			●
1,2,3,6,7,8-HxCDD			●		●		●					●	●			●
1,2,3,7,8,9-HxCDD			●		●		●					●	●			●
1,2,3,4,6,7,8-HpCDD			●		●		●				●	●	●			●
OCDD		●	●		●		●				●	●	●	●		●
2,3,7,8-TCDF		●	●		●		●				●	●	●	●		●
1,2,3,7,8-PeCDF		●	●		●		●					●	●			●
2,3,4,7,8-PeCDF		●	●		●		●					●	●			●
1,2,3,4,7,8-HxCDF					●		●					●	●			●
1,2,3,6,7,8-HxCDF					●		●					●	●			●
2,3,4,6,7,8-HxCDF			●		●		●					●	●			●
1,2,3,7,8,9-HxCDF			●		●		●					●	●			●
1,2,3,4,6,7,8-HpCDF			●		●		●					●	●			●
1,2,3,4,7,8,9-HpCDF			●		●		●					●	●			●
OCDF			●		●		●					●	●			●

Figure 2 6-15 Polychlorinated biphenyl compounds (PCBs) and dioxin and furan compounds detected in fish and crayfish samples collected for the lower Columbia River Reconnaissance Survey

Shaded areas indicate stations that were not sampled for dioxins or furans

Dioxins and Furans--Tissue samples were analyzed for seventeen dioxin and furan congeners. These congeners were widely distributed throughout the lower Columbia River, with levels being detected in fish collected at station D40 below Bonneville Dam to station D3 near Astoria (Figure 2.6-15). Peamouth had the highest tissue concentration of dioxins and furans, with a median toxicity equivalent concentration (TEC) of 2,3,7,8-TCDD equal to 7.93 pg/g. Median TECs for other species were 4.87, 3.02, 2.63, and 1 38 pg/g for carp, white sturgeon, largescale sucker, and crayfish, respectively The differences between species could be explained by considering species differences in the percentage of body lipid. When TECs were normalized for lipid content there were no significant differences between species. This result indicates that the highest doses of dioxins and furans to either wildlife or humans will result from the consumption of lipid-rich species.

The tissue concentration of 2,3,7,8-TCDD, the most toxic congener of this group of chemicals, can be compared to the median concentration measured in U S. EPA's National Bioaccumulation Study (NBS), which measured tissue concentrations at 388 sites nationwide (U.S. EPA 1991a) (see Table 2.6-6). The median fish tissue concentration of 2,3,7,8-TCDD in the U S EPA study was 1.38 pg/g. This value is identical to the median value measured in crayfish in the lower Columbia River. Median concentrations for peamouth, carp, white sturgeon, and largescale sucker all exceeded this value by factors ranging from two to six. It should be noted that this comparison may be somewhat misleading in that the U S. EPA median value was calculated using data from several species of fish, with whole bodies being analyzed for bottom feeding species and filets being analyzed for game species. Furthermore, the sites sampled in the U S. EPA study were skewed towards those suspected of being problem areas.

As was observed for PCBs, dioxins and furans were widely distributed throughout the lower Columbia River. Comparisons with NYS reference levels for the protection of piscivorous wildlife suggest that levels of dioxins and furans have the potential to adversely affect wildlife that feed upon aquatic biota in the river. TEC concentrations measured in crayfish, carp, peamouth, or largescale sucker exceeded NYS reference levels for the protection of piscivorous wildlife (3 pg/g) at 10 of the 20 stations sampled in the lower Columbia River (stations D10, D19, D21, D23, D24, D28, D29, D35, D38^{E}, and D40).

2.6.3.4 Benthos. Samples were collected from a total of 54 stations in the lower Columbia River. A total of 63,021 benthic infaunal organisms belonging to 114 taxa were identified from the 54 samples analyzed. Total abundances and richness varied widely throughout the river. Total abundance ranged from 1 to 7,693 individuals per 0.06 m^2 in a sample and richness ranged from 1 to 25 taxa per sample. Benthic community variability may be attributed to the effects of sediment grain size, sediment organic carbon content, salinity, and habitat stability Accordingly, results are summarized for both the entire river and by habitat type.

Habitats were classified as either estuarine or freshwater on the basis of near-bottom salinity measured during the water quality survey and presence of euryhaline (salinity-tolerant) benthic taxa. The habitats up through RM 26 were characterized as estuarine, and included 11 sampling stations The habitats upstream of RM 26 were characterized as freshwater, and included 43 sampling stations.

Habitat Classification--The grain size distribution at each station was examined because of its known effect on benthic community structure In the lower Columbia River, sediments tend to be coarse and distributed among various sand size fractions. However, material finer than 100 μm in size is often transported as suspended material in the water column (Conomos and Gross 1972, Glenn 1973, Sherwood et al. 1984). Presence of these finer sediments in amounts greater than 20 percent of the sample weight were thought to be indicative of more stable, depositional areas within the river. A total of 41 fine-grained and 13 coarse-grained stations were sampled. Benthic sampling stations that were reclassified as coarse-grained or fine-grained based on the sediment size classification data (see Section 2.6.3.2) are identified below using a superscript "E" or "D" (e.g., $E2^D$). Although the organic carbon content of the sediments also affects benthic community composition, the TOC content of the sediments was relatively low (i.e., all but one station was less than 1 6 percent TOC) and was not used to further classify habitat types.

Benthic Community Characteristics--Abundance and richness data for each sample collected are summarized in Table 2.6-7 Abundance, expressed as the number of individuals per 0.06 m^2, ranged from 9 individuals ($D38^E$) to 7,693 individuals ($D5^E$) in the lower river. The number of taxa per 0.06 m^2 ranged from 1 (E12) to 25 (stations D11, D12, and D18) Abundances and taxa richness at each station are plotted in Figure 2.6-16. Overall, organisms at freshwater stations appeared to be less abundant and with lower diversity (fewer taxa) compared to the estuary stations. Throughout the estuary, over 60 percent of the stations had less than 2,000 individuals and fewer than 16 taxa. Stations D1, $D5^E$, D7, and D8 in the estuary had the greatest abundances of benthic organisms, and stations D1 and D4 had the highest number of taxa. In the freshwater habitats, over 50 percent of the stations had less than 500

TABLE 2.6-7. RICHNESS, ABUNDANCE, AND SEDIMENT CONVENTIONAL CHARACTERISTICS AT EACH OF THE 54 BENTHOS SAMPLING STATIONS IN THE LOWER COLUMBIA RIVER
(Page 1 of 2)

Station[a,b]	River Mile	Taxa Richness (#taxa/0.06 m^2)	Total Abundance (#individuals/0.06 m^2)	Sediment Texture (% < 100um)	Total Organic Carbon (%)
D2	2	15	944	98	1.63
D4	6	20	1,997	82	1.13
D1	8	22	3,113	76	1.36
E1	8	10	60	4	0.13
D3	13	10	911	68	0.60
E2[b]	16	13	174	24	0.10
D5[a]	21	12	7,693	19	0.37
D6	21	14	1,921	26	0.46
D7	22	10	4,723	32	0.35
E3	22	8	80	14	0.21
D8	27	16	3,411	50	0.26
D11	29	25	5,960	70	0.80
E4	30	5	338	2	0.05
D9	34	8	352	25	0.51
D10	38	18	1,790	54	0.79
D12	40	25	2,014	94	0.77
D14	42	12	1,473	77	0.26
D13	43	13	516	89	0.37
E5	46	3	40	2	0.02
D15	50	14	434	43	0.68
D16	58	7	316	98	0.73
E6[b]	58	10	295	23	0.31
D17	59	20	903	73	0.44
D18	62	25	931	32	0.69
D19	63	9	578	57	0.18
E7	67	5	53	3	0.02
D21	70	9	445	61	0.87
D20	71	20	4,027	84	0.85
D22	76	16	919	76	1.54
E8	77	13	1,002	8	0.17

TABLE 2.6-7 RICHNESS, ABUNDANCE, AND SEDIMENT CONVENTIONAL CHARACTERISTICS AT EACH OF THE 54 BENTHOS SAMPLING STATIONS IN THE LOWER COLUMBIA RIVER (Page 2 of 2)

Station[a,b]	River Mile	Taxa Richness (#taxa/0.06 m^2)	Total Abundance (#individuals/0.06 m^2)	Sediment Texture (% < 100um)	Total Organic Carbon (%)
D23	80	16	3,176	84	0.68
E9[D]	83	13	890	55	0.68
D24	85	16	1,802	71	0.75
D25	88	17	919	80	0.51
D26	92	6	97	23	0.19
D27	94	11	421	21	0.41
D28	99	17	912	34	0.66
E10[D]	100	13	160	26	0 38
D29	101	10	289	21	0 41
D30	103	13	1,053	69	0.58
E11[D]	104	12	742	41	0.64
D31	106	16	538	41	0.43
D32[E]	108	9	210	18	0.24
D33	109	10	836	38	0 48
D34[E]	112	10	90	17	0.21
E12	114	1	37	<1	0.04
D35	118	24	2,444	44	4 06
D36	118	18	248	28	0.73
D37	121	11	303	50	0.47
D38[E]	124	3	9	16	0.07
E13	126	6	204	3	0.04
D39	128	7	38	30	0.06
E14	137	13	174	1	0.08
D40	142	6	16	36	0.45

[a] Stations with a superscript "E" or "D" were reclassified as coarse-grained or fine-grained sediment stations, respectively (see Section 3.6 1.2).

[b] Shaded areas indicate coarse-grained stations.

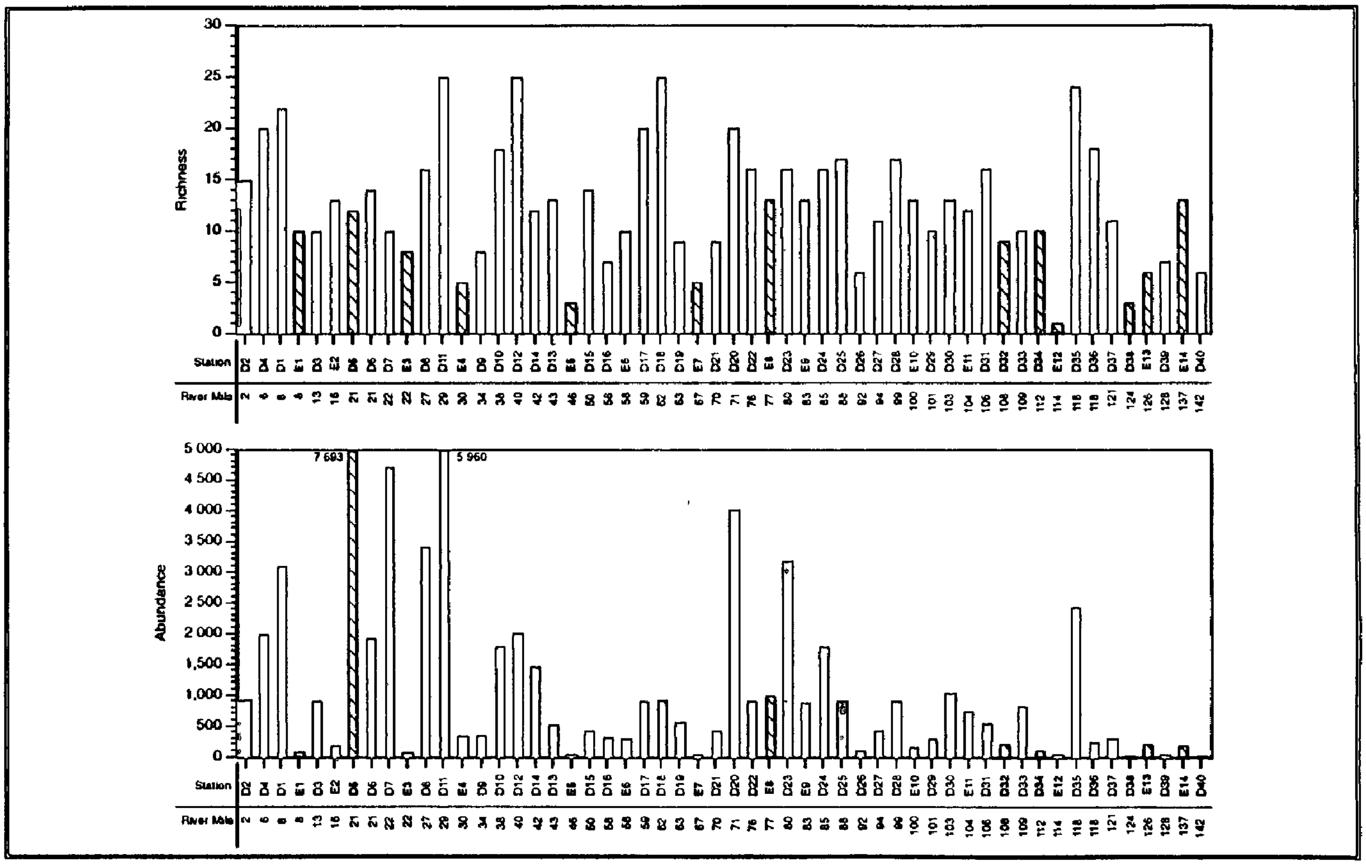


Figure 2 6-16. Richness and abundance per 0 06m² at each of the 54 sampling stations in the lower Columbia River. Hatched bars indicate coarse-grained habitats individuals and fewer than 13 taxa. Stations D11, D12, D20, D23, and D35 had the highest abundances, and stations D11, D12, D18, and D35 had the highest numbers of taxa.

Average abundance and taxa richness values were also calculated for the estuarine and freshwater stations that were grouped according to fine-grained and coarse-grained sediment characteristics (Table 2 6-8). Few differences were apparent in the estuary, when comparing richness and abundance by sediment type. In the estuary, mean abundance and richness per 0 06 m^2 ranged from 2,611 individuals and 10 taxa at the coarse-grained stations to 2,149 individuals and 15 taxa at the fine-grained stations. Greater differences appeared to occur between sediment types in the freshwater portions of the river Mean abundances and richness (per 0 06 m^2) in the freshwater habitats of the river ranged from 216 individuals and 7 taxa at the coarse-grained stations to 1,086 individuals and 14 taxa at the fine-grained stations

Major Taxa Abundance--Major taxa (i e., annelids, arthropods, and molluscs) contributions to total abundance at each station are presented in Figures 2.6-17 through 2.6-20. Annelids (i.e., oligochaetes and polychaetes) occurred at 50 of the 54 stations and were the most abundant taxonomic group at 25 stations. Arthropods (i.e., arachnids, crustaceans, and insects) were present at 53 stations and were the most abundant taxonomic group at 15 stations. Molluscs (i.e., bivalves and gastropods) occurred at 51 stations and were the most abundant taxonomic group at 9 stations Few miscellaneous taxa were observed in the estuary, and these consisted primarily of nematodes. Nematodes were widely distributed in the river and were the most abundant taxa at 5 stations.

Major taxa abundance was examined further by grouping stations according to salinity regime (estuarine or freshwater). Within the estuary, polychaetes dominated the higher salinity areas downstream of RM 13. Bivalve molluscs and crustaceans were also abundant at some stations in the higher salinity areas of the estuary while insects, nematodes, and gastropod molluscs were absent. As salinity decreased, crustaceans became the most abundant taxa at the estuarine stations and bivalve and polychaete abundances dropped. Nematode abundances appeared to increase with decreasing salinity. Oligochaetes were present, if not abundant, at most estuarine stations.

Abundant major taxa in the freshwater areas of the river included oligochaetes, crustaceans, and bivalves Oligochaetes were the most abundant taxa at 20 of the 43 freshwater stations. Oligochaetes are often indicative of organically-enriched sediments. However, these taxa are a highly adaptive, diverse group

TABLE 2.6-8. MEAN RICHNESS AND ABUNDANCE OF BENTHIC INFAUNAL ORGANISMS FOR ESTUARINE AND FRESHWATER FINE-GRAINED AND COARSE-GRAINED HABITATS IN THE LOWER COLUMBIA RIVER RECONNAISSANCE SURVEY				
	RICHNESS (#taxa/0.06 m^2)		ABUNDANCE (#individuals/0.06 m^2)	
	Mean	S D.	Mean	S.D.
Estuarine Stations				
Fine-Grained	15	4	2,149	1,517
Coarse-Grained	10	2	2,611	4,401
Freshwater Stations				
Fine-Grained	14	6	1,086	1,262
Coarse-Grained	7	4	216	295

S.D. = one standard deviation.

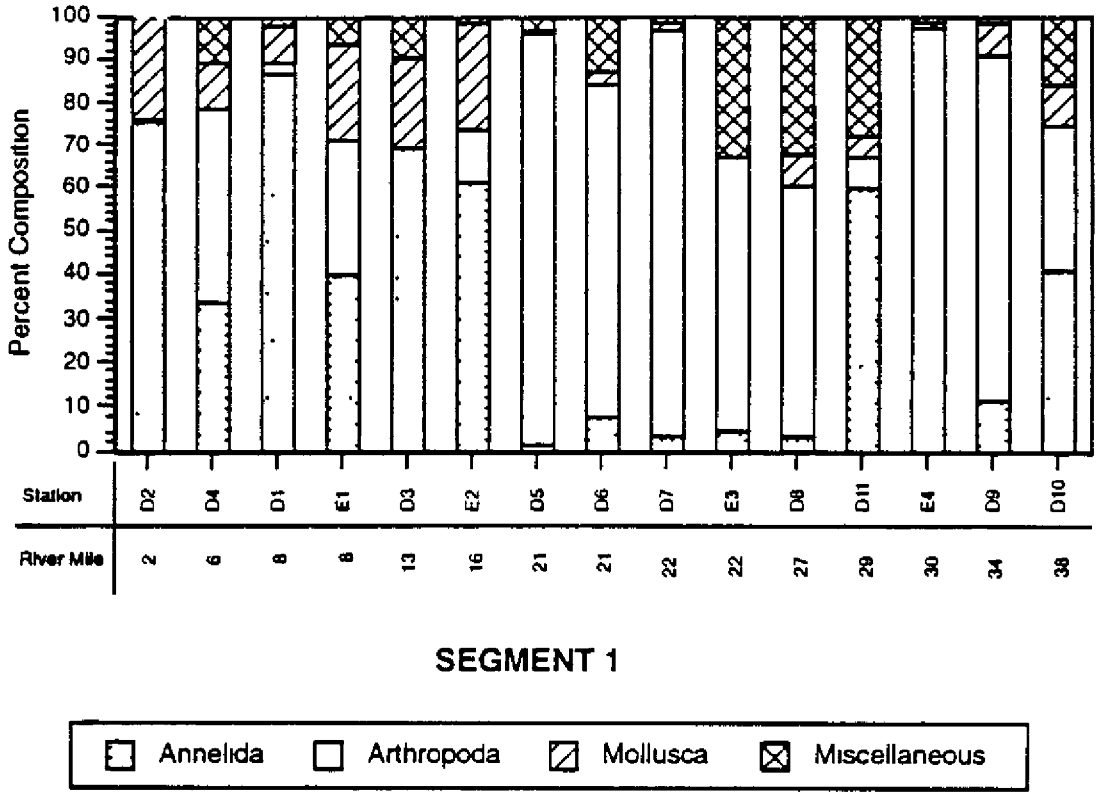


Figure 2.6-17 Percent composition of major taxa groups at 15 stations in Segment 1 of the lower Columbia River. Bolded stations were coarse-grained habitats.

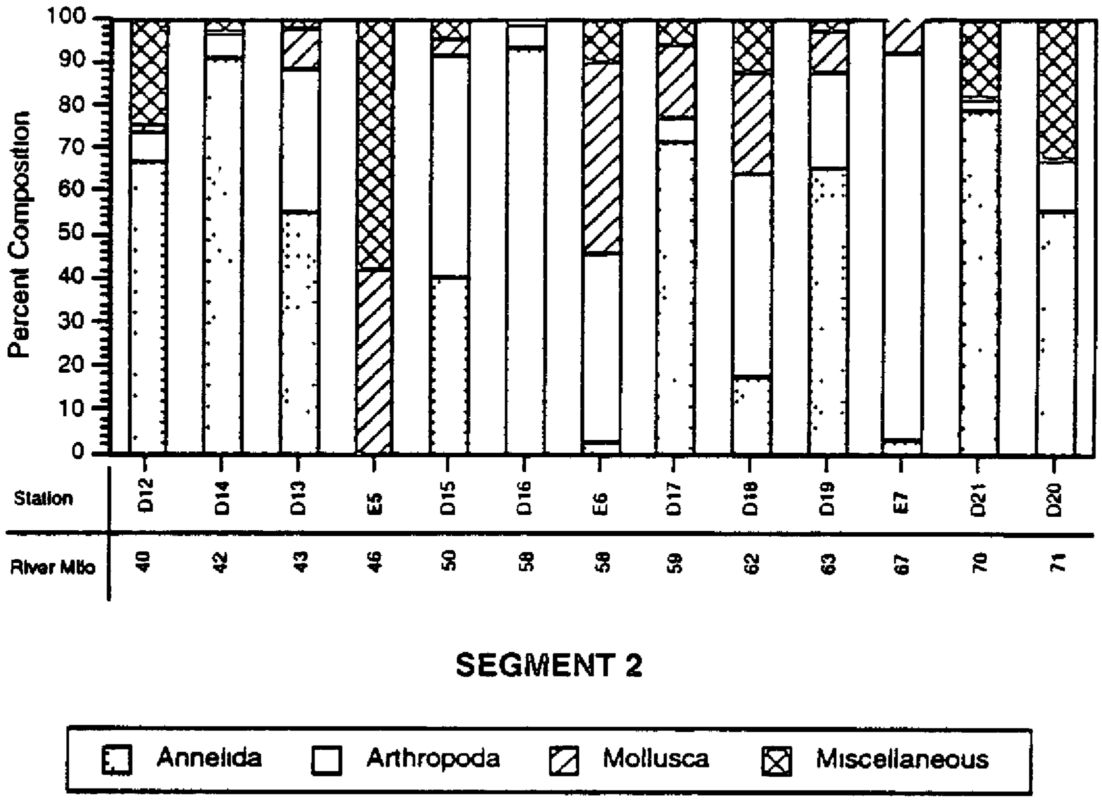


Figure 2.6-18. Percent composition of major taxa groups at 13 stations in Segment 2 of the lower Columbia River. Bolded stations were coarse-grained habitats.

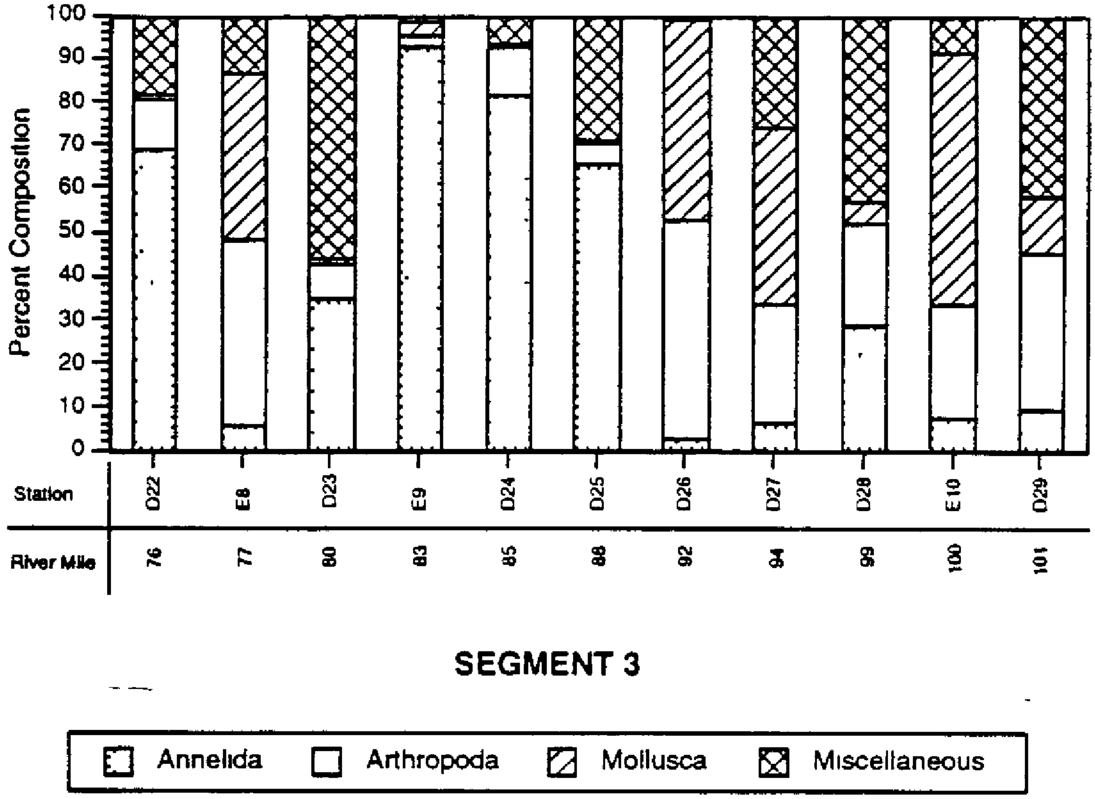


Figure 2.6-19. Percent composition of major taxa groups at 11 stations in Segment 3 of the lower Columbia River. Bolded stations were coarse-grained habitats.

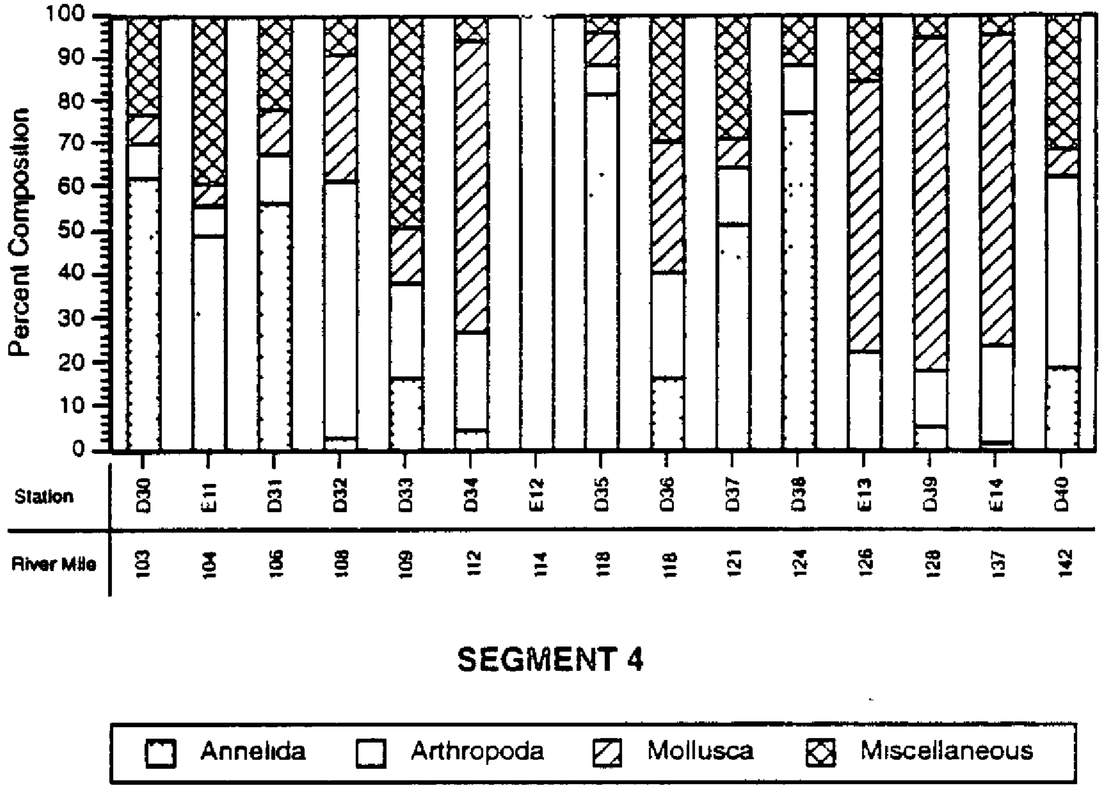


Figure 2.6-20. Percent composition of major taxa groups at 15 stations in Segment 4 of the lower Columbia River. Bolded stations were coarse-grained habitats.

and can be found in sediments ranging from sands to muds (Thorp and Covich 1991). Crustaceans and bivalve molluscs were the next most abundant groups, each dominating the total abundance at 9 freshwater stations. Crustaceans in the freshwater areas of the river were primarily represented by one species, *Corophium salmonis*. The bivalve, *Corbicula fluminea*, represented the majority of molluscs in the freshwater habitats. Both these taxa are highly adapted to life in more dynamic environments. Nematodes were present, if not abundant, at many of the freshwater stations and were numerically dominant at 5 stations. Nematodes are an ecologically diverse group, and have adapted to a wide variety of habitats in estuarine and freshwater environments. Insects were also relatively abundant in the freshwater portions of the river and were primarily represented by chironomids (freshwater midges). Chironomids are generally considered to be pollutant-tolerant (Burton 1990) and were found at 41 stations in the river. At station E12, these taxa represented 100 percent of the taxa present at the station. Polychaetes and gastropods were absent at most stations in the freshwater reaches of the river.

Station Comparisons--Because of the influence of habitat characteristics on community structure, differences or similarities in community indices were explored among habitat types. Comparisons of the sample means pooled by habitat type were made using *t*-tests to evaluate the effect of habitat on benthic community attributes. Results using abundance and richness data indicated that there were significant differences ($p \leq 0.05$) among fine-grained and coarse-grained habitats in mean richness, mean total abundance, mean annelid abundance, and mean miscellaneous taxa abundance. Results of all other comparisons were not statistically significant.

Pooling stations from throughout the river, fine-grained stations had significantly ($P \leq 0.05$) greater numbers of taxa compared to coarse-grained stations Significant differences in mean abundances pooled by sediment type occurred only within the freshwater portions of the river. Annelid and miscellaneous taxa abundance was also significantly higher at fine-grained stations compared to coarse-grained stations in the freshwater reaches of the river. No significant differences were identified in the estuary for any comparison of community indices by habitat type No significant differences were found in arthropod or molluscan abundance between fine-grained and coarse-grained stations throughout the river

Community Composition--Among the 114 taxa identified in the 54 samples collected in the lower Columbia River, only 40 occurred with any frequency. Of those, 7 taxa were common and abundant including oligochaetes, nematodes, *Corophium salmonis*, *Corbicula fluminea*, *Hobsonia florida*, *Macoma* *balthica*, and chironomids. Community composition was different among habitat types. While nematodes and oligochaetes were found at most stations, other taxa were more representative of the salinity regime or substrate characteristics that occurred at a given station. Stations within the estuary appeared to be divided into two distinct communities The estuarine stations that occurred closest to the mouth of the river (stations D1, D2, D3, and D4) were characterized by high salinities, fine-grained sediments and the presence of marine taxa including the polychaete *Hobsonia florida* and the bivalve *Macoma balthica*, as well as oligochaetes and nematodes. These stations had relatively low mean total abundance (1,700 individuals per 0.06 m^2). Stations with lower salinities and coarser substrates (stations $D5^E$, D6, D7, and D8) were characterized by the presence of euryhaline taxa including the crustacean *Corophium salmonis*, nematodes, and oligochaetes. The mean total abundance for these less saline stations in the estuary was greater than 4,400 individuals per 0 06 m^2. Several polychaetes (*Spio* spp and *Eteone spilotus*) and crustaceans (*Hemileucon spp.* and *Eohaustorius estuarius*) were characteristic of the estuarine stations but were dominant only at the more marine, coarse-grained stations (stations E1, $E2^D$, and E3).

For the freshwater reaches of the river, community composition was relatively similar among all stations with oligochaetes, nematodes, chironomids, *Corbicula fluminea* and *Corophium salmonis* representing the dominant taxa at most stations. Stations with coarser substrates tended to have fewer individuals and taxa. For the finer-grained freshwater stations with similar community composition, the mean total abundance was high (nearly 2,000 individuals per 0 06 m^2) compared to coarser-grained stations (300 individuals per 0.06 m^2).

Relationship Among Biotic and Abiotic Variables--Correlations of benthic community variables (i.e., total abundance, richness, and major taxa abundance), habitat characteristics (i.e., sediment fines and TOC), and chemical concentrations were examined. Throughout the river, richness, abundance, and annelid abundance were significantly ($P \leq 0.05$) correlated with sediment fines and TOC. In addition, miscellaneous taxa (primarily nematodes) abundance was correlated with sediment fines. However, the coefficient of determination, r^2, indicated that 19 to 33 percent of the variation in the benthic community variables was explained by TOC concentrations. While the correlation is still considered significant, it is possible that a relationship other than one of linearity may exist between these variables or that another variable explains more of the variation. Significant correlations for which the physical variables explained most of the variations (i.e., $r^2 > 0.65$) in the benthic data occurred only in the case of sediment fines and annelid abundances.

Relationships between benthic community variables and habitat attributes were examined further by grouping stations according to salinity For the estuarine stations, annelid abundance was significantly ($P \leq 0.05$) correlated with sediment fines and had a strong linear association. Richness, abundance, and annelid abundance were significantly ($P \leq 0.05$) correlated with sediment fines and TOC in the freshwater reaches of the river. In addition, miscellaneous taxa abundance was correlated with sediment fines However, 22 to 31 percent of the variation in benthic community variables was explained by TOC concentrations in the sediments. Sediment fines was the only physical variable which explained greater than 65 percent of the variation in a biological variable (i.e., annelid abundance).

Benthic community indices were analyzed in relation to individual chemical concentrations. Abundances of the several widely distributed, numerically dominant taxa (i e , *Corophium salmonis* and *Corbicula fluminea*) were also examined in light of chemical concentrations. No significant correlations that would indicate that benthic abundances and richness decreased with increasing sediment chemical concentrations were found. These results do not preclude an affect from the presence of contaminants but may indicate that on the scale examined (i e , 146 miles of river), other factors have greater influence on community structure.

Delineation of Ecological Zones--Salinity was the dominant factor in establishing ecological zones in the lower Columbia River. Two main zones were identified: the estuarine zone (> 1 ppt) and the riverine zone (< 1 ppt). Within the estuary, there was some evidence that an additional ecological zone may exist. Taxa present in the lower salinity areas (1 to 15 ppt salinity) are often distinct from the taxa found in areas with more marine conditions (> 15 ppt salinity), reflecting the different tolerances to salinity fluctuations. No further division of the estuary zone could be made because too few stations were sampled in some of the habitats delineated by grain size. While grain size appeared to affect benthic community abundances in the freshwater reaches of the river, community composition between sediment types was very similar. Therefore, no further zones were identified in the freshwater zone of the river.

Comparison with Columbia River Reference Area Data--To identify reference areas in the lower Columbia River, stations were first grouped according to salinity type (estuarine or freshwater).

Next, because the results of the t-tests indicated significant differences in richness and abundance between the freshwater fine-grained and coarse-grained stations, separate reference stations were selected for the fine-grained and coarse-grained freshwater habitats. Even though significant differences in richness occurred between the estuarine fine-grained and coarse-grained stations, no separate reference stations could be identified for each habitat type because there were only 3 coarse-grained stations, which could not be further separated. Finally, the richness and abundance data from each group of stations were ranked. Stations representing the upper 80th percentile value for richness and abundance were initially considered as candidate reference stations (i.e , highest richness and abundance values). Levels of contaminants at the candidate stations were then examined. Stations D24 and D35 were originally identified as freshwater reference stations but were dropped from further consideration because of the elevated concentrations of a number of contaminants at these two stations. In addition, anomalously high TOC values were also found in station D35 sediments making this station unlike any other station sampled.

High abundances are not necessarily indicative of reference conditions. Benthic communities are known to respond to organic enrichment by increasing abundances of opportunistic taxa with a concomitant loss of richness (Pearson and Rosenberg 1978). Abundances at candidate reference stations were further examined to address these considerations. Richness and abundances were highly correlated which allowed identification of anomalous richness and abundance values on the basis of a regression analysis using these two variables. Stations $D5^E$ and D7 were identified as outliers (i.e., having anomalously high abundances related to richness). While these two stations had extremely low TOC in the sediments, some other physical characteristics allowed the communities at these stations to be dominated by a few, highly adaptive taxa (i.e., *Corophium salmonis* and nematodes). These stations were considered potentially anomalous stations and were dropped from consideration as estuarine reference stations. These two stations were also identified as outliers as part of the distributional analysis [abundances were more than 1.5 times the (inner-quartile range) IQR above the 75th percentile]. Percentile values were recalculated using the remaining data (i.e., excluding stations $D5^E$, D7, D24, and D35), and the median value of the upper 80th percentile was used to represent reference conditions. Final reference stations and median reference values for richness and abundance are identified in Table 2.6-9. Those having both 50 percent or fewer taxa and individuals compared to reference were considered potentially stressed stations, without regard to the causative factors.

TABLE 2.6-9. MEDIAN RICHNESS AND ABUNDANCE VALUES FOR REFERENCE STATIONS SAMPLED IN THE LOWER COLUMBIA RIVER RECONNAISSANCE SURVEY

RICHNESS (#taxa/0 06 m²)		ABUNDANCE (#individuals/0.06 m²)	
	Median Value		Median Value
Estuarine Stations D1, D4	21	Estuarine Stations D1, D8	3,262
Freshwater Stations		Freshwater Stations	
Coarse-Grained E8, E14	13	Coarse-Grained E4, E8	670
Fine-Grained D10, D11, D12, D17, D18, D20, D36	20	Fine-Grained D10, D11, D12, D14, D20, D23, D30	2,014

Overall, 19 stations were identified as having less than 50 percent of both the richness or abundance values used to represent reference conditions. In the estuary, 3 benthic sampling stations (D3, E1, E3) were identified as having depauperate benthic communities based on low abundances and richness. The benthic communities at 6 of the freshwater coarse-grained stations (stations D38[E], E4, E5, E7, E12, and E13) were identified as depauperate with low diversity. In the freshwater fine-grained habitats, 10 of the 33 stations sampled were identified as having depressed abundances and numbers of taxa including stations D9, D16, D19, D21, D26, D29, D33, D39, D40, and E6[D].

2.6.4 Data Gaps

2.6.4.1 Water

- The reconnaissance survey focused on the low-flow period. The seasonal variability of the parameters of interest was not determined.

- Although the reconnaissance survey characterized the levels of many parameters in the lower Columbia River, the relative contribution of various point and nonpoint sources was not assessed.

- Levels of total recoverable metals were characterized and compared to available water quality criteria. However, the total recoverable method may over-estimate the potential toxicity of some metals, especially those that occur primarily in particulate form. The dissolved fraction of those metals that exceeded available water quality criteria should be evaluated.

- Priority pollutant organic compounds measured during the reconnaissance survey were typically below method detection limits. Therefore, the actual concentration of these compounds in the water column of the lower Columbia River is unknown. These compounds are likely bound to fine particles of suspended sediment.

- The reconnaissance survey characterized the levels of AOX throughout the lower Columbia River However, the halogenated organic compounds that constitute the AOX component measured is unknown

- Bacterial sampling was limited in scope. Bacterial levels during the seasonal period of intensive primary contact recreation was not assessed.

- Although the reconnaissance survey determined that phytoplankton biomass and species composition did not indicate excessive biomass of phytoplankton in spite of adequate nutrient levels, data were not adequate to explain the lack of response of the phytoplankton to elevated nutrient levels, although several hypotheses were proposed

- Biomass levels of periphyton in nearshore areas was not assessed to determine the response of periphyton to elevated nutrient levels.

2.6.4.2 Sediment. Section 2.1.4 described sediment data gaps identified in the review of past studies conducted under Task 1. Data gaps related directly to the reconnaissance survey results are listed below

- Each sediment station was represented by a single sample. Replicated sampling at a larger number of stations in each potential problem areas is needed to adequately characterize these areas

- Sediments were collected and analyzed for 54 sites in the lower river Overall characterization of sediment quality in the lower river would be improved by sampling at additional sites, especially depositional areas not yet sampled.

- Lowering detection limits by analyzing larger sample volumes would better characterize the occurrence of low-level contaminants such as PAHs and PCBs.

- The low levels of pesticides detected in the survey (very near the detection limits of the laboratory methods used) should be confirmed with additional sampling.

- Interpretation of the potential ecological effects of measured sediment contaminant levels is impeded by the lack of promulgated criteria or even generally accepted guidelines. Such criteria or guidelines should be developed by regulatory agencies.

2.6.4.3 Tissue. In addition to the bioaccumulation data gaps identified in Task 1 (see Section 2.1.3), the following data gaps related directly to the reconnaissance survey data have been identified.

- Fish/crayfish tissue samples were collected from only 20 sites in the lower river. Additional sites should be sampled.

- Only five species were sampled. Additional species should be sampled, emphasizing those consumed by humans and wildlife.

- Not all species could be collected at all designated sampling stations. This limits the comparability of results from the various species.

- Little information is available on the range/mobility of the species sampled. This impedes relating tissue data to sediment data and potential sources of contaminants

- Single samples were collected for each species at each site. There is thus no measure of variability among individuals.

- Health risks associated with the measured contaminant levels have not been determined.

2.6.4.4 Benthos. Section 2.1.4 described benthic infaunal data gaps identified in the review of past studies conducted under Task 1. Data gaps related directly to the reconnaissance survey results are listed below.

- Each benthic infauna station was represented by a single sample. Although three replicate grab samples were collected at each station, only one of the three was analyzed. Analyses of all three samples at each station is needed to obtain an estimate of variance for the benthic community samples. Future sampling of benthic infauna should incorporate replicated samples.

- Benthic samples were collected at only 54 stations throughout the lower river. Overall characterization of the lower Columbia would benefit from sampling at additional locations

- Benthic samples that were collected were limited to two general habitat types (depositional and non-depositional). Because of the limited number samples collected, not all of the different habitat types located in the lower Columbia River were characterized for benthic infauna during the reconnaissance survey Additional sampling to characterize other habitats in the lower Columbia River.

2.6.5 Conclusions

2.6.5.1 Water. Several potential water quality problems were identified based on the reconnaissance survey data and a review of historical water quality data. The limited indicator bacteria data collected during the survey suggests that a potential human health risk problem exists and warrants further study Dissolved oxygen did not meet standards at a number of stations and water temperature, primarily in the upper river reaches, exceeded the Washington standard of 20° C during July, August, and September However, nutrient concentrations, although adequate for the production of nuisance levels of phytoplankton (primarily blue-green algae), did not appear to result in nuisance growths of blue-green algae during the period of the reconnaissance survey This is likely due to the short detention time of the river and light limitation of phytoplankton production.

Detection of several metals above available chronic water quality criteria indicate potential effects to aquatic organisms due to metals. Total recoverable metals concentrations measured during the reconnaissance survey were within the range of metals concentrations measured historically by the USGS. However, the historical USGS data for several metals is suspected to have been positively biased due to field contamination of the samples due to use of a solenoid activated sampler. Although a metal sampler was not used for the reconnaissance survey, comparison of reconnaissance survey data to recent data for the lower Columbia River collected by WDOE (using ultra-clean sampling and analysis techniques) and the presence of relatively high levels of aluminum and iron in the laboratory blank sample suggest that the reconnaissance survey metals results may also be positively biased, especially for aluminum, cadmium, copper, lead, iron, mercury, and zinc. These qualifications should be considered when reviewing the reconnaissance survey water column metals data.

Several metals concentrations exceeded available chronic water quality criteria These metals included aluminum, cadmium, copper, iron, lead, selenium, and zinc Exceedances of chronic water quality criteria occurred most frequently for aluminum (11 samples) and lead (21 samples) However, overestimation of the toxic or available portion of these metals due to the use of the relatively vigorous total recoverable acid digestion procedure may have occurred This was very likely for the aluminum values reported. However, the detection of several trace metals, with some concentrations greater than chronic water quality criteria indicates that further study of metals concentrations in the water column is warranted

Based on the limited organic pollutant data it appears that generally, the water concentrations of organic priority pollutants are below the detection limits of conventional laboratory methods. Organic priority pollutant compounds including semivolatile and volatile compounds, and pesticides and PCBs were not detected at the five stations sampled for these compounds, with the exception of bis(2-ethylhexyl)phthalate, which was detected at two stations at concentrations above the chronic water quality criterion of 3 μg/L Although this compound is a typical laboratory contaminant, it is present in a variety of commercial and industrial products that potentially are discharged to the river

Although dioxins and furans in water were not sampled during this survey, it should be mentioned that the Columbia River has recently been identified as water quality limited due to the prediction that water column dioxin (2,3,7,8-TCDD) concentrations exceed the water column criteria for the consumption of contaminated fish and water (0.013 pg/L) and the finding that Columbia River fish tissue levels of 2,3,7,8-TCDD exceeded the human cancer risk factor of an increase of one additional cancer for a population of 1 million people for consumption of Columbia River fish (U S EPA 1991h,i) This prediction was based on modeling inputs of 2,3,7,8-TCDD to the Columbia River from pulp and paper mills on the mainstem of the river and the analysis of dioxin levels in fish tissue samples collected in the Columbia River. The U S. EPA has developed a total maximum daily load (TMDL) which will regulate the discharge of dioxin from U.S. pulp and paper mills in the Columbia River basin to reduce the level of 2,3,7,8-TCDD below the water quality standard. Further investigations are being conducted by U.S EPA Region X and the states of Oregon and Washington to provide additional information for the refinement of the TMDL and to monitor the effect of regulatory actions that have been implemented

The data indicate that AOX (halogenated organic compounds) discharged by pulp and paper mills are transported long distances downstream from their sources. AOX was detected above the detection limit of 5 ug Cl^{-}/L at all 19 stations measured with the exception of one sample from the Cowlitz River. Relatively low, but detectable concentrations were observed in the upper reach of the study area below Bonneville Dam. Relatively higher levels of AOX were noted in the Willamette River and at stations below the area of Longview These observations are consistent with the locations of pulp and paper mill sources of AOX compounds in the Willamette River basin and in Longview However, the composition and potential toxicity of the AOX measured in the water column is not known and therefore an assessment of potential affects to organisms including humans is not presently possible. Further studies are warranted to identify the AOX compounds identified in the water column and to assess the relative contribution of various AOX sources.

2.6.5.2 Sediment. Metals were the most frequently detected substances in sediment samples from the lower Columbia River. With the exception of beryllium, thallium, antimony, mercury, selenium, and silver, the metals analyzed for were detected in nearly every sediment sample. The high frequency of detection is primarily due to the combination of the abundance of these metals in Columbia River sediments (and the laboratory detection limits achieved in this study), as indicated by the fact that in most locations and for most substances, the concentrations were highly correlated with iron. However, some of the trace elements occurred at concentrations that appeared to exceed natural concentrations, indicating possible anthropogenic sources of these elements. In addition, arsenic, copper, cadmium, iron, nickel, silver, lead, and zinc were detected in at least one location at concentrations above levels that have been associated with adverse biological effects in other studies.

These exceedances occurred at 13 stations, of which seven were downstream of major urban and industrial discharges. With the exception of silver, the frequency of exceedances of the effects levels by each of these trace elements was relatively low (fewer than 5 exceedances for metals at any one station) Silver was found to exceed the effects level concentration in six of 10 samples and these occurred for samples collected between RM 21 and RM 34 However, there is no apparent anthropogenic source of silver in this reach of the river

Three of the seven radionuclides analyzed for were detected in sediments collected from six stations Europium-152 was detected at two stations, plutonium-239/230 was detected at one station, and cesium-137 was detected at all six stations The significance of the levels of radionuclides detected to the health of aquatic biota and humans is difficult to determine without established reference values for sediment concentrations of these radionuclides. However, comparisons made with recent sediment data reported for above and below the Hanford site indicate that the levels of radionuclides detected are generally lower than those directly below Hanford and are similar to, or lower than, those of sediments collected from above Hanford (see Table 2 6-10) This indicates that the levels detected are similar to those expected for sediments receiving only fallout-derived radionuclides (i e., radionuclides derived from historical above-ground weapons testing and the more recent accident at Chernobyl).

Of the organic chemicals detected in sediments of the lower Columbia River, the polychlorinated dibenzodioxins (PCDDs) and the polychlorinated dibenzofurans (PCDFs) were the most frequently detected (i.e., dioxins and furans) These compounds were detected in every sample collected from the river, indicating that they are probably more ubiquitous than demonstrated by the data collected from the reconnaissance survey Entry of PCDDs and the PCDFs into the environment has been associated with chlorophenol production, aerial application of phenoxy herbicides (2,4-D and 2,4,5-T), effluent discharge from kraft pulp mills, and from combustion processes (Czuczwa and Hites 1984). Comparatively high concentrations of PCDDs and PCDFs occurred at stations downstream of Multnomah Channel, St Helens, Wauna (Oregon), and Longview (Washington) Each of these locations is associated with kraft mill discharges, which are known sources of PCDDs and PCDFs.

The fact that organotins, used as biocides in antifouling coatings for boats and ships, were detected in seven of 10 sediment samples analyzed for these compounds, indicates that these compounds also may be widely distributed in the river Generally, the highest concentrations of organotins were found between Portland, and Longview, a reach of the river that receives heavy use by recreational boaters and commercial shipping traffic A number of marinas and drydocking facilities are located in Portland and Longview and may be sources of organotins in the Columbia River

TABLE 2.6-10. COMPARISON OF RECONNAISSANCE SURVEY SEDIMENT RADIONUCLIDE RESULTS WITH RECENT AND HISTORICAL DATA FROM LOCATIONS ABOVE (PRIEST RAPIDS DAM) AND BELOW (MCNARY DAM) HANFORD OPERATONS

Radionuclide	Radiologic Half-Life	Reconnaissance Survey	1989[a]		1977[b,c]	
			Priest Rapids	McNary	Priest Rapids	McNary
	Years	Maximum observed surficial concentration in pCi/g dry sediment				
Americium-241	458	<0.006	-[d]	-[d]	0.002	0.002
Cesium-137	30	0.29	0.30	0.86	1.16	1.30
Cobalt-60	5.3	<0.05	0.01	0.44	<0.02	1.37
Europium-152	13	0.14	-[d]	1.11	<0.03[e]	1.00[e]
Europium-155	1.8	<0.08	0.09	0.10	-[d]	-[d]
Plutonium-238	86	<0.006	0.0003	0.002	<0.001	0.001
Plutonium-239/240	24,400/6,580	0.005	0.003	0.022	0.014	0.014

[a] Source: Jaquish and Bryce (1990)

[b] Source. Robertson and Fix (1977)

[c] Data converted from units of disintegrations per minute (dpm) to pCi by multiplying dpm by 0.45045.

[d] No data reported for this radionuclide.

[e] Measurement of Europium-152/154.

Polycyclic aromatic hydrocarbons (PAHs), pesticides, and polychlorinated biphenyls (PCBs) were detected infrequently in sediments throughout the lower Columbia River. PAHs were generally found in sediments near urban areas and may have been due to discharges of urban runoff from storm sewers There are several possible sources of PAHs, including forest fires, combustion of fossil fuels, petroleum contamination, wood treatment facilities using creosote, and urban runoff Hoffman et al (1984) reported that urban runoff entering Narragansett Bay accounted for 71 percent of the total inputs for higher molecular weight PAHs and 36 percent of the total PAHs PAHs were most frequently detected at the highest concentrations at station D19, immediately downstream of the aluminum smelter in Longview

The occurrence of pesticide residues in the sediments may be due to historical and current agricultural usage in the Columbia River basin Many of the chlorinated pesticides are no longer used in the United States and their presence in the sediments probably represents the cycling and erosion of residual concentrations from past usage rather than from present uses.

Of the locations sampled during the survey, the reach from RM 58 to RM 80 appeared to be unique in the numbers of substance detected and the numbers of substances that exceeded enrichment and effects criteria. These high concentrations may reflect the fact that the area downstream of station D25 consisted of substantially finer sediments than those in the reach just below the Willamette River and hence could be a depositional area for both local inputs and for inputs from the large Portland metropolitan area Station E8 was particularly interesting because of the relatively high numbers of chlorinated pesticides present, even though station E8 was relatively coarse-grained and hence would not be expected to accumulate these compounds as readily as fine-grained sediments Station D19 also had a somewhat unique group of compounds that may reflect local inputs from shore-based industries and municipal development

2.6.5.3 Tissue. The reconnaissance survey analyzed crayfish, carp, largescale sucker, peamouth, and white sturgeon for the presence of 11 trace metals and 108 organic compounds. A total of 9 metals and 59 organic compounds were detected in these species

Trace metals, PCBs, dioxins and furans, and banned pesticides were all widely distributed throughout the lower Columbia River For the majority of these chemicals, mean levels measured in tissue were below mean levels measured in other national bioaccumulation studies. Metals and chemicals with geometric mean or median concentrations that exceeded similar parameters in U.S. Fish and Wildlife Services's NCBP, or U.S. EPA's NBS include arsenic, cadmium, copper, 1,2,4-trichlorobenzene, and 2,3,7,8-TCDF.

Comparison of measured tissue concentrations with NYS's proposed reference levels for the protection of piscivorous wildlife indicates that at least one species at all of the sites sampled had PCB levels that would exceed the NYS reference levels. Tissue samples analyzed at half of the stations within the lower Columbia River exceeded NYS reference levels for dioxin. Tissue samples from three stations exceeded NYS reference levels for DDE. Tissue concentrations of the pesticide BHC and the chlorinated benzene 1,2,4-trichlorobenzene exceeded NYS reference levels at a single station.

The tissue data collected during the reconnaissance survey suggests that the contaminants of primary concern in the lower Columbia River are PCBs, dioxins, and chlorinated pesticides. These groups of chemicals are widely distributed throughout the lower Columbia River. Tissue concentrations in biota collected from several stations are sufficiently high that they may adversely affect piscivorous wildlife.

2.6.5.4 Benthos. Benthic communities in the Columbia River reflect the dynamic nature of the aquatic environment in the lower Columbia River. Habitat characteristics (e.g., salinity, sediment grain size, and habitat stability) appear to strongly influence community composition throughout the river. Estuarine benthic communities are very different from riverine communities, in both species composition and total taxa abundances. Taxa richness between the estuary and the river appears to be similar. Community structure in the estuary appears to be primarily affected by salinity, although grain-size may also influence species distributions. Stations near the river mouth and in areas of higher salinity were characterized by marine taxa and generally finer-grained substrates. Taxa that are tolerant of salinity fluctuations or intermittent freshwater conditions were found at estuary stations with lower salinities. Sediments at these same stations tended to be coarser. The grain size effect on community structure could not be clearly identified in the estuary. Average taxa richness and abundances were similar between communities in fine-grained and coarse-grained habitats in the estuary Community composition also appeared to respond to salinity, as well as sediment characteristics. In fine-grained sediments in areas with higher salinity, the polychaetes *Hobsonia florida*, *Eteone spilotus*, several spionids and the bivalves *Macoma balthica*, and *Mya arenaria* were among the dominant taxa. These taxa were present in the coarser sediments in higher salinity areas but were not as abundant. Several other taxa including the crustaceans *Hemileucon* spp. and *Eohaustoris estuarius* were among the numerically dominant taxa at these stations. In lower salinity areas with mixed sediments, *Corophium salmonis* and *Corbicula fluminea* were among the dominant taxa. Oligochaetes and nematodes were dominant at all fine-grained stations, regardless of salinity.

Within the freshwater reaches of the river, sediment grain size appears to be the dominant factor affecting community richness and abundance. Few taxa were found at the coarse-grained riverine stations and abundances were low compared to the fine-grained riverine stations. Coarser sediments in the Columbia River tend to be indicative of unstable habitats. During different times of the year, coarse sands are carried down river by the force of the river currents and therefore benthic habitats are neither consistent or persistent. Dominant taxa (i.e., oligochaetes, nematodes, *Corbicula fluminea* and *Corophium salmonis*) that occur in the river habitats are characterized by highly adaptive lifestyles. Oligochaetes are a diverse group and can be found in sediments ranging from sands to muds (Thorp and Covich 1991). Nematodes are also an ecologically diverse group, and have adapted to a wide variety of habitats in estuarine and freshwater environments. These taxa often represent significant portions of freshwater benthic communities and provide food for many other taxa (e.g., crayfish prey on many types of nematodes). The amphipod *Corophium salmonis* and the bivalve, *Corbicula fluminea* also have highly adaptive strategies for living in more dynamic environments While these two species are sensitive to physical and chemical stresses, they are able to rapidly recolonize through various reproductive and dispersion strategies. These taxa may represent important food sources for other invertebrates, fish, and wildlife. Chironomids (freshwater midges) were found throughout the freshwater portions of the river and were among the dominant taxa at many stations Chironomids are generally tolerant of a wide range of environmental quality and members of this group have adapted to living in very different habitats.

Following the original approach developed in Task 1, 19 stations in both the estuary and freshwater portions of the river were identified as depauperate or lacking diversity on the basis of lower benthic community abundances and richness compared to reference conditions. This approach was based on the assumption that contaminant concentrations and benthic community structure would be highly correlated. However, no significant correlations were found between chemical concentrations and taxa richness and abundances. At those stations identified as potential areas of concern on the basis of anthropogenically-enriched chemical concentrations or concentrations above sediment quality guidelines, total taxa abundances and richness were usually greater than values used to identify stressed benthic communities.

Benthic community variability is more likely a function of physical habitat characteristics and changes in habitat on both a temporal and spatial scale. Grain size distributions change both diurnally and seasonally according tidal cycles, amount of water released at Bonneville Dam, and rainfall or snow melt. These factors affect the rates and direction of flow in the river, and the amount of sediment being actively transported or deposited which in turn affect habitat stability, sediment structure, and salinity. The lack of persistence in benthic habitats may have contributed to the great variation reported for benthic community abundances in the river, rather than any contaminant effects.

Use of benthic communities as indices of environmental health of the lower Columbia River may be limited. The results of the reconnaissance survey demonstrated that benthic community structure was highly variable in both estuarine and freshwater portions of the river Abundances and richness varied widely. Species distributions were strongly affected by habitat characteristics and did not show a clear correlation with sediment contamination concentrations.

The discussion presented in the Task 4 Report (Tetra Tech 1992h) stated that community level indices are not commonly used in environmental monitoring programs due to insufficient information on the population dynamics or degree of natural variability of most plant and animal species. Green et al. (1985) state that population and community level responses to environmental stress are often very non-specific. The response of a natural population or community to environmental variation is usually complex and multivariate, difficult to describe, and, according to Green et al. (1985) even more difficult to analyze statistically. In addition the scale to which benthic community indices are applied may play a role in their effectiveness to discern contaminant effects. Few stations distributed over many miles of river may not be able to clearly distinguish effects associated with specific point source inputs of contaminants to this unique ecosystem.

There may be some individual situations in the lower Columbia River where benthic community structure may be useful as a biological indicator of environmental health. Specifically, use of benthic community indices to evaluate specific point source impacts may be desirable. For example, the substrate in the vicinity of a particular outfall might be stable enough to support a diverse community. Benthic community indices could be used to evaluate the effects of the contaminants associated with the outfall. However, in order for this to be an effective approach, additional qualitative surveys must be conducted to ensure diverse, abundant benthic organisms are found in similar "unimpacted" areas for comparison.

3.0 PRIORITIZATION OF PROBLEM AREAS AND PROBLEM CHEMICALS/PARAMETERS

The primary objectives of the reconnaissance survey were to measure contaminant levels in water, sediment, and aquatic biota collected in the lower Columbia River to 1) determine the distribution of these contaminants both spatially and between media; 2) to determine whether contaminant concentrations exceed levels that may adversely impact beneficial uses of the lower Columbia River; and, 3) to identify any locations and chemicals for each media that are of particular concern. This section discusses a systematic approach used to address the last of these objectives.

The systematic approach used to identify locations and chemicals of concern in sediments and fish and crayfish tissues involved a six-step process. First, contaminant levels measured in sediment and all biota (except white sturgeon) were ranked from the lowest to highest concentration. Second, a category rank score for metals, semivolatiles, polycyclic aromatic hydrocarbons (PAHs), pesticides, polychlorinated biphenyl congeners (PCBs), and dioxins/furans were calculated for each collection station by summing the ranks for individual chemicals within each category. (The rank score for dioxins and furans was based on 2,3,7,8-TCDD toxicity equivalent concentrations (TEC) rather than a summation of rank score for individual congeners.) Third, the category rank score for each station was expressed as a percentage of the maximum possible score. Fourth, stations with sediment or tissue concentrations that exceeded effects-based reference values were identified and a value of 20 was added for each exceedance of reference levels to the category rank. Fifth, the category ranks were summed for each media, the resulting total was divided by the number of categories, and the resulting values were expressed as a percentage of the maximum observed rank. This procedure resulted in each station being assigned a priority score for sediment and tissue contaminants. The maximum possible score for each media was 100. Sixth, information from Tasks 1, 2, 3, and 5 was evaluated for each highly ranked station to see if any stations should be moved up or down in the ranking because it confirmed a problem area identified in Task 1, was located near a beneficial use area or point source, or was a depositional area.

The reconnaissance survey water column data were not subjected to the rigorous ranking scheme described above because 1) of the high degree of uncertainty in the water column metals data, 2) the low frequency of detection of organic contaminants that could have been present, but were below the limit of detection of the conventional laboratory techniques used in this study, and 3) the single samples collected in the water column survey were not considered to be adequate for rigorous prioritization of problem chemicals and problem locations of such a large and dynamic river. Additional, perhaps even long-term, water column sampling that included sampling of the water column during high flow periods and incorporated special sampling and analytical techniques would be required to utilize water column data for rigorous problem ranking. However, a less quantitative attempt has been made to identify problem areas and problem chemicals based on the limited water column data collected for the reconnaissance survey

The priority ranking approach for sediments and fish tissues was an attempt to synthesize a large amount of data into a single score for each station. Each station's score reflects differences in contaminant concentrations among sites sampled in the lower Columbia River, as well as any exceedances of effects-based reference levels. For these scores to be interpreted correctly, it is important to keep in mind several items regarding their formulation. First, the ranking of each station's contaminant concentrations considered only values that were above laboratory detection limits. A score of 1 was assigned to all non-detect values, regardless of their magnitude. This procedure was adopted to accentuate differences between station scores by giving more emphasis to those sites where chemicals were detected. Second, the ranking scores based on measured concentrations were deliberately adjusted upward in cases where contaminant concentrations exceeded levels that have been associated with adverse effects to biota. The amount added for each exceedance of a reference value (a value of 20) was equivalent to 20 percent of the maximum possible score. Reference values were available for only a small subset of the chemicals measured in sediment and tissue samples, so this adjustment is biased towards stations where chemicals with effects-based reference levels were detected. Third, the final ranking score for each station was derived by summing the scores derived for each pollutant category (Step 5). This procedure applies roughly equal weighting to each category of contaminants. It might be argued that some weighting factor should be applied, particularly for the metals which are present, at least in part, from natural sources; however, this was not done. Fourth, because dioxins and furans were not analyzed for at all stations, the sum of category scores were not comparable for all stations. To attempt to correct for this problem, the sum of categories scores was divided by the number of categories for each station. For example, the sum of category scores for a station where dioxins and furans were measured was divided by six, while a station where dioxins and furans were not analyzed was be divided by five. This adjustment is not completely satisfactory, but it is perhaps the best compromise possible given the absence of data and the desire to compare all sites sampled.

Reference Values

An important aspect of the station ranking process is the identification of reference values, against which the reconnaissance survey data (levels of contaminants measured in water, sediment and tissue) will be compared to identify and prioritize water quality problems and problem areas. These reference values can be of the "background" or the "effects-based" types. Background values are based on average levels of contaminants measured in the same or similar environmental systems. Levels of contaminants measured in areas considered relatively unpolluted are often used to establish background values For this project, background values could be based on the data from the reconnaissance survey itself (using levels measured at the "cleanest" stations, and/or the most upstream stations), from other studies in the lower Columbia, from other freshwater systems in North America, or some combination of the three.

Effects-based values are derived from environmental levels of individual contaminants previously observed to be associated with adverse biological effects. Such effects include increased mortality in a variety of aquatic species, reduced growth or reproduction, physical damage to organs, disease, and reduced diversity of aquatic communities. An average, or (to be more protective) low percentile, of the range of contaminant concentrations associated with such effects can be used to establish effects-based reference values. Because of the scarcity of such studies in the lower Columbia system, it is necessary to consider studies from aquatic systems across North America to have a data base that is large enough to provide meaningful values. Federal and state water quality standards are examples of effects-based values. These standards are adopted in law and can be protective of human health and aquatic and terrestrial wildlife.

Effects-based reference values were used for this study, primarily because they are based on observations of adverse biological effects. The reference values used were selected from promulgated federal and state criteria (for water), and from unofficial guidelines developed by various state and federal agencies for the media of sediment and tissue. The rationale for selecting the values is presented below.

Water—The issue of reference values is the most straightforward for this medium because of the existence of federal and state water quality standards. The federal, Washington or Oregon (whichever was lowest) chronic surface water quality standard for the protection of aquatic organisms was used as the reference value For most chemicals, all of these standards are the same because the states have adopted the federal standard Where state standards are lower, however, they were used as the reference value. Freshwater standards were used for most stations. In the estuary [river segments 1A and 1B (i e , from river mile 0 to 18.5 at Tongue Point), the stricter of the marine and freshwater standards (usually freshwater) were used. The marine standards were applied in the estuary due to the potential presence of sensitive marine aquatic species in the estuary and the requirement that the most restrictive criteria be used. These standards are effects-based in that they were developed from studies of the effects of various concentrations of chemicals in water on aquatic organisms Federal or state chronic surface water standards were available for 79 of the 150 water parameters measured in this study

Sediments--There are no obvious or straightforward effects-based reference values to use for sediment because, unlike for water, there are no promulgated federal or state standards for marine or freshwater sediments. Several agencies and authors have developed sediment reference values based on literature searches of studies on the biological effects of sediment contaminants Those selected for use in this study because of their good foundation in research are

1 National Oceanic and Atmospheric Administration's (NOAA's) National Status and Trends Program (Long and Morgan 1990). The ER-L's (effects range -low) identified by Long and Morgan (1990) for marine sediments were used These values (one per chemical) are based on 7 to 51 studies, depending on the chemical. These values represent the low end of the range of concentrations observed to have adverse biological effects in the applicable studies.

2 Ontario Ministry of the Environment's (Canada) Provincial Sediment Quality Guidelines for freshwater sediments (Persuad et al 1991). The lowest-effect level for freshwater benthic organisms (i.e., the level of sediment contamination that can be tolerated by most benthic organisms) was used

3. U S. EPA's recently issued draft freshwater sediment criteria for the polycyclic aromatic hydrocarbons (PAHs) acenaphthene, fluoranthene, phenanthrene, and the pesticides dieldrin and endrin were used (U S. EPA 1991c,d,e,f,g). These data required normalization to the total organic carbon content of the sediments for comparison to the criteria

For each chemical for which values were available from all of these sources, the lower value was used as the reference value. For most of the marine stations (river segments 1A and 1B), the Ontario guidelines were used if they resulted in a lower reference value; however, in some instances the lower Long and Morgan ER-L concentrations were used (e.g , mercury and PAHs). This approach used reference values that are both effects-based, and are derived independently of concentrations measured in the lower Columbia River, thus providing an "outside" measure of sediment quality in the river.

Tissue--For tissue, like sediment, there are no promulgated criteria that can be used as reference values. The most appropriate data to use as reference values for tissue are the fish flesh criteria developed by the New York Department of Environmental Conservation, Division of Fish and Wildlife (Newell et al. 1987). These criteria were developed for 16 organic compounds based on the results of many laboratory and field studies of the biological effects of consumption of contaminated fish flesh by wildlife (mammals and birds). The criteria are intended to be protective of piscivorous wildlife by estimating the No Observed Effects Level (NOEL), or the fish tissue concentration of a contaminant below which no adverse effect on consuming wildlife is expected. The New York Department of Environmental Conservation strongly discourages use of these criteria for regulatory purposes However, these criteria do appear to be appropriate guidelines for identifying tissue contaminant concentrations that are potentially harmful to piscivorous wildlife in the lower Columbia.

3.1 PROBLEM AREAS

3.1.1 Water

The ranking scheme used to identify sediment and tissue problems areas (see following Sections 3.1.2 and 3.1.3) was not applied to the water data. Because of the flow of water in a river, water collected at a given point at different times comes from different water masses. As a result, water quality measured at a point in a river is often highly variable, especially over an annual cycle. This makes identification of problem locations difficult The difficulty is increased when, as in the survey, each location is represented by a single one-time sample, so that there is no measure of temporal variability In addition, the data collected in this survey showed little evidence of spatial trends or local anomalies. Therefore, these data are not conducive to identifying problem locations, and application of a complex ranking scheme is not justified. There is ample evidence, however, to support identification of problem chemicals/parameters for the lower river as a whole, and these are addressed below in Section 3 2 1 The remainder of this section identifies the potential problem areas that can be identified from the water column data from the reconnaissance survey.

Based on available water quality criteria, potential problem areas were identified for dissolved oxygen (DO), water temperature, bacteria, metals, and organic pollutants The potential problem areas for these parameters are identified below

3.1.1.1 Dissolved Oxygen. DO concentrations not meeting the Washington freshwater standards of 8 mg/L and 90 percent saturation and the estuarine marine standard of 6 mg/L were noted at several stations. In the estuarine portion of the river, one potential problem area was identified DO concentration below the 6 mg/L standard was noted at station W4 in the Skipanon River In the freshwater portion of the river, potential problem areas were noted where DO was below the 8 mg/L standard and below 90 percent saturation. These stations were Grays Bay (W9, DO below 8 mg/L and 90 percent saturation standard), station W10 (DO below 90 percent saturation), Marsh Island (W12, DO below 90 percent saturation), near Skamokawa Creek (W13, DO below 8 mg/L and 90 percent saturation), transect station near Cathlamet (W14. DO below 90 percent saturation), transect station above Puget Island (W17, DO below 90 percent saturation), Coal Creek Slough (W20, DO below 90 percent saturation), transect station below Kalama (W26. DO below 90 percent saturation), Cowlitz River (W24, DO below 90 percent saturation), Lewis River (W31, DO below 90 percent saturation), and in Lake River (W34, DO below 8 mg/L and 90 percent saturation). However, at stations where only the DO percent saturation level was below the 90 percent standard, the DO concentration was greater than 8 mg/L and 85 percent saturation (except station W9) Low DO measured in Grays Bay (station W9) may have been due to the slight estuarine influence (with naturally low DO levels) at this station Only the station near Skamokawa Creek in the lower Columbia River had a DO concentration substantially lower (6.5 mg/L and 67 percent saturation) than the established standards.

3.1.1.2 Temperature. Water temperature above the Washington freshwater standard of 20° C was not noted at any station during the reconnaissance survey, but temperatures of 19° C and slightly higher were noted at several stations in the upper reach of the study area between station W37 above the confluence with the Willamette River and station W45 just below Bonneville Dam. Historical observations indicate that water temperatures in this upper river reach chronically exceeds the 20° C standard in July, August, and September, and therefore, this river segment has been identified as a potential problem area for temperature

3.1.1.3 Metals. Several potential problem areas were indicated by comparison of the total recoverable metals concentrations measured during the reconnaissance survey with available chronic water quality criteria. However, the total recoverable method may overestimate the soluble or available, and hence, toxic portion of each metal analyzed by this technique The overestimation is due to the relatively more rigorous total recoverable metal (heated acid digestion) extraction method which may extract metals from mineral particles that are biologically unavailable. This may be particularly true for aluminum and iron which are primarily in mineral form in the suspended sediment Therefore, exceedances of available chronic water quality criteria for aluminum and iron were not considered for identification of potential problem areas.

The identification of problem areas due to exceedances of water quality criteria for metals must be further qualified due to the detection of aluminum and iron in the laboratory method blank which indicated a potential positive bias in the results reported for the water concentrations of aluminum and iron. Many of the reported concentrations of aluminum and iron have been qualified as undetected due to method blank contamination of these samples. The water column metal concentration results have also been qualified as estimates due to the incomplete calibration check standard data provided by the laboratory. Furthermore, recent studies performed by the Washington Department of Ecology (WDOE) indicate that the concentrations of cadmium, copper, lead, and zinc in the lower Columbia River are typically much lower than the concentrations reported for the reconnaissance survey. Although the study design and laboratory techniques of these two investigations differed, WDOE's data suggest that some of the reconnaissance survey metals data (particularly cadmium, copper, lead, and zinc) are positively biased due to contamination of the samples in the field or laboratory. Therefore, the results of problem area identification based on water column metals data should be viewed with caution and as preliminary only. The difficulties associated with accurately assessing the concentration of trace levels of metals in ambient marine and fresh waters has been recognized by several investigators, and warrants closer attention in future water column studies of the lower Columbia River

With the exception of aluminum and iron, metal concentrations exceeded available water quality criteria at 19 water quality sampling stations. Water quality criteria were exceeded only for lead at 10 of these 19 stations. Stations with two or more exceedances of the available chronic water quality criteria for metals (except for aluminum and iron) were identified as potential problem areas This resulted in the identification of ten potential problem areas. These were station W16 near Puget Island (a shore-based bacteria sampling station) for exceedances of lead and zinc criteria, station W21 in the channel behind Fisher Island near Longview for exceedances of lead and copper criteria, station W22 near Longview due to exceedances of lead and cadmium criteria, station W23 in the channel behind Lord Island near Longview for exceedances of lead, selenium, and copper criteria, station W26 near Kalama for exceedances of lead and selenium criteria, station W28 in the channel behind Sandy Island for exceedances of lead, cadmium, and copper criteria, station W30 near Deer Island for exceedances of lead, selenium, and copper criteria; station W37 in the Portland/Vancouver area for exceedances of the lead and cadmium criteria; station W39 near Government Island for exceedances of lead and copper criteria; and station W42 below Reed Island for exceedances of the lead and zinc criteria.

3.1.1.4 Organic Compounds Organic compounds were typically below detection limits in all water samples analyzed with the exception of bis(2-ethylhexyl)phthalate which was detected at two stations This result was not unexpected since the concentrations of organic contaminants in the water column are typically below the detection limits of conventional sampling and laboratory techniques These stations were W26 below Kalama and station W37 in the Portland/Vancouver area. The concentrations of bis(2-ethylhexyl)phthalate measured at both stations exceeded the chronic freshwater criterion of 3 μg/L for phthalate esters. Therefore, these two stations have been identified as potential problem areas for organic compounds.

3.1.1.5 Indicator Bacteria. Bacteria (fecal coliforms and enterococcus) were sampled at 6 locations along the river. The federal standards for enterococcus were exceeded at all 6 stations, and the Washington standard for fecal coliforms was exceeded at 3 of the 6 stations. Because of the small number of stations sampled for bacteria, identification of problem areas for bacteria is not reasonable However, bacteria has been identified as a problem parameter for the lower river as a whole, as discussed below in Section 3.2.1, and further study to better characterize the extent and seriousness of this problem is recommended.

3.1.2 Sediment

This section describes the results of the sediment station ranking scheme, based on concentrations of contaminants measured at the stations Rankings for each of the five major chemical groups (metals, PAHs, pesticides, dioxins/furans, and organotins) are addressed in the first five sections, and overall ranking is addressed in the last section. The PCB and other semivolatile chemical groups are not included in the ranking analysis because of the very infrequent detection of chemicals in these groups in sediment. One PCB, Aroclor 1254, was detected at one station, and only one other semivolatile compound [bis-2-(ethylhexyl)phthalate] was detected, albeit at most stations. Representing an entire large chemical group by this one chemical, a common laboratory contaminant, was not considered justified.

3.1.2.1 Metals. The results of the sediment metals ranking are shown in Table 3.1-1 and Figure 3.1-1. From these results, the following five stations stand out from the rest as being the most metals-contaminated: D6 (Grays Bay), D35 (Camas), D2 (Ilwaco/Baker Bay), D22 (Kalama), and D9 (Skamokawa). In addition to having high total ranks for metals concentrations, these stations all showed several exceedances of effects-based levels D6 (exceedances for five metals), D35 (three), D2 (three), D22 (three), and D9 (three). As a result these five stations were ranked the highest overall for metals.

It should also be pointed out that three stations in a short reach in the middle of the study area had high total metals rankings, but were not among the highest ranked stations overall because they had no effects level exceedances. These stations were $E9^D$, D24, and D25, which are located at the Lake River mouth (D25), and downstream of St. Helens and the mouth of the Multnomah Channel (D24 and $E9^D$).

These high-ranking stations may indicate no more than local elevation of metals concentrations. However, the fact that two (D2 and D6) or three (D2, D6, and D9) of the stations (depending on the definition of the estuary used) are located in the estuary, may indicate that the estuary is something of a sink for metals carried by the Columbia River The sixth-ranked metals station (D1-Hammond, OR) is also in the estuary.

Table 3 1-1 Summary of Metals Ranking Results in Sediments

METALS	Sediment Metals Ranking														Metals Rank
	Aluminum	Arsenic	Barium	Beryllium	Cadmium	Chromium	Copper	Iron	Lead	Mercury	Nickel	Selenium	Silver	Zinc	
Station	rank	rank	rank	rank	rank	rank	rank	rank	rank	rank	rank	rank	rank	rank	sum
D1	48	48	6	1	47	51	50	42	45	1	46	1	1	39	426
D2	54	53	7	1	48	54	53	52	52	53	48	1	1	46	523
D3	36	38	9	1	40	49	30	39	46	47 5	25	1	46	37	444 5
D4	45	41	4	1	44	48	45	41	38	1	29	1	1	30	369
E1	5	23	3	1	3 5	7	1	12	20	1	10	1	45	5	137 5
E2	23	4	13	1	3 5	21	7	20	11	1	17	1	1	8	131 5
D5	35	14	29	1	8 5	33	10 5	31	7	1	31	1	1	14	217
D6	50	54	42	1	51	41	39	53	53	1	54	1	54	49	543
D7	10	20	22	1	30 5	9	10 5	6	26	1	12	1	49	16	222
D8	19	13	33	1	15	15	13	9	25	1	16	1	51	11	223
D9	53	46	28	1	54	30	44	54	23	1	35	1	52	22	444
D11	40	33 5	37	1	26 5	42	35	34	37	1	30	1	47	27	392
E3	6	7	14	1	10 5	13	6	15	8	1	9	1	50	9	150 5
E4	3	5	10	1	49	1	3	4	5	1	2	1	53	2	140
D10	33	27	34	1	29	35	34	29	3	1	27	1	1	32	287
D12	41	24	24	1	32 5	28	48	38	32	1	19	1	1	28	318 5
D13	27	11 5	15	1	12 5	14	36	14	16	1	11	1	53	15	228
D14	17	19	17	1	20 5	10	33	10	14	1	8	1	1	17	169 5
E5	14	16	16	1	2	3	12	16	3	1	7	1	1	4	97
D15	26	26	27	1	17	20	27	21	21 5	1	15	1	1	19	223 5
D16	38	45	25	1	32 5	37	49	37	34	49	13	1	1	25	387 5
D17	15	6	8	1	15	8	32	5	10	1	3	1	48	7	160
D18	18	30	19	1	18	11	26	13	19	1	14	1	1	23	195
D19	4	3	2	1	8 5	6	31	3	4	1	4	1	1	6	75 5
D20	46	49	41	1	42 5	36	47	40	41	1	40	1	1	42	428 5
D21	43	39	46	1	52	47	41	43	54	1	44	1	1	44 5	457 5
E6	7	17	11	1	6 5	12	15	11	13	1	24	1	1	12	132 5
E7	2	1	1	1	1	1	28	2	1	1	6	1	1	1	48
D22	47	37	43	1	50	46	52	47	51	52	41	1	1	53	522
D23	44	52	51	1	41	44	43	44	44	1	43	1	1	43	453
D24	52	44	48	1	42 5	53	46	51	50	54	53	1	1	50	546 5
D25	42	47	52	54	38 5	50	37	46	42	46	45	54	1	33	587 5
E8	8	15	12	1	12 5	5	20	7	6	1	5	1	1	10	104 5
E9	51	22	49	1	36 5	52	40	49	43	51	51	1	1	44 5	492
D26	11	21	31	1	20 5	18 5	5	17	12	51	23	1	1	18	231
D27	25	25	30	1	23	18 5	18	24	17	1	32	1	1	21	237 5
D28	20	35	38	1	35	25	29	25	36	1	22	1	1	40	309
D29	21	29	36	1	29	27	19	23	27	1	36	1	1	34	285
E10	24	11 5	26	1	20 5	22	14	22	21 5	1	18	1	1	26	209 5
D30	34	33 5	39	1	45 5	40	38	33	39	47 5	39	1	1	35	426 5

Table 3 1-1 Summary of Me[illegible] Ranking Results in Sediments

METALS	Sediment Metals Ranking														
	Aluminum	Arsenic	Barium	Beryllium	Cadmium	Chromium	Copper	Iron	Lead	Mercury	Nickel	Selenium	Silver	Zinc	Metals Rank
Station	rank	rank	rank	rank	rank	rank	rank	rank	rank	rank	rank	rank	rank	rank	sum
D31	29	51	35	1	29	26	22	30	28	1	21	1	1	38	313
D32	16	28	32	1	20 5	31 5	17	26	31	1	33 5	1	1	36	275 5
D33	28	31 5	40	1	34	31 5	21	28	30	1	37	1	1	41	326
D34	9	8	20	1	15	23	8	8	9	1	26	1	1	20	150
D35	49	50	50	1	53	45	51	48	48	50	49	1	1	54	550
D36	22	10	21	1	31	29	24	18	24	45	21	53	1	24	324
D37	32	40	45	1	26 5	38	23	36	49	1	42	1	1	51	386 5
D38	13	18	18	1	10 5	24	9	19	35	1	28	1	1	31	209 5
E11	31	36	44	1	45 5	34	54	32	40	1	33 5	1	1	48	402
E12	1	2	5	1	5	4	4	1	2	1	1	1	1	3	32
D39	12	9	23	1	6 5	39	2	27	18	1	38	1	1	13	191 5
D40	39	42	47	1	24 5	43	42	45	47	1	47	1	1	52	432 5
E13	37	43	54	1	36 5	17	16	50	29	1	52	1	1	47	385 5
E14	30	31 5	53	1	24 5	16	25	35	15	1	50	1	1	29	313

Table 3.1-1 Summary of Metals Ranking Results in Sediments

METALS Station	Adjusted Metals Rank sum	# Reference Level Exceedances	Reference Level Exceedance score	Final Metals Rank sum
D1	56 3	2	40	96 3
D2	69 2	3	60	129 2
D3	58 8		0	58 8
D4	48 8		0	48 8
E1	18 2		0	18 2
E2	17 4		0	17 4
D5	20 7		0	20 7
D6	71 8	5	100	171 8
D7	29 4	1	20	49 4
D8	29 5	1	20	49 5
D9	58 7	3	60	118 7
D11	51 9		0	51 9
E3	19 9	1	20	39 9
E4	18 5	2	20	38 5
D10	38 0		0	38 0
D12	42 1	1	20	62 1
D13	30 2		0	30 2
D14	22 4		0	22 4
E5	12 8		0	12 8
D15	29 6		0	29 6
D16	51 3	1	20	71 3
D17	21 2		0	21 2
D18	25 8		0	25 8
D19	10 0		0	10 0
D20	56 7	1	20	76 7
D21	60 5	1	20	80 5
E6	17 5		0	17 5
E7	6 3		0	6 3
D22	69 0	3	60	129 0
D23	59 9		0	59 9
D24	72 3		0	72 3
D25	77 7		0	77 7
E8	13 8		0	13 8
E9	65 1		0	65 1
D26	30 6		0	30 6
D27	31 4		0	31 4
D28	40 9		0	40 9
D29	37 7		0	37 7
E10	27 7		0	27 7
D30	56 4		0	56 4

Table 3 1-1 Summary of Metals Ranking Results in Sediments

METALS Station	Adjusted Metals Rank sum	# Reference Level Exceedances	Reference Level Exceedance score	Final Metals Rank sum
D31	41 4		0	41 4
D32	36 4		0	36 4
D33	43 1		0	43 1
D34	19 8		0	19 8
D35	72 8	3	60	132 8
D36	42 9		0	42 9
D37	51 1		0	51 1
D38	27 7		0	27 7
E11	53 2	1	20	73 2
E12	4 2		0	4 2
D39	25 3		0	25 3
D40	57 2		0	57 2
E13	51 0		0	51 0
E14	41 4		0	41 4

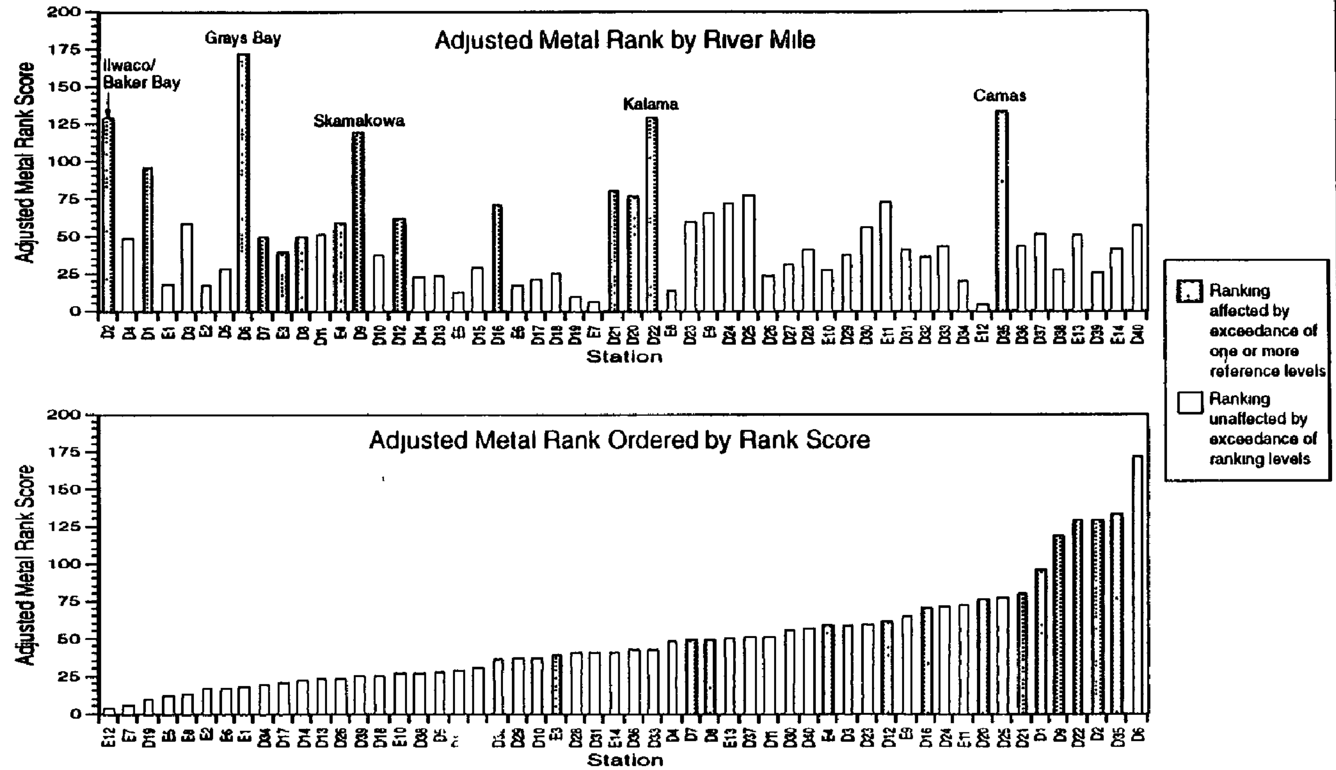


Figure 3 1-1. Summary of Metal Ranking Results in Sediments

The results also show that the reach of the river from approximately the Lake River mouth (D25) to Kalama (D22) may also be a problem area for metals. These stations may be depositional areas that are collecting metals from sources such as the Multnomah Channel, the Lake and Lewis rivers, the Willamette River, the City of St. Helens treatment plant, industrial sources in Portland/Vancouver, and other industrial sources in the area.

The Camas Slough station also showed high levels of metals, where the upper Columbia River is a potential source. The James River pulp mill discharges to the mainstem of the Columbia near Camas, but the present pulp mill, without chlor-alkali facilities, is not generally considered a major source of metals. However, historically pulp and paper mill operations at Camas discharged directly to Camas Slough (Robeck et al 1954) which is another potential source of metals to this slough.

All of these locations are worthy of further study to better define the extent and seriousness of metals contamination.

3.1.2.2 PAHs. The results of the sediment station ranking for PAHs are shown in Table 3 1-2 and Figure 3.1-2. These results are fairly simple because PAHs were detected at only five stations: D19 (Longview), E8 (Deer Island), $E9^D$ (downstream of St Helens), D24 (downstream of St Helens), $D32^E$ (Vancouver).

By far the two highest ranking stations, due to multiple exceedances of the PAH effects level, are D19 and D24. The major source of PAHs in the aquatic environment include releases of petroleum fuels, aluminum smelters, and combustion by products The fact that PAHs were detected at only a few stations may indicate localized sources of these compounds

3.1.2.3 Pesticides. The results of the sediment station ranking for pesticides are shown in Table 3.1-3 and Figure 3.1-3. Pesticides were detected at 20 of the 54 stations, and the following five stations had the highest overall ranking for pesticide occurrence E8 (Deer Island), D35 (Camas), $E9^D$ (downstream of St. Helens), D16 (Coal Creek Slough), D24 (St. Helens) Much of the high ranking for these stations comes from effects-level exceedances: E8 (exceedances for three pesticides), D35 (two), $E9^D$ (two), D16 (two), and D24 (two). Other stations with high total pesticide rankings but without effects-level exceedances are D1 (Hammond, OR), D22 (Kalama), and D23 (Burke Slough).

Table 3 1-2 Summary of PAH Ranking Results in Sediments

PAHs / Station	Benzo(a)-anthracene rank	Benzo(a)-fluoranthene rank	Benzo(k) fluoranthene rank	Benzo(a) pyrene rank	Benzo(g,h,i)-perylene rank	Chrysene rank	Fluoranthene rank	Indeno(1,2,3-c,d)-pyrene rank	Phenanthrene rank	Pyrene rank	PAHs Rank sum	Adjusted Metals Rank sum
	PAH Ranking											
D2	1	1	1	1	1	1	1	1	1	1	10	1 9
D4	1	1	1	1	1	1	1	1	1	1	10	1 9
D1	1	1	1	1	1	1	1	1	1	1	10	1 9
E1	1	1	1	1	1	1	1	1	1	1	10	1 9
D3	1	1	1	1	1	1	1	1	1	1	10	1 9
E2	1	1	1	1	1	1	1	1	1	1	10	1 9
D5	1	1	1	1	1	1	1	1	1	1	10	1 9
D6	1	1	1	1	1	1	1	1	1	1	10	1 9
D7	1	1	1	1	1	1	1	1	1	1	10	1 9
E3	1	1	1	1	1	1	1	1	1	1	10	1 9
D8	1	1	1	1	1	1	1	1	1	1	10	1 9
D11	1	1	1	1	1	1	1	1	1	1	10	1 9
E4	1	1	1	1	1	1	1	1	1	1	10	1 9
D9	1	1	1	1	1	1	1	1	1	1	10	1 9
D10	1	1	1	1	1	1	1	1	1	1	10	1 9
D12	1	1	1	1	1	1	1	1	1	1	10	1 9
D14	1	1	1	1	1	1	1	1	1	1	10	1 9
D13	1	1	1	1	1	1	1	1	1	1	10	1 9
E5	1	1	1	1	1	1	1	1	1	1	10	1 9
D15	1	1	1	1	1	1	1	1	1	1	10	1 9
D16	1	1	1	1	1	1	1	1	1	1	10	1 9
E6	1	1	1	1	1	1	1	1	1	1	10	1 9
D17	1	1	1	1	1	1	1	1	1	1	10	1 9
D18	1	1	1	1	1	1	1	1	1	1	10	1 9
D19	54	54	1	53	1	54	54	53	53	53	430	79 6
E7	1	1	1	1	1	1	1	1	1	1	10	1 9
D21	1	1	1	1	1	1	1	1	1	1	10	1 9
D20	1	1	1	1	1	1	1	1	1	1	10	1 9
D22	1	1	1	1	1	1	1	1	1	1	10	1 9
E8	1	1	1	1	1	1	50	1	1	50	108	20 0
D23	1	1	1	1	1	1	1	1	1	1	10	1 9
E9	52	52	1	52	53	52	52	52	52	52	470	87 0
D24	53	53	54	54	54	53	53	54	54	54	536	99 3
D25	1	1	1	1	1	1	1	1	1	1	10	1 9
D26	1	1	1	1	1	1	1	1	1	1	10	1 9
D27	1	1	1	1	1	1	1	1	1	1	10	1 9
D28	1	1	1	1	1	1	1	1	1	1	10	1 9
E10	1	1	1	1	1	1	1	1	1	1	10	1 9
D29	1	1	1	1	1	1	1	1	1	1	10	1 9
D30	1	1	1	1	1	1	1	1	1	1	10	1 9
E11	1	1	1	1	1	1	1	1	1	1	10	1 9

Table 3 1-2 Summary [illegible]H Ranking Results in Sediments

PAHs / Station	*PAH Ranking* Benzo(a) anthracene rank	Benzo(a)-fluoranthene rank	Benzo(k) fluoranthene rank	Benzo(a) pyrene rank	Benzo(g,h,i)-perylene rank	Chrysene rank	Fluoranthene rank	Indeno(1,2,3-c,d)-pyrene rank	Phenanthrene rank	Pyrene rank	PAHs Rank sum	Adjusted Metals Rank sum
D31	1	1	1	1	1	1	1	1	1	1	10	1 9
D32	1	1	1	1	1	51	51	1	51	51	210	38 9
D33	1	1	1	1	1	1	1	1	1	1	10	1 9
D34	1	1	1	1	1	1	1	1	1	1	10	1 9
E12	1	1	1	1	1	1	1	1	1	1	10	1 9
D35	1	1	1	1	1	1	1	1	1	1	10	1 9
D36	1	1	1	1	1	1	1	1	1	1	10	1 9
D37	1	1	1	1	1	1	1	1	1	1	10	1 9
D38	1	1	1	1	1	1	1	1	1	1	10	1 9
E13	1	1	1	1	1	1	1	1	1	1	10	1 9
D39	1	1	1	1	1	1	1	1	1	1	10	1 9
E14	1	1	1	1	1	1	1	1	1	1	10	1 9
D40	1	1	1	1	1	1	1	1	1	1	10	1 9

Table 3 1-2 Summary of PAH Ranking Results in Sediments

PAHs Station	# Reference Level Exceedances	Reference Level Exceedance score	Final PAH Rank sum
D2		0	1 9
D4		0	1 9
D1		0	1 9
E1		0	1 9
D3		0	1 9
E2		0	1 9
D5		0	1 9
D6		0	1 9
D7		0	1 9
E3		0	1 9
D8		0	1 9
D11		0	1 9
E4		0	1 9
D9		0	1 9
D10		0	1 9
D12		0	1 9
D14		0	1 9
D13		0	1 9
E5		0	1 9
D15		0	1 9
D16		0	1 9
E6		0	1 9
D17		0	1 9
D18		0	1 9
D19	4	80	159 6
E7		0	1 9
D21		0	1 9
D20		0	1 9
D22		0	1 9
E8		0	20 0
D23		0	1 9
E9		0	87 0
D24	2	40	139 3
D25		0	1 9
D26		0	1 9
D27		0	1 9
D28		0	1 9
E10		0	1 9
D29		0	1 9
D30		0	1 9
E11		0	1 9

Table 3 1-2 Summary of [illegible] Ranking Results in Sediments

PAHs Station	# Reference Level Exceedances	Reference Level Exceedance score	Final PAH Rank sum
D31		0	1 9
D32		0	38 9
D33		0	1 9
D34		0	1 9
E12		0	1 9
D35		0	1 9
D36		0	1 9
D37		0	1 9
D38		0	1 9
E13		0	1 9
D39		0	1 9
E14		0	1 9
D40		0	1 9

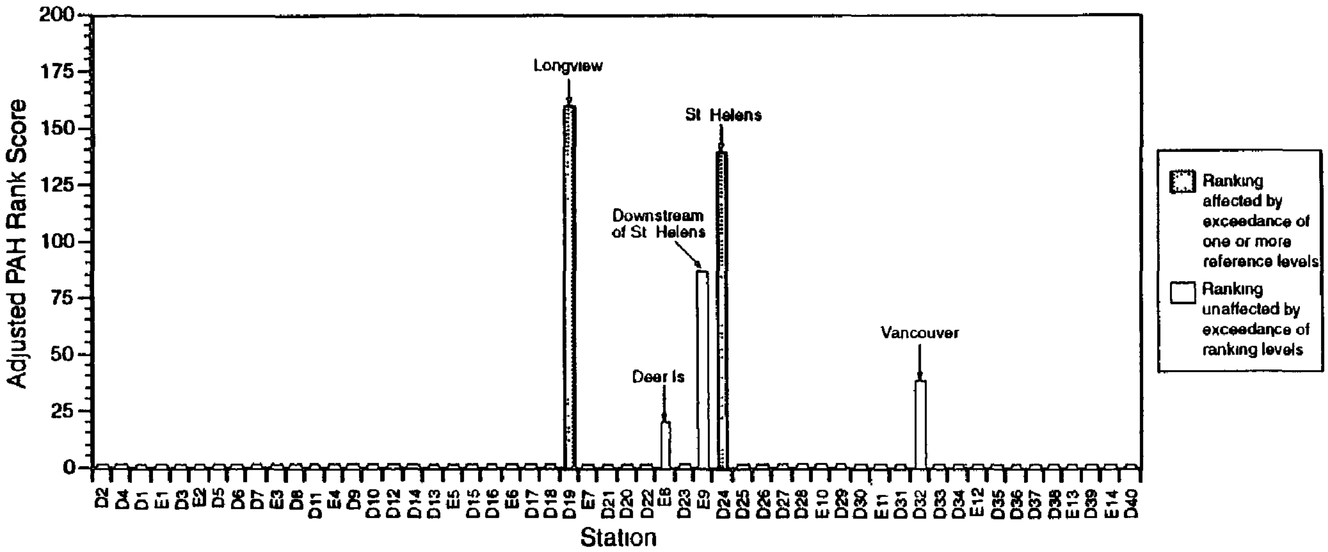


Figure 3.1-2 Summary of Polynuclear Aromatic Hydrocarbon (PAH) Ranking Results in Sediments

Table 3 1-3 Summary of P[illegible]e Ranking Results in Sediments

Pesticides station	o,p-DDD rank	o,p-DDE rank	o,p-DDT rank	4,4'-DDE rank	4,4-DTT rank	Hepta-Chlor rank	Aldrin rank	Diedrin rank	Mirex rank	Dacthal rank	Meth-parathion rank	Parathion rank	Malathion rank	Endrin rank	alpha BHC rank	delta BHC rank	gamma-BHC rank
	Pesticides Ranking																
D2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
D4	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
D1	1	1	54	1	1	1	1	1	1	1	54	1	1	1	1	1	1
E1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
D3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
E2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
D5	1	1	1	1	1	1	1	1	1	1	44	1	1	1	1	1	1
D6	1	1	1	1	1	1	1	1	1	1	47	1	1	1	1	1	1
D7	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
E3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
D8	1	1	1	1	1	1	1	1	1	1	43	1	1	1	1	1	1
D11	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
E4	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
D9	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
D10	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
D12	1	1	1	1	1	1	1	1	1	1	52	1	1	1	1	54	1
D14	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
D13	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
E5	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
D15	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
D16	1	1	1	51	1	1	1	1	1	1	1	1	1	1	1	52	1
E6	1	1	1	1	1	1	1	1	1	1	42	1	1	1	1	1	1
D17	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	53	1
D18	1	1	1	1	1	1	1	1	1	1	49	1	1	1	1	1	1
D19	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
E7	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
D21	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
D20	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
D22	1	1	1	1	1	53	1	1	1	1	53	1	1	1	51	1	1
E8	54	54	51	1	53	1	1	54	53	54	48	54	54	54	1	1	1
D23	1	1	1	1	1	1	1	1	1	1	51	1	1	1	1	1	54
E9	1	1	1	1	54	52	54	1	1	1	1	1	1	1	53	1	1
D24	1	53	53	53		1	1	1	1	1	45	1	1	1	52	1	1
D25	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
D26	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
D27	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
D28	1	1	50	1	1	1	1	1	1	1	1	1	1	1	1	1	1
E10	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
D29	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
D30	1	1	1	1	1	1	1	1	1	1	50	1	1	1	1	1	1
E11	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

Table 3 1-3 Summary of Pesticide Ranking Results in Sediments

Pesticides station	o,p-DDD rank	o,p-DDE rank	o,p-DDT rank	4,4'-DDE rank	4,4'-DTT rank	Hepta-Chlor rank	Aldrin rank	Diedrin rank	Mirex rank	Dacthal rank	Meth-parathion rank	Parathion rank	Malathion rank	Endrin rank	alpha-BHC rank	delta-BHC rank	gamma-BHC rank
	Pesticides Ranking																
D31	1	1	1	1	1	1	1	1	1	1	46	1	1	1	1	1	1
D32	1	1	52	1	1	1	1	1	1	1	1	1	1	1	1	1	1
D33	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
D34	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
E12	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
D35	1	1	1	54	1	54	1	1	54	1	1	1	1	1	54	1	1
D36	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
D37	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
D38	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
E13	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
D39	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
E14	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
D40	1	1	1	52	1	1	1	1	1	1	1	53	1	1	1	1	1

Table 3 1-3 Summary of Pe[illegible] Ranking Results in Sediments

Pesticides station	Pesticides Rank sum	Adjusted Pesticides Rank sum	# Reference Level Exceedances	Reference Level Exceedance score	Final Pesticides Rank sum
D2	17	1 7		0	1 7
D4	17	1 7		0	1 7
D1	123	12 0		0	12 0
E1	17	1 7		0	1 7
D3	17	1 7		0	1 7
E2	17	1 7		0	1 7
D5	60	5 8		0	5 8
D6	63	6 1		0	6 1
D7	17	1 7		0	1 7
E3	17	1 7		0	1 7
D8	59	5 8		0	5 8
D11	17	1 7		0	1 7
E4	17	1 7		0	1 7
D9	17	1 7		0	1 7
D10	17	1 7		0	1 7
D12	121	11 8	1	20	31 8
D14	17	1 7		0	1 7
D13	17	1 7		0	1 7
E5	17	1 7		0	1 7
D15	17	1 7		0	1 7
D16	118	11 5	2	40	51 5
E6	58	5 7		0	5 7
D17	69	6 7	1	20	26 7
D18	65	6 3		0	6 3
D19	17	1 7		0	1 7
E7	17	1 7		0	1 7
D21	17	1 7		0	1 7
D20	17	1 7		0	1 7
D22	171	16 7		0	16 7
E8	589	57 4	3	60	117 4
D23	120	11 7		0	11 7
E9	226	22 0	2	40	62 0
D24	267	26 0	1	20	46 0
D25	17	1 7		0	1 7
D26	17	1 7		0	1 7
D27	17	1 7		0	1 7
D28	66	6 4		0	6 4
E10	17	1 7		0	1 7
D29	17	1 7		0	1 7
D30	66	6 4		0	6 4
E11	17	1 7		0	1 7

Table 3 1-3 Summary of Pesticide Ranking Results in Sediments

Pesticides station	Pesticides Rank sum	Adjusted Pesticides Rank sum	# Reference Level Exceedances	Reference Level Exceedance score	Final Pesticides Rank sum
D31	62	6 0		0	6 0
D32	68	6 6		0	6 6
D33	17	1 7		0	1 7
D34	17	1 7		0	1 7
E12	17	1 7		0	1 7
D35	229	22 3	2	40	62 3
D36	17	1 7		0	1 7
D37	17	1 7		0	1 7
D38	17	1 7		0	1 7
E13	17	1 7		0	1 7
D39	17	1 7		0	1 7
E14	17	1 7		0	1 7
D40	120	11 7	1	20	31 7

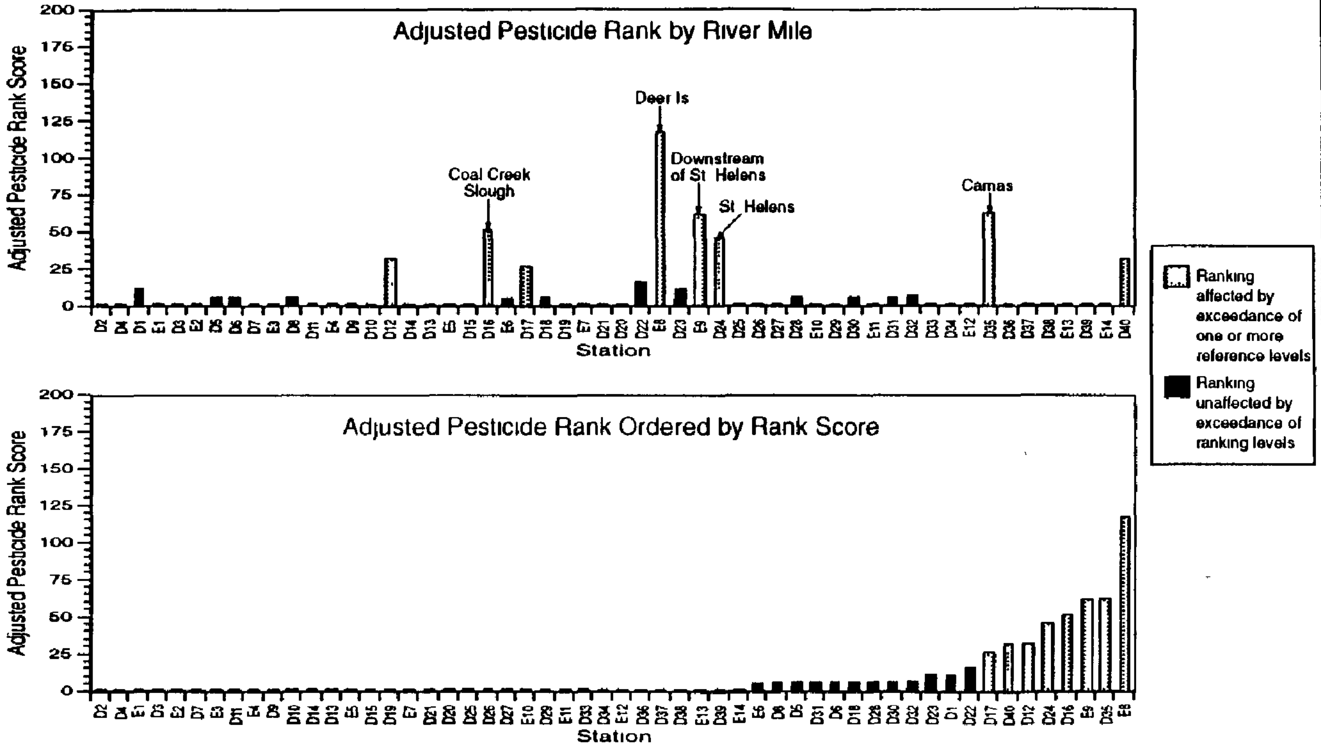


Figure 3.1-3. Summary of Pesticide Ranking Results in Sediments

As with metals, there is an indication of a general pesticide problem area in the middle of the study area. Five of the eight highly ranked stations lie between St. Helens and Kalama. These stations may be located in depositional areas that are collecting pesticides from a variety of potential sources such as those listed for metals in Section 3.1.2.1. One of the major sources of pesticides is agricultural runoff, which may enter the Columbia River from tributaries that drain agricultural areas. Other possible sources are local runoff, sewage treatment plants, and manufacturers/shippers of pesticides. The most prevalent pesticides, the DDTs, have been banned for over 20 years but are chemically persistent. These chemicals' presence in the sediments may be due less to runoff than to these persistent chemicals being recycled in the environment.

Station E8 (Deer Island) is by far the highest ranked sediment station for pesticides, with both the highest total rank sum (57.4) and the greatest number of effects level exceedances (3). This station is located within the general problem area between St. Helens and Kalama, but it is not clear why pesticide levels are particularly high at this station.

The results also indicate potential sources of pesticides in Camas (D35) and Coal Creek Slough (D16).

3.1.2.4 Dioxins and Furans. The results of the sediment station ranking for dioxins and furans are shown in Table 3.1-4 and Figure 3.1-4. These are not true rankings in that the score for each station is based directly on the toxicity equivalent concentration (TEC) calculated for each station.

The results show that two stations, D24 (St Helens) and D10 (Clifton Channel), had dioxin/furan levels that were clearly higher than the other stations Station D18 (downstream of Longview) was also high. These three stations stood out from the rest, based on TEC. Dioxins and furans were detected at all 20 stations at which they were sampled for.

Considering the high toxicity of dioxins and furans, and the high level of concern about their potential impact on the Columbia River, additional sampling should be conducted in the areas of Stations D24, D10, and possibly D18 to better characterize the extent and level of dioxin/furan occurrence.

3.1.2.5 Organotins. The results of the sediment station ranking for organotins are shown in Table 3.1-5 and Figure 3.1-5. There are no effect-based reference levels for organotins. Organotins were detected

TABLE 3.1-4 SUMMARY OF DIOXIN/FURAN RANKING RESULTS IN SEDIMENTS

Dioxin/Furan Station[a]	TEC Concentration	Adjusted TEC Score	Number of Reference Level Exceedances	Reference Level Exceedance Score	Final TEC Rank Sum
D4	1 7264	23 8		0	23 8
D5	1 1776	16 3		0	16 3
D6	0.99276	13 7		0	13 7
D8	0 67218	9 3		0	9 3
D11	1 48009	20 4		0	20 4
D10	4 5984	63 5		0	63 5
D14	1 09776	15 2		0	15 2
D15	1 00915	13 9		0	13 9
D16	2 10791	29 1		0	29 1
D18	2 9236	40 4		0	40 4
D19	0 76275	10 5		0	10 5
D20	2 0986	29 0		0	29 0
D23	1 0754	14 9		0	14 9
D24	7 23976	100 0		0	100 0
D26	0 60924	8 4		0	8 4
D28	1 79904	24 8		0	24 8
D30	1 07559	14 9		0	14 9
D35	1 6088	22 2		0	22 2
D38[a]	0 25665	3 5		0	3 5
D40	1 01282	14 0		0	14 0

[a] All stations were classified as fine grained (i e , >20% finer than 100 μm) with the exception of D38 which was reclassified as a coarse-grained station

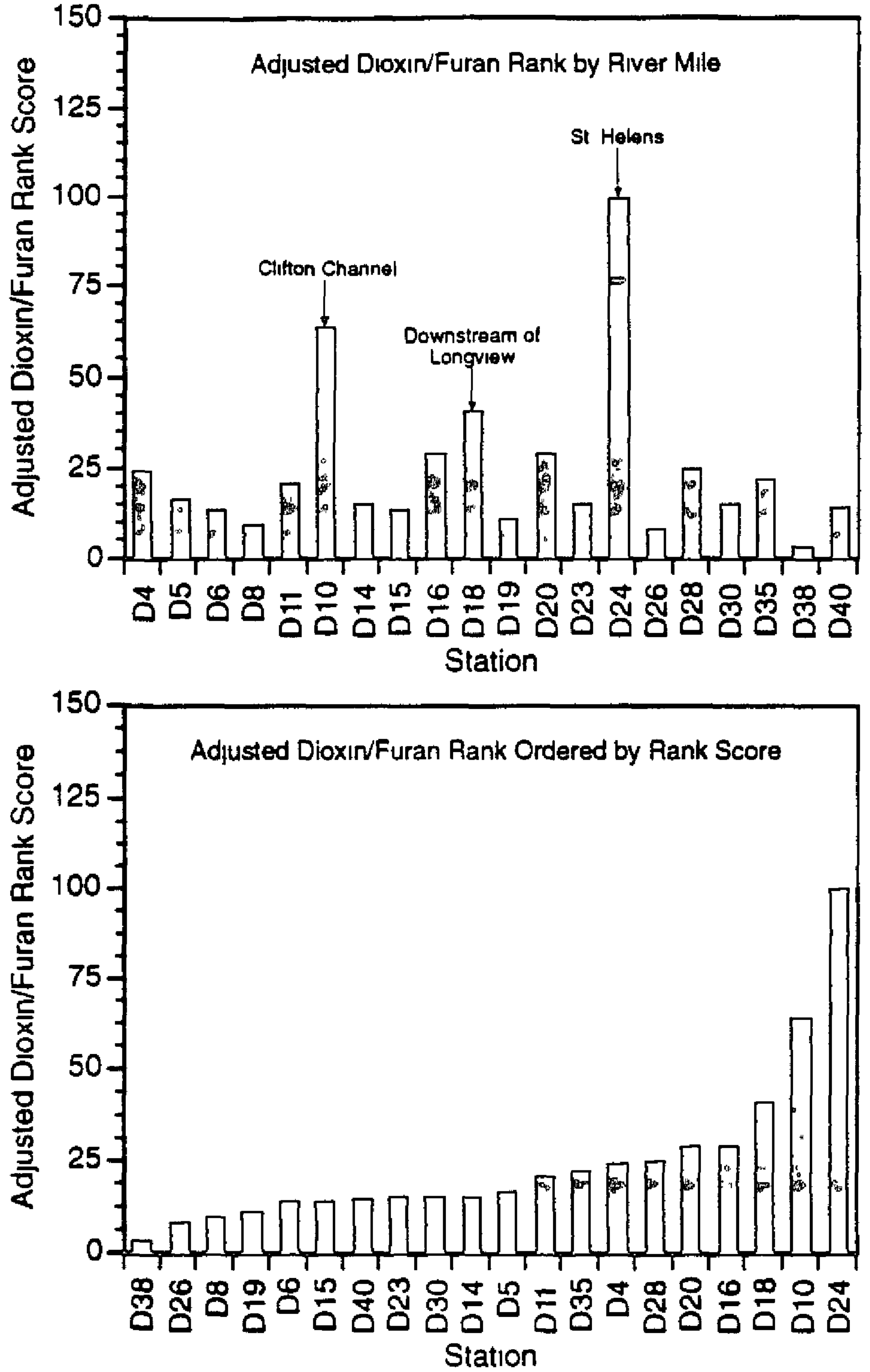


Figure 3.1-4. Summary of Dioxin/Furan Ranking Results in Sediments

Table 3.1-5. Summary of Organotin Ranking Results in Sediments

Organotins Station	Triethyl Butyl Tin rank	Diethyl Dibutyl Tin	Ethyl Tributyl Tin	Organotins Rank sum	Adjusted Organotins Rank sum	# Reference Level Exceedances	Reference Level Exceedance score	Final Organotins Rank sum
D2	1	1	1	3	10.0			10.0
D3	1	1	1	3	10.0			10.0
D12	1	8	8	17	56.7			56.7
D19	10	1	10	21	70.0			70.0
D22	1	9	7	17	56.7			56.7
D24	1	10	9	20	66.7			66.7
D29	1	1	6	8	26.7			26.7
D31	1	1	1	3	10.0			10.0
D37	1	1	1	3	10.0			10.0
D40	1	1	1	3	10.0			10.0

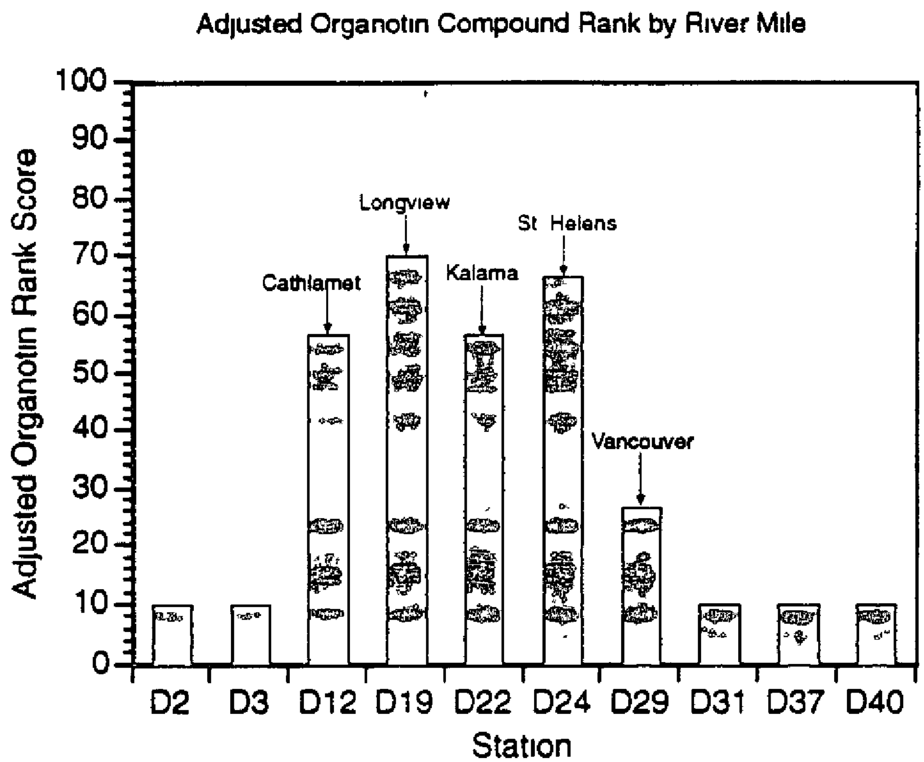


Figure 3.1-5. Summary of Organotin Ranking Results in Sediments

at seven of the ten stations sampled, but the laboratory had high confidence in the detection at five stations: D12 (Cathlamet), D19 (Longview), D22 (Kalama), D24 (St. Helens), and D29 (Vancouver).

The rank sum for Station D29 was considerably lower than for the other four stations. Organotins are used as biocides on the hulls of boats and ships, and so detection of these chemicals in the above areas with high boat traffic is not surprising. The fact that organotins were found at most of the stations sampled indicates that they may be widespread in the lower Columbia, and more reconnaissance-type sampling may be warranted (see Section 3 2 1). Additional problem confirmation sampling in the above-listed sites should include organotin analysis.

3.1.2.6 Overall Ranking. The overall sediment station rankings are shown in Table 3 1-6 and Figure 3.1-6 Several patterns are discernable in these results First, with the exception of D35 (Camas), all of the highly ranked stations are located in the lower part of the study area, below St. Helens (Figure 3.1-6). This suggest that major inputs of pollutants to the river are occurring at and/or below the St. Helens/Multnomah Channel/Lewis River area. The highly ranked stations below this point could be depositional areas collecting contaminants from many sources, indicators of local pollutant input, or a combination of both.

The Willamette River is a potential major source of pollutants to the lower Columbia, but the stations immediately below the Willamette are ranked relatively low. These stations are fairly coarse-grained and not likely to be depositional. Therefore, pollutants discharged by the Willamette may be carried further downstream before settling in the sediments.

From Figure 3 1-6, a group of seven highest ranked stations can be identified: D24 (St. Helens), $E9^D$ (below St. Helens), D22 (Kalama), D35 (Camas), E8 (Burke Slough), D19 (Longview), D6 (Grays Bay). Consistent with the pattern for metals and pesticides, many of these highly ranked stations are located between St. Helens and Kalama, indicating a general sediment problem area in this reach. Four of the top seven stations are located in this reach: D24, $E9^D$, D22, and E8. Two of these stations, D24 and $E9^D$, have rank sums considerably higher than the others

Table 3.1-6 Summary of Overall Ranking Results in Sediments

SEDIMENT Station	Final Metals Rank sum	Final PAH Rank sum	Final Pesticides Rank sum	Final Organotin Rank sum	Final TEC Rank sum	TOTAL CHEMICAL RANK SUM	NUMBER OF CHEMICAL CLASSES	FINAL RANK ADJUSTED FOR # OF CHEM CLASSES	RELATIVE RANKING SCORE
D2	129.2	1.9	1.7	10.0		142.7	4	35.7	42.0
D4	48.8	1.9	1.7		23.8	76.2	4	19.0	22.4
D1	96.3	1.9	12.0			110.2	3	36.7	43.3
E1	18.2	1.9	1.7			21.7	3	7.2	8.5
D3	58.8	1.9	1.7	10.0		72.3	4	18.1	21.3
E2	17.4	1.9	1.7			20.9	3	7.0	8.2
D5	28.7	1.9	5.8		16.3	52.7	4	13.2	15.5
D6	171.8	1.9	6.1		13.7	193.5	4	48.4	57.0
D7	49.4	1.9	1.7			52.9	3	17.6	20.8
E3	39.8	1.9	1.7			43.4	3	14.5	17.1
D8	49.5	1.9	5.8		9.3	66.4	4	16.6	19.6
D11	51.9	1.9	1.7		20.4	75.8	4	19.0	22.3
E4	58.5	1.9	1.7			62.0	3	20.7	24.4
D9	118.7	1.9	1.7			122.2	3	40.7	48.0
D10	38.0	1.9	1.7		63.5	105.0	4	26.2	30.9
D12	62.1	1.9	31.8	56.7		152.4	4	38.1	44.9
D14	22.4	1.9	1.7		15.2	41.1	4	10.3	12.1
D13	23.3	1.9	1.7			26.8	3	8.9	10.5
E5	12.8	1.9	1.7			16.3	3	5.4	6.4
D15	29.6	1.9	1.7		13.8	47.0	4	11.8	13.9
D16	71.3	1.9	51.5		29.1	153.7	4	38.4	45.3
E6	17.5	1.9	5.7			25.0	3	8.3	9.8
D17	21.2	1.9	26.7			49.7	3	16.6	19.5
D18	25.8	1.9	6.3		40.4	74.4	4	18.6	21.9
D19	10.0	159.6	1.7	70.0	10.5	251.8	5	50.4	59.4
E7	6.3	1.9	1.7			9.9	3	3.3	3.9
D21	80.5	1.9	1.7			84.0	3	28.0	33.0
D20	76.7	1.9	1.7		29.0	109.2	4	27.3	32.2
D22	129.0	1.9	16.7	56.7		204.2	4	51.1	60.2
E8	13.8	20.0	117.4			151.2	3	50.4	59.4
D23	59.9	1.9	11.7		14.9	88.3	4	22.1	26.0
E9	65.1	87.0	62.0			214.1	3	71.4	84.1
D24	72.3	139.3	46.0	66.7	100.0	424.2	5	84.8	100.0
D25	77.7	1.9	1.7			81.2	3	27.1	31.9
D26	23.9	1.9	1.7		8.4	35.9	4	9.0	10.6

Table 3 1-6 Summary of Ov[illegible] Ranking Results in Sediments

SEDIMENT Station	Final Metals Rank sum	Final PAH Rank sum	Final Pesticides Rank sum	Final Organotin Rank sum	Final TEC Rank sum	TOTAL CHEMICAL RANK SUM	NUMBER OF CHEMICAL CLASSES	FINAL RANK ADJUSTED FOR # OF CHEM CLASSES	RELATIVE RANKING SCORE
D27	31 4	1 9	1 7			34 9	3	11 6	13 7
D28	40 9	1 9	6 4		24 8	74 0	4	18 5	21 8
E10	27 7	1 9	1 7			31 2	3	10 4	12 3
D29	37 7	1 9	1 7	26 7		67 9	4	17 0	20 0
D30	56 4	1.9	6 4		14 9	79 6	4	19 9	23 4
E11	73 2	1 9	1 7			76 7	3	25 6	30 1
D31	41 4	1 9	6 0	10 0		59 3	4	14 8	17 5
D32	36 4	38 9	6 6			82 0	3	27 3	32 2
D33	43 1	1 9	1 7			46 6	3	15 5	18 3
D34	19 8	1 9	1 7			23 4	3	7 8	9 2
E12	4 2	1 9	1 7			7 7	3	2 6	3 0
D35	132 8	1 9	62 3		22 2	219 1	4	54 8	64 6
D36	42 9	1 9	1 7			46 4	3	15 5	18 2
D37	51 1	1 9	1 7	10 0		64 6	4	16 2	19 0
D38	27 7	1 9	1 7		3 5	34 8	4	8 7	10 2
E13	51 0	1 9	1 7			54 5	3	18 2	21 4
D39	25 3	1 9	1 7		14 0	42 8	4	10 7	12 6
E14	41 4	1 9	1 7			44 9	3	15 0	17 6
D40	57 2	1 9	31 7	10 0		100 8	4	25 2	29 7

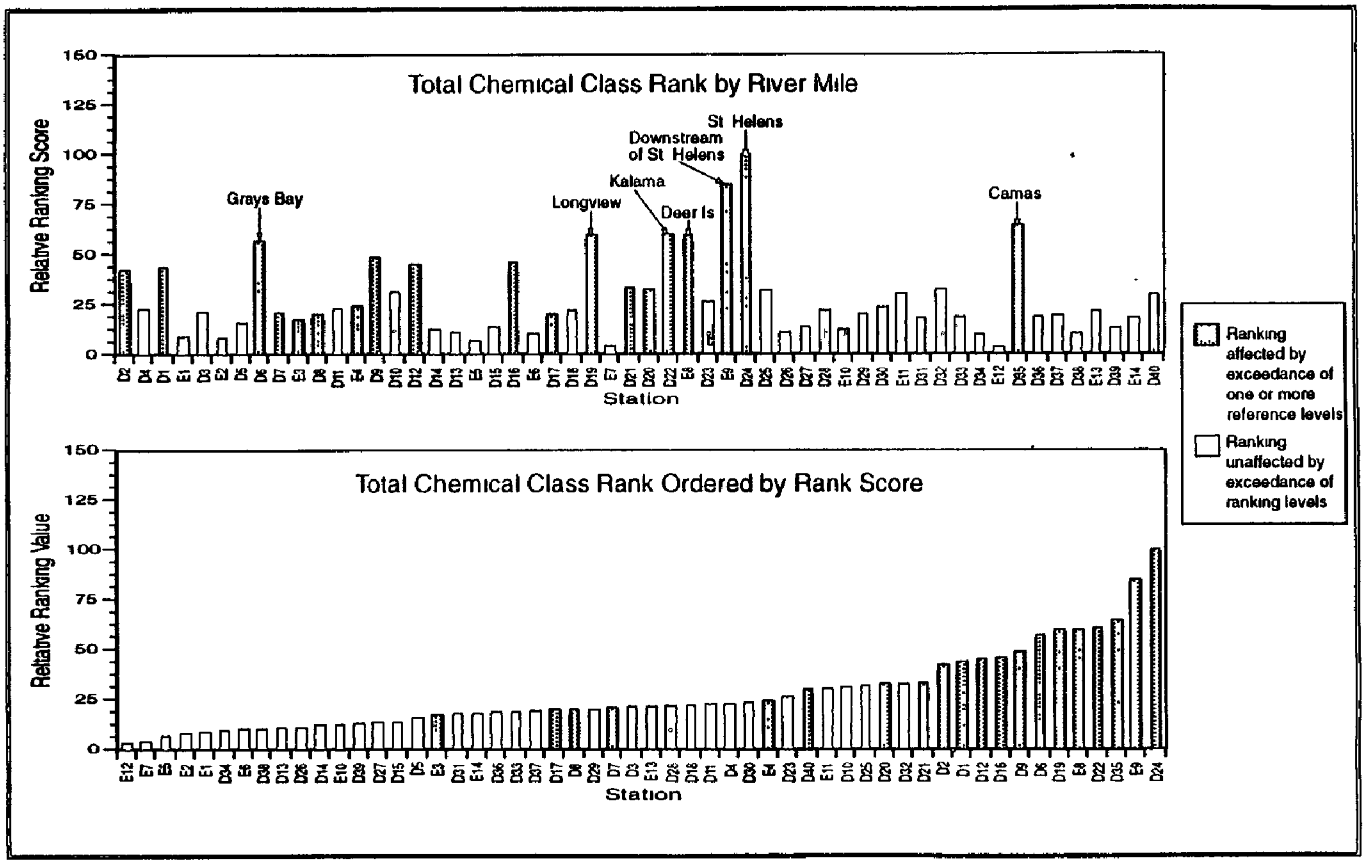


Figure 3 1-6. Summary of Total Ranking of all Chemical Classes in Sediments

The reasons for high ranking of the top seven sediment stations are described below:

- **D24 (St. Helens):** The highest rank for dioxins/furans and organotins; high ranks for pesticides and PAHs-; moderate rank for metals

- **E9[D] (Downstream of St. Helens):** High ranks for pesticides and PAHs; moderate metals rank

- **D35 (Camas):** High ranks for metals and pesticides, moderate-low rank for dioxins/furans.

- **D22 (Kalama):** High ranks for metals and organotins, low-moderate ranks for PAHs and pesticides

- **E8 (Deer Island):** Highest pesticide ranks; low-moderate for PAHs, low for metals.

- **D19 (Longview):** High ranks for PAHs and organotins, low ranks for pesticides, metals, and dioxins/furans

- **D6 (Grays Bay):** Highest metals rank; low ranks for other chemical groups.

The above stations should be given high priority for additional, problem confirmation sampling. Efficient allocation of resources may require future sampling to focus on the indicated problem chemicals at each station. For example, future sediment testing at station D6 perhaps should address only metals Station D19 is ranked high based primarily on two minor chemical groups, PAHs and organotins. Future sediment sampling at this site perhaps should be given only moderate priority, or should focus on PAHs and organotins.

From Figure 3 1-6, a second group of five highly ranked stations can be discerned below the first group of seven. These five stations are: D9 (Skamokawa), D2 (Ilwaco), D16 (Coal Creek Slough), D12 (Cathlamet), and D1 (Hammond, OR). These stations tend to be highly ranked based on fewer chemical groups than the top seven (Table 3.1-6), and so identifying them as general problem areas is not warranted. However, these stations should be considered for additional surveys of river-wide problem chemicals as identified in Section 3.2.2. In addition, the ranks of these five stations, as well as the top seven stations, should be combined with identified tissue problem areas (Section 3.1.3) in identifying overall top problem areas for future study.

Consideration of Information from Tasks 1 through 5

Table 3.1-7 presents information from Tasks 1,2,3 and 5 for the top-ranked sediment sections. Each station gets a "hit" if it confirms a potential problem area identified in Task 1, is located near a beneficial use area (Task 5), is near a known source of pollutants found at the station (Task 2), or is a depositional area that may be a risk for contaminants (Tasks 3 and 6). The purpose of this analysis is to determine whether any stations should be moved up or down in the ranking based on this additional information For example, a station perhaps should be moved up in the ranking if it gets a hit (indicated by an X in the table) for all four of these factors.

It is interesting that the three top-ranked (based on contaminants) stations (D24, E9[D] and D35) have either three or four hits, confirming their high priority (Table 3 1-7). The other stations in the top group of seven have from one to three hits. Removing any of these stations from the top-ranked group based on these results is not recommended because of the importance of their high level of contamination.

Among the second group of stations (D9 through D2 in Table 3 1-7), the bottom two stations (D1 and D2) have three hits each. These results confirm that these two stations should be maintained at least in the second-ranked group of stations, and consideration should be given to including these stations in the high-priority group in future studies. The fact that these two stations are located in the estuary increases somewhat the importance of conducting additional problem confirmation sampling in the estuary.

Several stations ranked below D2 based on contamination (Table 3.1-7) have three hits. However, the contamination rating for these stations is so much lower (30.1-33.0) than those of the top group (57.0-100.0) that upgrading any of these lower-ranked stations to the first-ranked stations to the first-ranked or even second-ranked group (which also contains several stations with three hits) does not seem justified.

TABLE 3 1-7 CONSIDERATION OF ADDITIONAL FACTORS FOR 20 TOP-RANKED SEDIMENT STATIONS

		Additional Factors				
Station[a]	Final Ranking Score[b]	Task 1 Problem Area[c]	Beneficial Use[d]	Pollution Source[e]	Depositional Area[f]	Combined Score
D24	100 0	X	X	X	X	100 0 XXXX
E9[D]	84 1		X	X	X	84 1 XXX
D35	64 6	X	X	X		64 6 XXX
D22	60 2		X		X	60 2 XX
E8	59 4		X			59 4 X
D19	59 4	X	X	X	X	59 4 XXXX
D6	57 0		X			57 0 X
D9	48 0		X			48 0 X
D16	45 3		X		X	45 3 XX
D12	44 9		X		X	44 9 XX
D1	43 3	X	X		X	43 3 XXX
D2	42 0	X	X		X	42 0 XXX
D21	33 0		X	X	X	33 0 XXX
D32[E]	32 2	X	X	X		32 2 XXX
D20	32 2		X	X	X	32 2 XXX
D25	31 9		X		X	31 9 XX
D10	31 0		X	X	X	31 0 XXX
E11[D]	30 1	X	X	X		30 1 XXX
D40	29 7		X			29 7 X
D23	26 0		X		X	26 0 XX

Note Stations classified as coarse-grained have been shaded

[a] Station number prefixes "D" and "E" were assigned prior to sampling to stations expected to have fine-grained and coarse-grained sediments, respectively Following sampling, some stations were reclassified based on the grain size analysis [> 20% fines (< 100 μm) was considered a fine-grained sediment station] Reclassifed stations are identified by superscript "E" or "D"

[b] From Table 3 1-6

[c] Confirms a potential problem area identified in Task 1 (past studies) for same chemical group

[d] Station located within 3 miles of a beneficial use site as identified in Task 5

[e] Station located within 5 miles downstream of known source of contaminants found at the station

[f] Station classified as depositional (at least 50% of sediments finer than 100 μm)

3.1.3 Tissue

This section describes the results of the tissue station ranking. Prioritization of problem areas for contaminants measured in tissue is complicated by the fact that measurements were made for five different species (crayfish, largescale sucker, carp, peamouth, and white sturgeon). Potential differences among species in exposure to contaminants because of differences in feeding habits and mobility, and the fact that not all species were collected throughout the study area makes identification of problem areas more difficult than in other media.

In the following discussion, conclusions regarding problem areas are based primarily on tissue contaminant patterns in crayfish and largescale sucker because both of these organisms were collected from stations throughout the lower Columbia River (RM 20 to RM 141). This allows contaminant levels to be compared throughout the study area Ranking scores for these two species at each station were summed and expressed as a percentage of the maximum score to obtain an overall priority ranking for tissue.

Analysis of contaminant levels in peamouth and carp were made for fish collected over only a portion of the study area. Thus, while differences among stations for these species are informative, it is not possible to compare all stations within the lower Columbia River Rankings from both of these species were used to support conclusions reached for crayfish and largescale sucker, or to indicate additional stations that should be considered as problem areas.

Tissue contaminant data for white sturgeon were not considered in the identification of problem areas Contaminant levels in sturgeon represent the integrated spatial and temporal exposure to contaminants over the range and lifetime of the individual fish analyzed. Because of the age of the fish collected (mean age from 7 to 20 years) and the mobility of this species, tissue contaminant levels are not likely to be correlated with collection locations. Therefore, this species is not a good indicator of specific problem areas.

Ranking results for PAHs and other semivolatiles in tissue are not presented or discussed in this section because of the infrequent detection of the chemicals in tissue. The results for these chemicals were included in the overall tissue rankings, however.

In the following sections, tissue ranking results are presented in figures only for brevity. Tables summarizing the tissue ranking results are included in Appendix A.

3.1.3.1 Metals. The combined ranking of metals for crayfish and largescale sucker are shown in Figure 3 1-7 Four stations stand out from the rest as having the highest tissue metal concentrations These stations are:

- D40 (Beacon Rock)
- D28 (Sauvie Island)
- $D38^E$ (Reed Island)
- D6 (Grays Bay)

The ranking scores for carp are shown in Figure 3 1-8 This figure provides an example of the differences that were observed between species While station D40 had the highest overall combined ranking for crayfish and largescale sucker, it was ranked fourth for carp. Station $D38^E$, which was ranked number three for crayfish and largescale sucker, was the station with the highest metals concentrations for carp. The second highest metals ranking for carp was at station D26. This result, combined with the fact that station D26 was rated number five in the crayfish and largescale sucker ranking, suggests that it should also be added to the list of stations of potential concern for metals

The metals ranking for peamouth was quite different from other species (Figure 3 1-9), with only one of the top five stations corresponding to that named for other species (Station D28). The two highest ranked stations for peamouth were station D24 and station D15 The fact that both of these stations were ranked quite low for other species is justification for not including them in a list of stations of high priority for metals.

The high priority stations based on crayfish, largescale sucker, carp, and peamouth rankings of metal concentrations are:

- D40 (Beacon Rock)
- D28 (Sauvie Island)
- $D38^E$ (Reed Island)

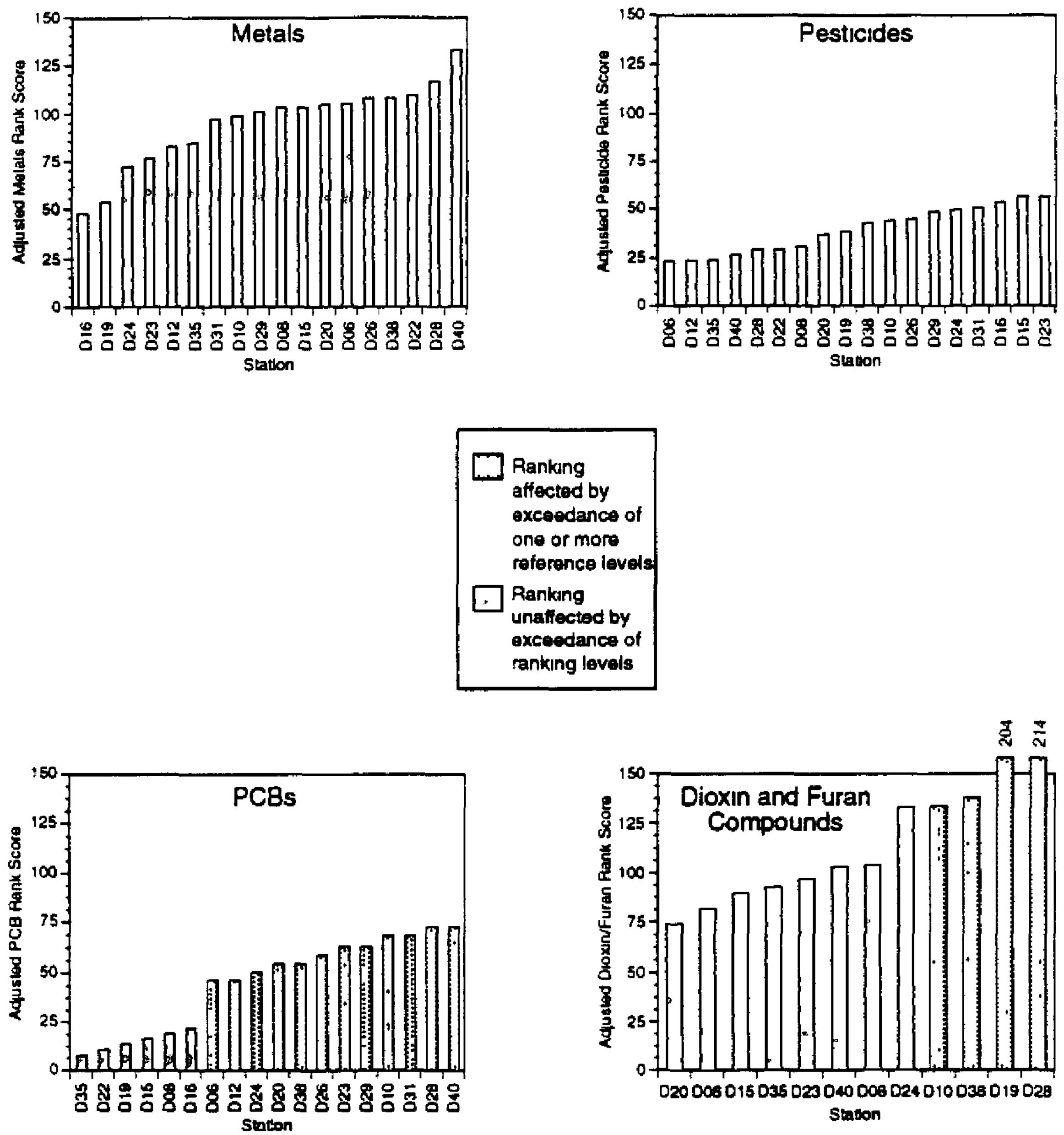


Figure 3.1-7. Crayfish and Sucker combined tissue ranking scores for major chemical groups

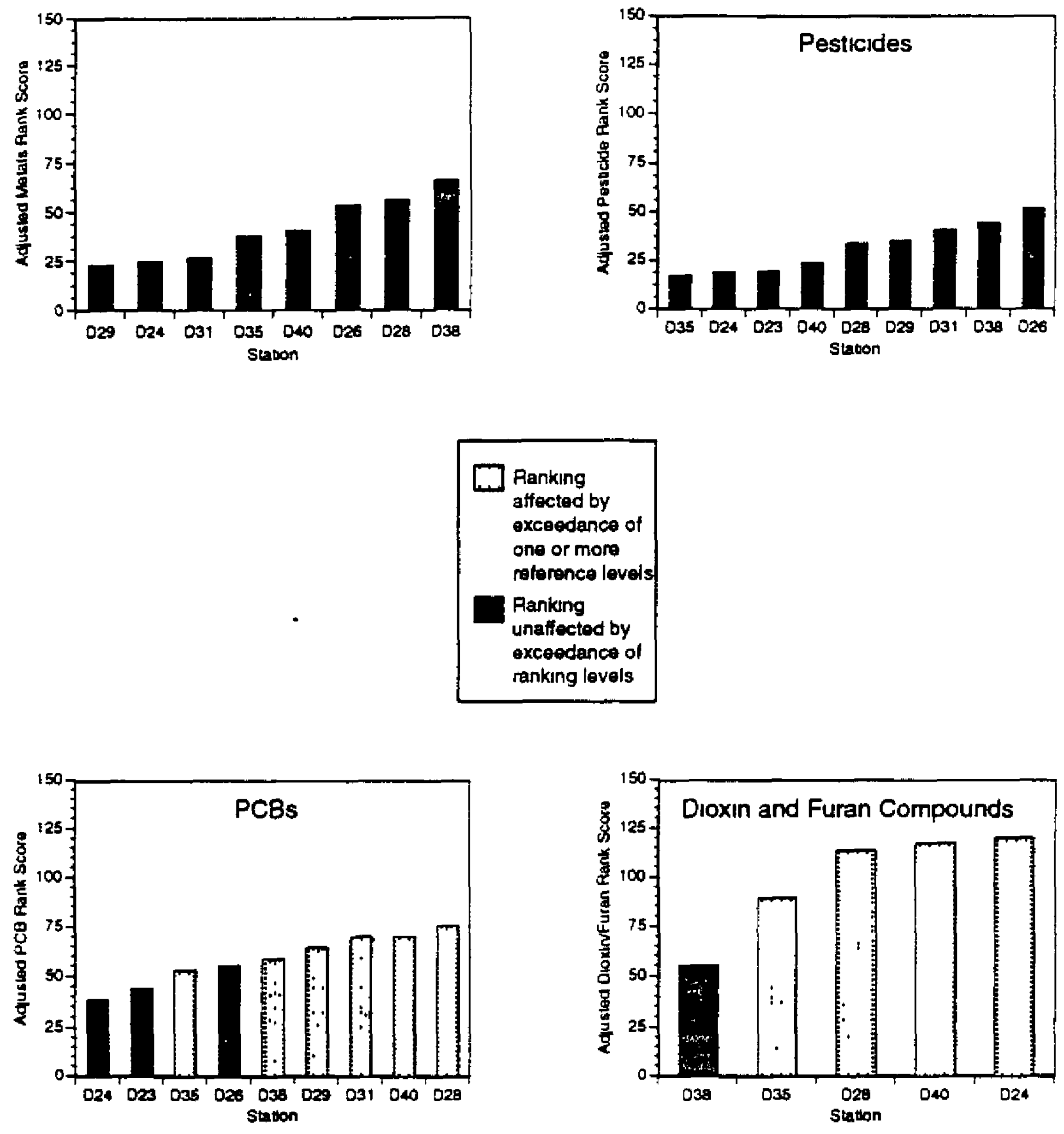


Figure 3.1-8. Carp tissue ranking scores for major chemical groups

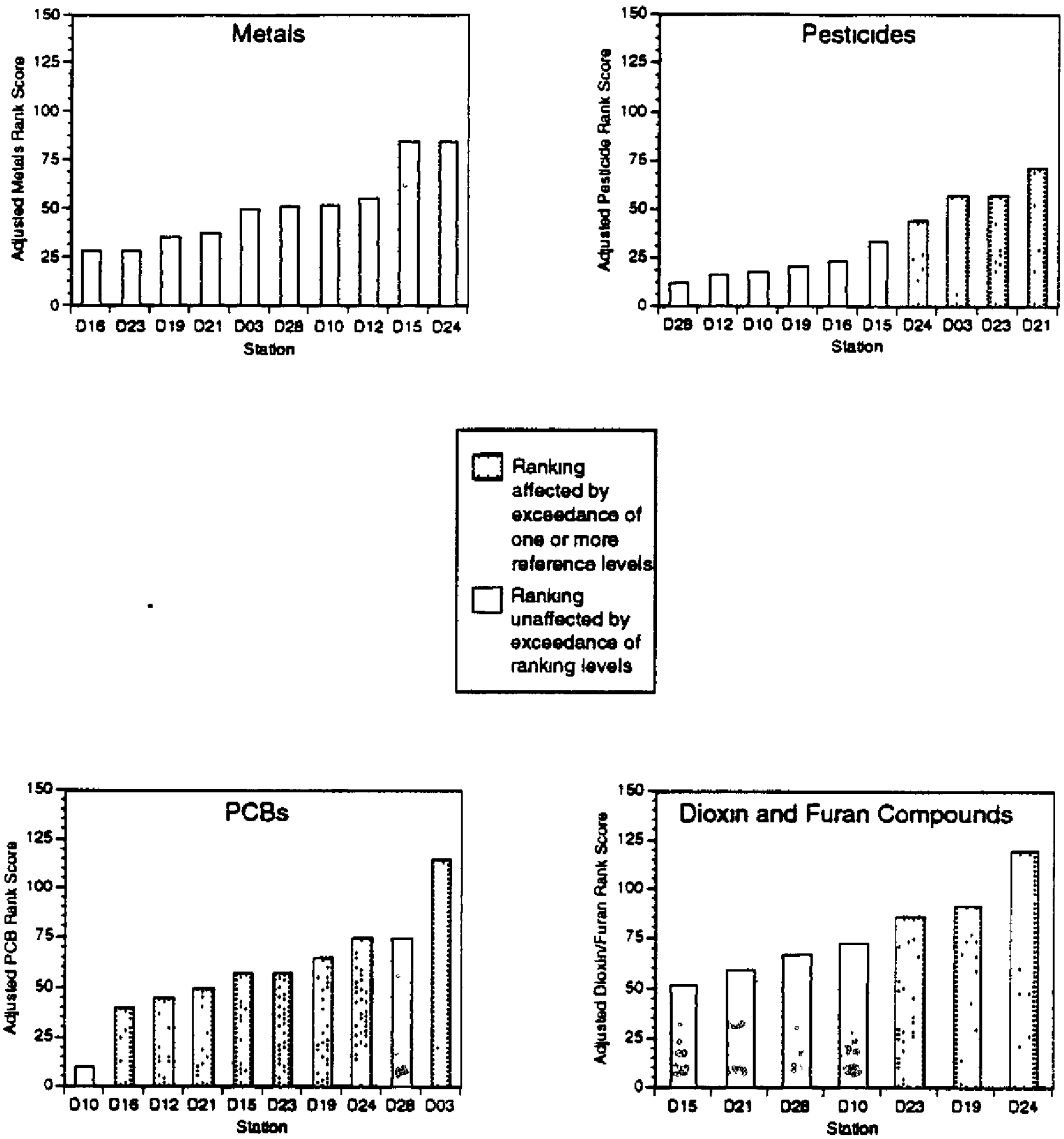


Figure 3.1-9. Peamouth tissue ranking scores for major chemical groups

- D6 (Grays Bay)
- D26 (Bachelor Point)

With the exception of Station D6, all of these station are located in the upper reaches of the lower Columbia River above RM 92 5 Stations D40 (RM 141) and D38[E] (RM 125) were located below Bonneville Dam and are not impacted by any known point sources that might contribute to the elevated tissue metals concentrations Stations D28 (RM 98) and D26 (RM 92 5) are located 3 and 8 5 miles downstream of the mouth of the Willamette River, respectively, and are located downstream of the Portland/Vancouver metropolitan area. Station D6 is located in the estuary in Grays Bay near the mouths of the Grays and Deep rivers at RM 22 5

3 1 3.2 ***Pesticides*** The combined ranking of pesticides for crayfish and largescale sucker are shown in Figure 3 1-7 There is no apparent cluster of high ranking scores, however, the top five stations are

- D23 (Burke Slough)
- D15 (Wallace Slough)
- D16 (Coal Creek Slough)
- D31 (North Portland Harbor)
- D24 (St Helens)

The ranking scores for carp pesticides are shown in Figure 3 1-8 The top five ranked stations for carp all fall between RM 92 5 and RM 125 5 (i e , from downstream of Portland/ Vancouver to just upstream of Washougal, WA) Station D31 is the only station in this group that coincides with the sites indicated for crayfish and largescale sucker

The ranking scores for peamouth are shown in Figure 3 1-9 Peamouth collected from the top four ranked stations (D21, D23, D3, and D24) all had tissue concentrations of that exceeded New York State (NYS) reference levels for the protection of piscivorous wildlife Peamouth from Station D21, which had the highest ranking, had tissue levels which exceeded NYS criteria for hexachlorocyclohexane (Table 3 1-8), while fish from Stations D23, D3 and D24 all had tissue levels of DDE which exceeded NYS criteria

TABLE 3 1-8 COMPARISON OF LOWER COLUMBIA RIVER RECONNAISSANCE SURVEY TISSUE DATA WITH PROPOSED NEW YORK STATE PISCIVOROUS FISH CRITERIA
(Page 1 of 2)

Chemical	New York State Proposed Non-Carcinogenic Fish Flesh Criteria[a]	Species	Median Concentration[b]	Number of Samples With Exceedances	Stations with Exceedances
4,4'-DDT	200 µg/kg	Carp	3 5 µg/kg	0	
		Crayfish	1 5 µg/kg	0	
		Peamouth	12 5 µg/kg	0	
		Sturgeon	2 3 µg/kg	0	
		Largescale sucker	5.15 µg/kg	0	
4,4'-DDE	200 µg/kg	Carp	22 µg/kg	0	
		Crayfish	7 5 µg/kg	0	
		Peamouth	**111 µg/kg**	**3**	**D3, D23, D24**
		Sturgeon	10 45 µg/kg	0	
		Largescale sucker	25 50 µg/kg	0	
4,4'-DDD	200 µg/kg	Carp	4 65 µg/kg	0	
		Crayfish	1 5 µg/kg	0	
		Peamouth	15 µg/kg	0	
		Sturgeon	1 5 µg/kg	0	
		Largescale sucker	17 µg/kg	0	
Aldrin	120 µg/kg	Carp	ND[c] (1 5 µg/kg)	0	
		Crayfish	ND (1.5 µg/kg)	0	
		Peamouth	ND (12.5 µg/kg)	0	
		Sturgeon	ND (1 5 µg/kg)	0	
		Largescale sucker	ND (1 5 µg/kg)	0	
Dieldrin	120 µg/kg	Carp	ND (1 5 µg/kg)	0	
		Crayfish	ND (1 5 µg/kg)	0	
		Peamouth	ND (12 5 µg/kg)	0	
		Sturgeon	ND (1 5 µg/kg)	0	
		Larrgescale sucker	ND (1 5 µg/kg)	0	
Endrin	25 µg/kg	Carp	ND (1 5 µg/kg)	0	
		Crayfish	ND (1 5 µg/kg)	0	
		Peamouth	ND (12 5 µg/kg)	0	
		Sturgeon	ND (1 5 µg/kg)	0	
		Largescale sucker	ND (1 5 µg/kg)	0	
Heptaclor	200 µg/kg	Carp	ND (1 5 µg/kg)	0	
		Crayfish	ND (1 5 µg/kg)	0	
		Peamouth	ND (12 5 µg/kg)	0	
		Sturgeon	ND (1 5 µg/kg)	0	
		Largescale sucker	ND (1 5 µg/kg)	0	
Hexachlorocyclohexane (BHC)[d]	100 µg/kg	Carp	ND (1 5 µg/kg)	0	
		Crayfish	ND (1 5 µg/kg)	0	
		Peamouth	ND (16.25 µg/kg)	0	
		Sturgeon	ND (1 5 µg/kg)	0	
		Largescale sucker	ND (1 5 µg/kg)	0	
Mirex	300 µg/kg	Carp	ND (1 5 µg/kg)	0	
		Crayfish	ND (1 5 µg/kg)	0	
		Peamouth	ND (12 5 µg/kg)	0	
		Sturgeon	ND (1 5 µg/kg)	0	
		Largescale sucker	ND (1 5 µg/kg)	0	

TABLE 3 1-8 COMPARISON OF LOWER COLUMBIA RIVER RECONNAISSANCE SURVEY TISSUE DATA WITH PROPOSED NEW YORK STATE PISCIVOROUS FISH CRITERIA

(Page 2 of 2)

Chemical	New York State Proposed Non-Carcinogenic Fish Flesh Criteria[a]	Species	Median Concentration[b]	Number of Samples With Exceedances	Stations with Exceedances
PCBs[e]	110 μg/kg	Carp	135 μg/kg	5	D28, D29, D31, D38, D40
		Crayfish	ND (50 μg/kg)	0	
		Peamouth	190 μg/kg	8	D3, D12, D15 D16 D19 D21, D23, D24
		Sturgeon	50 μg/kg	2	RM 75 (2 fish)
		Largescale sucker	150 μg/kg	12	D6, D10, D12, D20, D23, D24, D26, D28, D29, D31, D38, D40
Dioxin (2,3,7,8-TCDD Toxicity Equivalency Concentration)	3 pg/g	Carp	4.88 pg/g	4	D24, D28, D35, D40
		Crayfish	1.38 pg/g	2	D19, D28
		Peamouth	7.93 pg/g	7	D10, D15, D19 D21, D23, D24 D28
		Sturgeon	3 02 pg/g	4	RM 27, RM 49, RM 75 (2 fish)
		Largescale sucker	2.63 pg/g	4	D10, D19, D28, D38
Trichlorobenzenes	1300 μg/kg	Carp	100 μg/kg	1	D29
		Crayfish	ND (100 μg/kg)	0	
		Peamouth	ND (100 μg/kg)	0	
		Sturgeon	ND (100 μg/kg)	0	
		Largescale sucker	ND (100 μg/kg)	0	

[a] Newell et al (1987)

[b] In cases where data were reported as nondetected, one half the detection limit was used to calculate the median concentration

[c] Median concentration is less than the detection limit (ND)

[d] Data presented is for β-BHC.

[e] Median concentrations of PCBs were calculated by summing the concentrations of Aroclor 1254 and 1260, if either of these chemicals were reported as nondetected, one half the detection limit was used to calculate median concentration

Based on a consideration of the rankings from all species the following stations should be considered high priority sites for investigation of pesticide levels in biota:

- D23 (Burke Slough)
- D15 (Wallace Slough)
- D16 (Coal Creek Slough)
- D31 (N. Portland Harbor)
- D24 (St. Helens)
- D26 (Bachelor Point)
- D21 (below Kalama)
- D3 (Astoria)

These sites appear to fall into two general categories. Those that are located in sloughs (D23, D15, D16) and those that are located downstream of large urban areas (D31, D26, D24, D21, D3)

3.1.3.3 PCBs. The combined ranking of PCBs for crayfish and largescale sucker are shown in Figure 3.1-7. This ranking is based entirely on results from largescale sucker, as PCBs were not detected in crayfish at any sites within the lower Columbia River The most obvious feature of this figure is that at 12 of the 18 stations largescale sucker had PCB concentrations that exceeded NYS reference levels for the protection of piscivorous wildlife. The majority of stations where carp and peamouth were collected also had tissue concentrations that exceeded NYS wildlife reference levels for PCBs. In fact, all sites analyzed for tissue levels of PCBs had at least one species (largescale sucker, carp, peamouth) with PCB levels that exceeded the reference level for protection of piscivorous wildlife.

While all sites appear to warrant increased investigation due to elevated tissue levels of PCBs, the following stations had the highest ranking and may therefore be listed as priority sites for evaluation of PCB levels in biota:

- D31 (N. Portland Harbor)
- D10 (Clifton Channel)
- D28 (Sauvie Island)
- D29 (Vancouver Lake flushing channel)

- D23 (Burke Slough)
- D38[E] (Reed Island)
- D3 (Astoria)

3.1.3.4 Dioxins and Furans. The combined ranking of dioxins and furans for crayfish and largescale sucker are shown in Figure 3.1-7. These rankings were based on toxicity equivalent concentrations (TEC) of 2,3,7,8-TCDD, rather than the concentrations of individual congeners. Five stations stand out from the rest of the sites in the river:

- D28 (Sauvie Island)
- D19 (Longview)
- D38[E] (Reed Island)
- D10 (Clifton Channel)
- D24 (St Helens)

The top four of these stations all had TEC tissue concentrations that exceeded NYS wildlife criteria for protection of piscivorous wildlife

Figures 3.1-8 and 3.1-9 show the dioxin/furan ranking for carp and peamouth, respectively. Carp collected from the top four ranked stations all had TEC concentrations that exceeded the NYS reference level for dioxins. Of these four stations, all but D40 and D35 are listed above. Three of the seven sites sampled for peamouth exceeded the NYS reference level for dioxin. Station D23 was the only site not listed above for other species.

Three quarters of the stations where dioxins and furans were analyzed had at least one species with tissue levels that exceeded the NYS reference level for dioxin These sites all warrant increased investigation due to elevated levels of dioxins and furans:

- D28 (Sauvie Island)
- D19 (Longview)
- D38[E] (Reed Island)
- D10 (Clifton Channel)

- D24 (St Helens)
- D40 (Beacon Rock)
- D35 (Camas Slough)
- D23 (Burke Slough)

3.1.3.5 Overall Ranking Scores. Figure 3 1-10 shows the overall ranking scores for tissue for crayfish, largescale sucker, carp, and peamouth. This figure shows that the vast majority of stations analyzed for tissue contaminants had at least one species with levels that exceeded the NYS reference levels for protection of piscivorous wildlife. This result might indicate that virtually all stations warrant some investigation regarding the uptake of contaminants by biota. Overall, the stations that received the highest ranking score and appear to be priority sites for increased investigation are:

- D28 (Sauvie Island)
- $D38^E$ (Reed Island)
- D19 (Longview)
- D10 (Clifton Channel)
- D40 (Beacon Rock)
- D24 (St. Helens)
- D29 (Vancouver Lake flushing channel)
- D3 (Astoria)

It is perhaps surprising that stations D40 and $D38^E$ are included on this final list of priority sites. Both of these sites are located at the upper end of the study area, above any known point sources of contaminants. These sites may be examples of depositional environments which increase the bioavailability of contaminants to biota by serving as sinks for contaminants from upstream sources. All of the other sites listed are located downstream of potential sources of contaminants. Station D28 is located downstream of the Portland/Vancouver metropolitan area and is also influenced by the discharge from the Willamette River. Station D29 is located in a flushing channel connecting Vancouver Lake with the Columbia River downstream from the mouth of Willamette River. Stations D19, D10, and D24 are all located downstream of bleach kraft pulp and paper mill discharges. Site D24 also may be a repository for contaminants discharged from the Multnomah Channel. Station D3 is located near the City of Astoria.

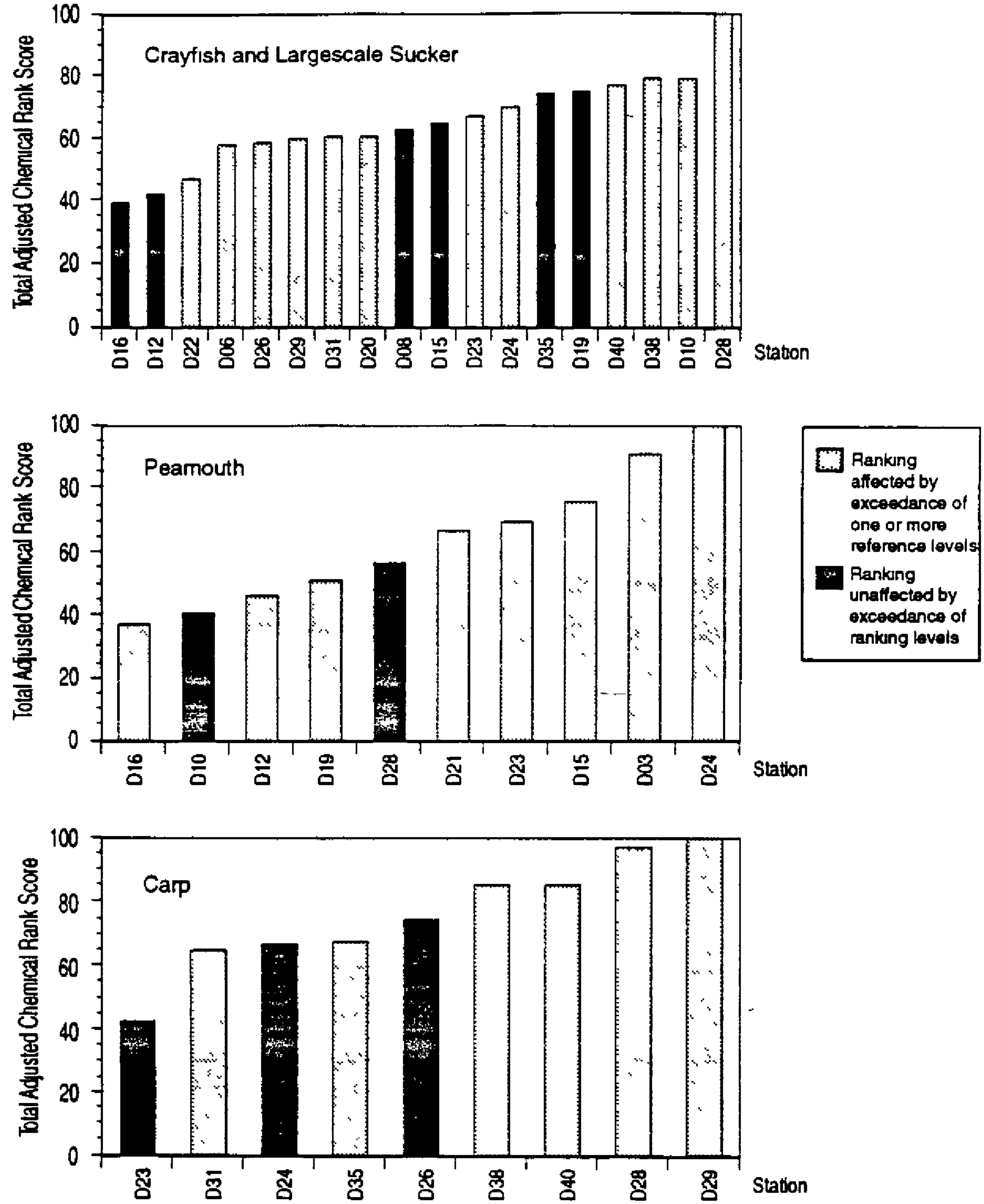


Figure 3.1-10. Total Adjusted Tissue Rank Scores for Fish Species Analyzed from the lower Columbia River

3.2 PROBLEM CHEMICALS/PARAMETERS

This section addresses chemical groups and parameters identified as potential water quality problems in the lower Columbia River as a whole. This identification is based on the frequency of detection of chemicals and parameters, and the frequency of exceedance of effects-based reference values for these chemicals and parameters in the lower river overall, without regard to measurements at specific locations. Problem chemical/parameters are addressed in the following sections for each medium separately. Table 3.2-1 shows, for each medium, the mean frequency of detection (percent of stations), and the mean frequency of reference value exceedance (percent of detected values exceeding reference value), for the chemicals within each chemical group

3.2.1 Water

Table 3.2-1 shows the results for the chemical groups detected in water (metals and AOX) and the conventional parameters (e.g., dissolved oxygen and temperature) for which there are state or federal criteria. The conventional parameters were detected at every station due to the availability of adequate laboratory or field measurement methods, and so the frequency of detection is not informative and is not reported in Table 3.2-1 for conventional parameters. Organic chemicals were detected so rarely in water samples that this chemical group is omitted from the table. The survey data provided no evidence for organic chemical problems in the water column due to the limitations of sampling and laboratory methods to quantify the concentrations of these contaminants in the water column.

3.2.1.1 Metals. Metals were detected frequently in the water samples. The average frequency of detection for the metals was 30 percent, and an average (by metal) of 64 percent of these detections exceeded the state or federal chronic criterion. The frequency of detection and criterion exceedance for individual metals were:

TABLE 3 2-1 PROBLEM CHEMICAL/PARAMETER SUMMARY
FREQUENCY OF DETECTION AND FREQUENCY OF
EXCEEDANCE OF EFFECTS-BASED REFERENCE VALUE
FOR EACH CHEMICAL GROUP/PARAMETER, BY MEDIUM
VALUES SHOWN ARE MEANS FOR EACH CHEMICAL GROUP

Chemical Group/Parameter	Mean Percent Stations Detected	Mean Percent Detections Exceeding Reference Value	Combined Score
Water			
Metals	30	64	47
AOX	95	NA	95
Bacteria	-	75	75
DO	-	29	29
pH	-	0	0
Temperature	-	0	0
Unionized Ammonia	-	0	0
Sediment			
Metals	65	10	38
PAHs	4	9	6 5
Other Semivolatiles	1	0	1
Pesticides	3	52	28
PCBs	0	0	0
Dioxins and Furans	96	NA	96
Organotins	60	NA	60
Tissue			
Metals	58	NA	58
PAHs	0 5	NA	0.5
Other Semivolatiles	1 7	2.1	1 9
Pesticides	9 7	2 6	6 2
PCBs	8 6	68	38
Dioxins and Furans	68	48	58

Metal	Percent Stations Detected	Percent Detections Exceeding Criteria
Aluminum	24	100
Barium	98	No Criterion
Cadmium	7	100
Chromium	7	0
Copper	22	70
Iron	24	36
Lead	56	84
Selenium	7	100
Zinc	27	25

The above results would seem to indicate that several metals (aluminum, cadmium, copper, lead, selenium, and possibly iron and zinc) should be considered problem chemicals. Several factors, however, suggest caution in identifying problem chemicals among the metals. First, metals have many natural sources, so that detection alone is not cause for concern. Second, the water quality criteria are based on studies of the effects of dissolved metals, while this study measured total recoverable metals which is generally considered to be more conservative. Since most of the metal atoms in the water samples are likely to be in mineral or other non-dissolved or biologically unavailable forms, the total recoverable method probably overestimates metals available to biota. Although EPA recommends comparing total recoverable metals results to the criteria to be conservative, exceedance of a criterion may not necessarily indicate a potential for adverse effects. Finally, there is a possibility that metals contamination of these samples occurred during the sample collection or laboratory analyses steps. This, of course, would result in measurement of artificially high metals concentrations. The USGS has found metals contamination of their water samples from the Columbia River.

Considering the above factors, the identification of aluminum, cadmium, copper, lead, iron, selenium, and zinc as potential problem chemicals should be viewed as qualitative only. Although some of the aluminum in the samples was likely to be in mineral form, and therefore not bioavailable, aluminum should be considered a potential problem chemical in the lower Columbia until more data are collected. Future studies should include additional sampling to confirm and better characterize the prevalence and levels of these metals in the lower Columbia.

3.2.1.2 Adsorbable Organic Halogens (AOX). Adsorbable organic halogens (AOX) were detected in 95 percent (18 of 19) of the stations sampled. There is no water quality criterion for AOX. This group of chemicals, which are discharged primarily by bleached kraft pulp and papers mills, is widespread in the lower Columbia. Identification of AOX as a problem in the lower Columbia is questionable because the difficulty of determining the toxicity of any given measurement of AOX concentration. Because AOX is a measure of all halogenated organic compounds, it does not distinguish the relative contribution of the more toxic constituent halogenated organic compounds The absolute concentration of AOX does not accurately reflect the actual toxicity or carcinogenicity of the water sampled. The relative contribution of the more toxic halogenated organic compounds may vary from sample to sample and hence it is likely that AOX concentrations will be poorly correlated with toxicity. Determination of the relative contribution of the more toxic halogenated organic compounds in AOX measurements may prove more informative in assessing the biological significance of AOX measurements

3.2.1.3 Bacteria. Bacteria (fecal coliforms and enterococcus) were sampled at six locations along the river. The federal standards for enterococcus were exceeded at all six stations, and the Washington standard for fecal coliforms was exceeded at three of the six stations. Based on these results, bacteria have been identified as a problem parameter for the lower river as a whole, and further sampling to better characterize the extent and seriousness of this problem is recommended

3.2.1.4 Conventionals. Among the conventional water quality variables for which criteria are available, only dissolved oxygen (DO) measurements exceeded the criterion (29 percent of stations). The low DO levels in the estuary are partly due to the influence of marine water, which usually has lower DO levels than freshwater. DO concentrations and/or DO percent saturation was below the standards at eleven stations in the freshwater portion of the river However, eight of these stations had acceptable concentrations of DO, but the DO percent saturation was within 5 percent of the 90 percent standard Locations in the river with particularly low DO levels are addressed in Section 3 1 1.

No significant problems were identified among the other conventional water quality variables, with the exception of water temperature which has been identified as a chronic problem in the upper reach of the lower Columbia River based on evaluation of historical data.

3.2.2 Sediments

3.2.2.1 ***Metals.*** Metals were frequently detected in the sediments. The mean frequency of detection of the individual metals was 65 percent (Table 3.2-1) Except for antimony, beryllium, mercury, silver, and thallium, the metals were detected in all or almost all of the sediment samples. However, the mean frequency of exceedance of reference values was fairly low for metals (10 percent). The detected metals most frequently exceeding the reference value were silver (70 percent), cadmium (17 percent), and copper (15 percent). Future studies should focus on locations known or suspected to have particularly high levels of metals, and only the most abundant and toxic metals species should be tested for.

3.2.2.2 ***PAHs.*** PAHs, on the average, were detected at only 4 percent of the sediment stations, and about 9 percent of the detections exceeded the reference value. Although lower detection limits might reveal more widespread occurrence of these chemicals, it is expected that concentrations high enough to be of concern will be relatively uncommon. PAHs do not appear to be a general problem in the lower Columbia River, and future sampling should be limited to locations known or suspected to have elevated PAHs levels.

3.2.2.3 ***Other Semivolatiles.*** Other semivolatile organic chemicals were detected rarely in sediments Based on the reconnaissance survey data, this group of chemicals does not appear to be a general problem in the lower Columbia River.

3.2.2.4 ***Pesticides.*** Although pesticides as a category were detected at 30 percent of the stations, the large number of undetected individual pesticides reduces the mean frequency of detection to 3 percent (Table 3.2-1). Of the detected values, over half (52 percent) exceeded the reference value. Frequently detected pesticides included methyl parathion (13 detections), DDT and derivatives (total of 14 detections), and the BHCs (total of 8 detections) The DDTs and BHCs also frequently exceeded reference values (there is no reference value for methyl parathion).

Based on these results, pesticides as a category should be considered a minor problem for lower Columbia sediments. However, methyl parathion, BHC, and especially DDT and its derivatives may be significant problems that warrant further study.

3.2.2.5 PCBs. PCBs were detected very rarely in lower Columbia sediments (one Aroclor was detected at low levels at one station). PCBs do not appear to be a problem in sediments.

3.2.2.6 Dioxins and Furans. Dioxins and furans were detected at every sediment station, and the mean frequency of detection of the individual dioxin and furan congeners was 96 percent (Table 3.2-1). One reason for this frequent detection was the very low detection limits achieved for dioxins and furans (less than one part per trillion). Detection frequency may have been similarly high for chemicals such as PAHs and PCBs if similar detection limits had been achieved There are no effects-based reference values for dioxins and furans. However, considering the toxicity of dioxins and furans, the high frequency of detection of these compounds justifies identifying dioxins and furans as problem chemicals in the sediments of the lower Columbia. Additional studies should be conducted to better document the distribution of these chemicals in the sediments of the lower river, and to better characterize locations of particularly high dioxin/furan levels, as identified in Section 3.1.2.

3.2.2.7 Organotins. Organotins were detected at 7 of the 10 stations sampled, and the mean frequency of detection for the three organotin compounds was 60 percent (6 of 10 stations). This indicated that organotins may be prevalent in the lower Columbia Despite the lack of an effects-based reference value for these chemicals, organotins are identified as a potential problem chemical for the lower Columbia based on their frequent detection and known toxicity (Huggett et al. 1992). Additional studies should be conducted to better characterize the occurrence of organotins in the lower river, and to assess the effects of the levels of organotins measured.

3.2.3 Tissue

3.2.3.1 Metals. Metals were detected in every tissue sample; the mean frequency of detection for the individual metals was 58 percent (Table 3.2-1). Despite this high frequency of detection, it is difficult to determine if metals are a problem, because of the lack of effects-based reference values for metals in tissue. In addition, there are many natural sources of metals, and a number of metals (iron, aluminum, barium) occur at fairly high levels in the environment naturally. At present, therefore, tissue metals are not identified as a problem for the lower Columbia. This may change once health risk has been evaluated for the tissue data in the next phase of the Program.

3.2.3.2 ***PAHs.*** PAHs were detected rarely in tissue samples and none of the detected values exceeded the reference value. Although PAHs are known to bioaccumulate, they appear to be relatively uncommon in the water, sediments and tissue of the lower Columbia.

3.2.3.3 ***Other Semivolatiles*** Other semivolatiles were detected rarely in tissue and there were few exceedances of reference values. Bis-2-(ethylhexyl)phthalate was detected in many tissue samples. One sample (carp at D29) contained many semivolatile compounds, and this station is identified as a problem area for tissue in Section 3.1.3. However, semivolatiles as a group are not identified as a general problem in tissue in the lower Columbia.

3.2.3.4 ***Pesticides.*** Over all pesticides, the mean frequency of detection was only about 10 percent. However, certain pesticides, primarily DDT and its derivatives, were detected frequently: DDT (43 percent), DDD (44 percent), DDE (78 percent), BHC (17 percent), dieldrin (15 percent), aldrin (10 percent), and endrin (7 percent). In addition, pesticides of some type were detected in 96 percent of the tissue samples. Exceedances of effects-based reference values were uncommon; three of 56 DDE detected values exceeded the reference value. Therefore, pesticides in general appear to be a problem of moderate priority in tissues, but DDT and its derivatives appear to be particularly widespread and of some concern regarding potential health effects. Additional sampling of at least DDT and derivatives should be conducted to better characterize the distribution of these chemicals and the potential health risk posed by them.

3.2.3.5 ***PCBs.*** PCBs were detected in 57 percent of the tissue samples, but the mean frequency of detection for all Aroclors measured was only about 9 percent (several of the aroclors were detected rarely or never). The mean frequency of detected values exceeding the reference value (the New York State guideline for Total PCBs) was high (68%). The conclusion is that PCBs are widespread in fish tissue in the lower Columbia, and the concentrations are high enough to potentially have adverse effects on biota. Therefore, PCBs in tissue are identified as a problem chemical for the lower Columbia, and additional studies are needed to better characterize the pervasiveness (additional species should be sampled) and potential health effects of these chemicals

3.2.3.6 ***Dioxins and Furans*** Dioxins and furans were detected in every tissue sample, but the mean frequency of detection for the 17 congeners was about 68 percent. At about half of the stations (21 of 44 = .48 percent), the calculated toxicity equivalent concentration (TEC) exceeded the New York State guideline Considering the frequent detection of dioxins and furans, the frequent exceedance of the effects-based reference value, and the toxicity of these chemicals, dioxins and furans in tissue are identified as problem chemicals in the lower Columbia River Additional studies are needed to better define the pervasiveness (additional species should be sampled) and potential health effects of these chemicals.

3.2.4 Conclusions

In conclusion, the following chemical groups/parameters are preliminarily identified as problems for the lower Columbia River

Water

1. Bacteria
2. Metals
3. Temperature
4. Dissolved Oxygen
5. AOX (potential)

Sediment

1. Dioxins and furans
2. Organotins
3. DDT and derivatives, BHC, methyl parathion
4. Metals (selected chemicals and locations)

Tissue

1. Dioxins and furans
2. PCBs
3. DDT and derivatives

The above chemical groups and parameters should be given priority in future studies on the lower Columbia. These studies should include additional sampling and analysis to better define the pervasiveness of these chemicals in the lower river, the extent of identified problem areas and the levels of contaminants therein, and the ecological and human health risks posed by these contaminants.

4.0 PRIORITIZATION OF FUTURE STUDIES

This section lists technical studies that would make a significant contribution to the understanding of water quality conditions and biological health of the lower Columbia River. The studies were identified based on the results of the first year's studies (Tasks 1-6), and on fundamental physical, chemical, and biological process that determine water quality and ecological health. Implementation of all of these studies, at some time and by some entity, is recommended. Section 5.0 lists the studies recommended for implementation by the Bi-State Program

Studies area listed below by category. Within each category, the studies are prioritized according to their contribution to accomplishing the objectives of the Bi-State Program. In addition, the categories themselves are prioritized on the same basis. A rationale/justification for implementing each study is provided.

4.1 RECOMMENDED STUDIES

4.1.1 Problem Confirmation

1. **Conduct sampling to confirm and better define identified problem areas. Locate and sample additional depositional areas in the lower river. Conduct bioassays to assess toxicity of sediments at problem areas.**

   The identification of putative problem areas in the river was based on collection and analysis of widely spaced, single samples. Designation of some of the sampled stations as problem areas needs to be confirmed by further sampling in the same locations. The areal extent and variation in contamination around putative problem areas also needs to investigated by replicated sampling along transects. The limited nature of the reconnaissance survey did not allow investigation of depositional areas in large portions of the lower river. Moreover, the dynamic nature of riverine systems suggests that depositional areas are likely to be variable depending on water flow conditions. A more extensive survey of depositional areas under different flow regimes is necessary to identify most problem areas in the river.

Sediment AVS analysis should be performed along with other chemical analysis to assess bioavailability of sediment metals. Bioassays (using endemic test species if possible) also need to be conducted to evaluate the toxicity of the contaminated sediments.

2. **A broad ranging, and seasonal sampling program with replication should be conducted for indicator bacteria and parasitic protozoan pathogens, with emphasis on sampling beneficial use areas and tributary mouths.**

The very limited sampling for indicator bacteria conducted during the reconnaissance survey revealed U.S. EPA criteria exceeding concentrations of enterococcus bacteria at all six stations sampled. Five of the six stations were in beneficial use areas, which included contact recreation and shellfish harvesting. In view of these results, a more comprehensive bacterial sampling program of the lower Columbia River is necessary to assess sanitary quality and potential risks to public health. Another factor that should be considered for public health reasons is the occurrence in the river of the fecal- transmitted, enteric protozoan *Giardia*, which is responsible for the gastrointestinal illness Giardiasis. The incidence of Giardiasis in Oregon has risen steadily since 1981, with 1.1 million cases recorded in 1989. No studies have investigated the occurrence of this water borne parasite in the lower Columbia River.

3. **Conduct additional sampling of potential problem chemicals (e.g., PCBs, Pesticides, Organotins).**

Although PCBs were not detected in water column samples and only detected at one station in sediments, they were widespread in the tissues sampled. Pesticides and organotins were detected in sediments at many of the stations sampled. These observations suggest that the distribution of these chemical may be widespread in the river, and that additional sampling for these chemicals may be necessary to gain a better assessment of their distribution.

4.1.2 Characterization

1. **Sample during other seasons and flow regimes.**

   This recommendation is given a high priority within the category because information on conditions during flow regimes other than low flow is lacking and is considered a large data gap Additionally, sampling during other flow regimes will provide information to assist in answering questions such as. How do contaminant levels in water and sediments differ during high flows (or do they?)? Sampling during other for conditions will allow access to areas that were inaccessible during low flow (i.e , most depositional areas and inside the mouths of some tributaries). This sampling could be conducted in a similar manner as the reconnaissance survey (i.e., broad scale without replication) or could be conducted at a smaller suite of representative stations defined from the reconnaissance survey data.

2. **Collect sediment chemistry cores and analyze sediments from different sediment depths (e.g., 0-2, 2-5, 5-10, 10-20, 20-30, 30+ cm).**

   These studies were recommended as part of the original sampling plan but were delayed because of competing priorities and relatively high cost. However, collecting and analyzing deep sediment cores in depositional areas (especially those areas identified as problem areas) remains on the list of studies that should be conducted These studies will provide additional information on the extent of sediment contamination, and by analyzing subsample layers, will provide an indication of historical contamination as well. In addition, performing sediment coring in non-problem depositional areas will indicate if historical contamination existed at these sites.

3. **Conduct additional sampling of sediments and tissues in the wildlife refuge areas of the upper estuary.**

   Approximately 18 miles of river in the upper portions of the Columbia River estuary have been designated as national wildlife refuge. Limited sediment and tissue sampling was conducted in this section of the river during the reconnaissance survey. Most stations sampled here , however, showed enriched levels of at least one contaminant in the sediments. Dioxins and furans were also detected in sediments from this area from both stations sampled for these compounds. In view of the importance of the areas as refuges and as nursery and feeding grounds for biota, it may be important to conduct a more extensive spatial characterization of sediments and tissues to gain an accurate assessment of the impact of pollutants in these biological sensitive habitats.

4. **Develop a long-term monitoring program, including establishment of a set group of stations for regular monitoring (with replication and a reduced analyte list) at different flows (e.g., high, runoff, low).**

Establishing a standard set of monitoring stations will allow assessment of changes in conditions over time. This will allow an assessment of water quality changes in relation to pollution reduction activities. The results of the reconnaissance survey would be used to focus on fewer stations and parameters to be monitored An advantage to monitoring fewer stations and parameters will be the ability to add additional replication to the sampling efforts.

5. **Summarize the status (population characteristics, potential problems, etc.) of migratory and resident fish.**

The Columbia River has historically supported large populations of migratory and resident fish. The longstanding introduction of pollutants, coupled with the use of the river for hydroelectric power generation has long been suspected of impacting these fish populations. A comparative review and summary of the historical and current status of selected of fish populations in the lower river will provide an overall assessment of the impact of decades of industrial activity and fishing effort on the area's fish resources.

6. **Quantify low levels of contaminants in the water column. Quantify levels of contaminants in the dissolved and suspended particulate phases.**

The reconnaissance survey detected several organic contaminants in tissues that were undetected in the water column and detected infrequently in sediments. Lack of organic contaminant detection in the water column is likely to have resulted from the presence of these chemicals at levels lower than the analytical detection limits achieved in the survey. However, bioaccumulation of organic contaminants from the dissolved and suspended particulate phases of the water column is a well documented phenomenon. Assessment of the levels of contaminants in the different water column phases is important for determining the major routes of contaminant bioavailability. Quantification of low levels of water column contaminants is also important for assessing if established water quality and fish consumption criteria are being met. Quantification can be achieved by efforts to lower analytical detection limits and by filtering or centrifuging large volumes of water and concentrating the contaminants for chemical analysis.

7 **Investigate induction of mixed-function oxygenase (MFO) enzymes in selected fish and avian species.**

Numerous studies have validated the use of MFO enzyme induction as sensitive, early indicators of the presence and bioavailability pollutants and the resulting sublethal stress caused to exposed biota. The use of these biochemical indicators (EROD enzyme activity and cytochrome P-450 concentration) should be incorporated into studies to assess the exposure and response of the biota to pollutants in the lower Columbia River, as well as to confirm differences in water quality between putative hot spots and reference areas in the river.

8. **Sample sediment and tissue for bromodioxins.**

Analyzing tissue and sediment samples for these compounds is recommended because little is known about their distribution in the river and there are indications that these compounds may be as or more toxic than the other dioxin congeners. These compounds are also produced as part of the pulp and paper process.

9. **Monitor for exotic species (zebra mussels).**

Results of the benthic infauna reconnaissance survey did not find any evidence of problematic exotic species such as, zebra mussels. Zebra mussels are small clams that have invaded several east coast rivers and lakes, including the Great Lakes, and have caused millions of dollars of damage by clogging intakes and outfalls in these locations. Once these organisms are introduced to an area, it is very difficult (if not impossible) to eliminate them from the environment. The fact that none were detected during the study is encouraging. However, continued low-level monitoring for them (along with developing a policy to avoid its introduction to the system) will allow an early warning of an invasion by this species.

10. **Determine the individual organic halogen compounds making up AOX measured in the water column to better estimate toxicity of the AOX.**

The occurrence and widespread distribution of relatively high concentrations of AOX in the river below bleach kraft mill discharges is of concern. Assessing the biological significance of the detected levels is difficult, however, because AOX is a measure of all organic halogenated compounds present in the sample. Since there are several sources of AOX compounds, the constituent chemicals in the measured AOX are likely to be different in different samples. A better estimate of the potential toxicity of the measured AOX will, therefore, require knowledge of the constituent chemicals.

4.1.3 Bioaccumulation/Risk Assessment

1. **Estimate human and wildlife health risk using tissue data from the reconnaissance survey and other studies.**

The tissue contaminant data collected during the reconnaissance survey provide information necessary to answer at least two fundamental questions concerning the health of the lower Columbia River ecosystem: Do the concentrations of contaminants measured in aquatic species collected from the river pose a threat to either 1) human health or 2) wildlife that feed on aquatic species residing in the river? This question is best addressed using standard risk assessment methodologies.

2. **Expand tissue contaminant analysis to other species, emphasizing those commonly consumed by humans and wildlife.**

The reconnaissance survey measured tissue contaminant levels in five aquatic species. These species were selected, at least in part, because they had physiological (e.g., high lipid content) or behavioral (e g , bottom fedders) characteristics that might suggest that they would have a higher potential for accumulating tissue contaminants. This species selection was valid for the tissue contaminants This species selection was valid for the purposes of a reconnaissance survey, as the goal was to determine what chemicals were accumulating in tissue of aquatic biota Given this information, it is now important to evaluate tissue contaminant levels of species that are widely consumed by humans and key wildlife species This knowledge will allow more accurate assessment of the risks associated with consuming aquatic biota from the lower Columbia River

3 **Based on reconnaissance survey and the following years' studies, make recommendations for species to use for bioaccumulation monitoring for specific types of chemicals.**

The reconnaissance survey measured levels of tissue contaminants in four fish species and an invertebrate These data showed that contaminant levels and spatial trends within the river varied among species In some cases, chemicals were detected in high levels in one species, but were not detected in another collected from the same location This results points out that the selection of the aquatic species can affect the conclusions reached in monitoring studies. This study would further evaluate the reconnaissance data and data from follow-on studies to provide recommendations regarding indicator species that are best suited for evaluating bioaccumulation of different categories of pollutants The recommended species would depend on the objectives of the monitoring study (e g , evaluation of specific chemicals, evaluation of point sources, evaluation of impacts to human health or wildlife)

4 **Conduct tissue contaminant studies of piscivorous wildlife; conduct studies on the diet of piscivorous wildlife and fish; estimate consumption rates; target diet species for bioaccumulation studies.**

The bioconcentration of contaminants in tissues of higher trophic level consumers is well documented in pollution-impacted ecosystems Assessing the health of these consumers will require, in part, analysis of their tissue chemical burdens. Determining the composition of the diet of piscivorous wildlife and the river's fish species is necessary to identify which prey items are most important and should be the focus of bioaccumulation studies This type of information, compiled with estimates of prey consumption rates is necessary for the accurate assessment of health risks to ecosystem wildlife.

5. **Conduct a survey of fish consumption along the river. What are the principal species eaten? Does this vary along the river or among subpopulations? What are consumption rates?**

One of the key parameters required to provide accurate assessments of risks to humans from consuming fish from the lower Columbia is the amount and identity of fish species consumed. In particular, it is important to identify groups of individuals that may be exposed to higher risks due to either the amount of fish consumed or because of the way fish are prepared prior to consumption. This study would seek to provide an evaluation of the relative frequency with which different species of fish are consumed along the river, and to identify rates of consumption of particular groups of that may consume higher than average amounts of fish from the river.

6. **Conduct tissue contamination analysis on salmonids, including juvenile fish migrating downstream.**

The commercial importance of the salmonid fishery in the Columbia River, coupled with high human consumption rates for these species suggests that assessing tissue chemical burdens in these fish is important for assessing both the health of these species as well as risks to human health. Sampling should include juvenile fish that have migrated downstream to the lower part of the estuary. This type of sampling will take into account exposure to contaminants in both the water column and in food items during the often long migrations of the juvenile fish towards the ocean.

7. **Conduct tissue contaminant studies for aquatic vascular plants and algae, emphasizing those known to be consumed by herbivores.**

The bioconcentration of pollutants by aquatic vascular plants has long been of concern for several reasons. The rooted plants can absorb contaminants directly from the water column, as well as mobilize sediment-bound contaminants. This redistribution of contaminants makes them available to herbivorous and higher trophic level animals, and should be considered in assessments of the health of the lower Columbia River. Tissue analysis in algae, which form the bottom of the food chain, may also be warranted.

8. **Conduct tissue contaminant studies on the amphipod *Corophuim*, a principal food species for salmon smolt.**

One of the main mechanisms whereby aquatic organisms and wildlife bioaccumulate tissue contaminants is via consumption of contaminated prey. Predictive modeling of potential impacts to key economic or ecological species requires estimates of tissue burdens of key prey species. The amphipod *Corphium* is a key prey organism for many aquatic organisms in the lower Columbia River. Measurement of tissue contaminant levels in this species will provide the data necessary to evaluate the potential for bioaccumulation in many aquatic organisms that prey upon this species.

9. **Conduct "mussel watch" type bioaccumulation studies by placing "clean" freshwater clams (*Corbicula*) in cages at locations of interest for period of time, and then collect and analyze tissues. Place upstream and downstream of major sources/source areas.**

The "mussel watch" program, conducted by NOAA is a program that is used to monitor trends in near-coastal marine water quality The program is conducted by using "clean" mussels collected from known reference areas. These mussels are placed in various locations throughout the coastal regions for a specified period of time (e.g., 30 days), several times per year. The tissues are analyzed at the end of the exposure period. By collecting this information over several time periods, NOAA can monitor improving or degrading conditions. A study similar to the NOAA program could be used by the Bi-State Program to monitor the lower Columbia. Use of a resident species is (e.g., *Corbicula*) would be the most informative and indicative of instream conditions. A drawback to using *Corbicula* is finding a relatively "clean" source of organisms This would have to be overcome before implementation could begin.

4.1.4 Sources

1. **Conduct additional and regular sampling of tributaries. Conduct tributary flow gauging.**

   Much of the contaminant input into the lower Columbia River is likely introduced by tributary rivers whose basins also support extensive human activity. Estimating contaminant loading from these tributaries will require more frequent and regular data collection on water flows and levels of pollutants in the tributary water column and sediments.

2. **Conduct source-tracking studies near high priority problem areas. Sample along transects. Additional sampling of suspect effluent. Chemical "fingerprinting" for compounds with isomers, such as dioxins.**

   Once a potential problem area has been identified or confirmed, the question of the source of the contamination is raised. Studies to locate or track the source of the contamination are necessary. These studies would consist of systematic sampling that would provide increasing resolution of potential locations or sources of contamination. For example, if a problem area was identified below a tributary then the first step would be to take samples above the tributary. If no contamination was found above, then sampling would begin in the tributary above the first point source or subtributary. This type of source-tracking would continue until an area or a point source of contamination could be identified. Additional sampling of the suspect effluent for specific compounds or "fingerprints" would occur to confirm the identification of an area or point source. Methods similar to these have been used successfully in Puget Sound to identify sources of specific contaminants to storm drains.

3. **Sample water, sediment and tissue upstream of Bonneville.**

   To conduct a true characterization of how Columbia River water quality changes during its course, comparative data should also be collected above the Bonneville Dam. Information on upper river water quality will answer several questions. First, it will provide information valuable in assessing whether various aspects of river or aquatic habitat quality change from the upper to the lower river. Second, it will help evaluate the current assumption that the upper river is relatively pristine in certain respects. This second piece of information will help validate or invalidate assumptions about "control" or "background" stations sampled in the lower river

4. **Characterize the types and amounts of pollutants generated by various industries. Inventory use of pesticides and other toxic chemicals in the basin.**

This recommendation is presented because of the importance of identifying linkages between types of contaminants measured in the river and their potential sources. ·Information about industrial chemicals, pesticides, and other toxic chemicals used in the basin will provide fundamental source information about trends observed during the reconnaissance survey. This information can also help identify the relative importance of point and nonpoint sources in contributing to contaminants detected in other studies of water, sediment, or tissue. Finally, it may possibly provide information on potential future problems in the river, based upon recent increases in certain types of waste inputs

5. **Map and quantify land use in the lower Columbia river basin. Estimate types and amounts of pollutants generated by different land uses. Estimate nonpoint pollution loading for the basin. Assess relative importance of point and nonpoint sources.**

Most of the nonpoint source pollution entering the lower Columbia river results from land use activities in the river's extensive drainage basin. An integrated characterization of land use in the drainage basin is therefore necessary to gain an estimate of the magnitude of nonpoint pollutant loading river. Land use might be mapped and quantified using satellite imagery coupled with information collected by various government agencies. Estimates of nonpoint source loadings will be useful for evaluating the relative importance of different sources of pollution input and assist in decisions for managing water quality in the lower river.

6. **Inventory and characterize point sources to the Canadian border. Make a database.**

Since the lower Columbia River is obviously affected by point and nonpoint source discharges to the expansive drainage basin upstream from the Bonneville Dam, some characterization of the potential anthropogenic point sources within this area should be made. Information concerning location, activity, effluent volumes, and effluent characterizations would provide a basis for comparison of industrial point source loading between the upper and lower river areas.

7. **Conduct full-scan analyses of effluent from major dischargers.**

Full-scan analysis of pollutants contained in effluent from major industrial and municipal dischargers will provide information useful both for better characterizing pollutant loading from these sources and for determining whether there are unusual chemicals being discharged that could be of potential concern to the receiving environment. They will also help determine if monitoring requirements specified in NPDES permits are adequate for assessing potential adverse effects of the effluent.

8. **Make recommendations for standardization of effluent monitoring requirements between the two states, for each industry type.**

The impetus for this recommendation is to more efficiently utilize existing NPDES monitoring resources to calculate pollutant on loading to the river. Important factors to consider include consistency in chemicals analyzed by discharger, sampling methods and equipment, and sampling intervals. Consistent procedures, including comparable sampling techniques and intervals, will allow for much more accurate assessment of point source contributions to the river. In addition, it will offer further insight into the relative importance of point source contributions to the river compared to non-point sources.

4.1.5 Habitat

1. **Map/inventory wetlands and riparian habitats associated with the lower Columbia river.**

Assessment of the extent, distribution and kind of wetland and riparian habitats associated with a river system is integral to understanding the overall health, values and functions of such a system. Wetlands and riparian habitats are inextricably tied to their adjacent upland and aquatic areas, both of which affect and are affected by the health and quality of these adjacent habitats. It is well documented that in addition to their high inherent wildlife value, wetlands and riparian habitats provide numerous other benefits including energy and food to aquatic organisms, soil and bank stabilization, flood control and pollutant filtering. Consistent and uniform mapping and inventorying of wetlands also on the lower Columbia river would enable regulators, planners and land managers to make more informed policy, protection and development decisions that affect the quality and health of the river and its associated biota. Data should be input to a geographic information system for quick and easy access and use.

2. **Document loss of habitat in areas where historical data (aerial photos, satellite imagery) is available.**

Although the extensive loss of wetlands and riparian habitat throughout the United states is well documented, regional losses along the lower reach of the Columbia River are less well known Planning for a balanced and healthy river system and its related wetland and riparian habitats requires an understanding of the physical, chemical and biological characteristics of these systems prior to man's influence. While it may be difficult and prohibitively expensive to reconstruct the chemical component, it is possible, through review of historical photos and reports, to document the extent and distribution of physical and biotic components including wetland and riparian habitats associated with the river. Documenting loss of wetland and riparian habitat is an important part of assessing the overall status of the river. Furthermore, data on the historical extent and distribution may assist decision-makers in identifying potential restoration/enhancement sites.

3. **Conduct habitat quality assessments in selected areas.**

Degradation of habitat quality is a major factor impacting the health of associated populations. Conducting habitat quality assessments along the lower river will allow determination of changes in habitat quality associated with a variety of factors, and serve as a basis for determining anthropogenic impacts nd mitigation needs. Several well researched and documented procedures (i.e. HEP, WET) are available for assessing habitat quality.

4.1.6 Beneficial Uses

1. **Collect and evaluate information on the sensitivity of key fish and wildlife species to water quality conditions.**

   In addition to their inherent biological value, the fish and wildlife resources of the lower Columbia River play a major role in the socio-economic well-being of human populations associated with the river. Determining the influence of water quality conditions on the long-term health of key fish and wildlife species is therefore recommended. A through literature review and analysis should be conducted on key species to better understand the relationship between the current uses of the river and the potential hazards to fish and wildlife species, resulting from degradation of habitat and/or direct influence of pollutants through the food chain.

2. **Collect and evaluate information on the sensitivity of recreational uses of the river to water quality conditions.**

   The lower Columbia River supports significant recreational activities, including contact recreation, fishing and shellfish harvesting. However, no quantitative data are available about the intensity and exact location of recreational uses in the river. It is therefore difficult to determine if water quality changes affect the wide variety of recreational uses. A survey of users, providers of recreational services and supplies, and detailed interviews with agencies and health officials will help to relate actual and future recreational use to changes in water quality. As populations increase and new uses occur it may become essential to predict and control some of the recreational uses of the river.

3. **Collect and evaluate existing information on the sensitivity of domestic, agricultural, and industrial use of river water quality conditions.**

   Evaluating the sensitivity of lower Columbia River water quality on domestic, industrial and agricultural uses of river water may be warranted as part of the Bi-State's objective of assessing the impact of water quality on the river's beneficial uses. Evaluating the sensitivity of these uses will necessitate collecting information on the water quality requirements of theses uses, and assessing whether the water quality conditions (as determined by the reconnaissance survey and forthcoming studies) are sufficient to meet these requirements

4. **Examine historical trends in water use/withdrawal in the lower river and project future demand.**

This recommendation will provide information for planners working to anticipate problems such as water shortages on potential pollution impacts in the future Review of past water use, trends in consumption levels, and demands by individual uses can form the baseline for predictive models to insure future health of the river, and equity in the distribution of water supplies.

4.1.7 Protocols

1. **Develop standard protocols for sample collection, handling, analysis, QA etc. for all environmental studies conducted on the lower Columbia River.**

This recommendation stems from the review and evaluation of existing and historical data as part of Tasks 1 and 2 of the reconnaissance survey. In those studies it was very difficult and often impossible to evaluate the data with any confidence because of the differences in sample collection and handling methodologies, the level of quality assurance/control, and the analytical methodologies used by different agencies and investigators. Therefore, it is highly recommended that standardized methodologies be established for typical analyses that are conducted by agencies conducting work on the lower Columbia River. It will be very important for future studies conducted for the Bi-State program to use similar protocols to those utilized in the reconnaissance survey to ensure comparability of data.

2. **Develop or select a data information management system to store analytical data. Establish standardized data formats to allow sharing of data among agencies and investigators working on the lower Columbia River.**

Development or selection of a data management system that establishes a common data format is very important to ensure that data collected for the program is readily available to all investigators and interested parties. A data repository will ensure that the data collected for the program will not be "lost" or become unavailable except in a data report (which essentially makes it unusable). Establishment of a database is often overlooked initially and lack of one is often regretted.

3. **Develop a proposed policy to avoid introduction of exotic species (zebra mussels) into the Columbia River.**

As discussed above (#9 of Characterization), developing a policy to avoid the introduction of the zebra mussel, and potentially other exotic species, could result in the savings of millions of dollars for industries, ports, and communities along the river by avoiding the costly repair of damaged and clogged intake and outfall facilities. A statement as simple as no ballast water releases in the river environment may be a first step along with a commitment to monitor the river for these organisms.

4.1.8 Research

1. **Conduct basic biology studies for bioaccumulation target species.**

Bioaccumulation of contaminants is influenced by a multitude of biological factors, including the age, diet, and dispersal range of the biota sampled. Relatively little information exists on these factors for most of the species analyzed in the reconnaissance survey. Correct interpretation of tissue chemical burden data and assessment of ecological risk will require elucidation of these factors.

2. **Conduct toxicological studies evaluating the effect of contaminated prey on higher tropic level wildlife consumers.**

The Columbia River basin supports a large diversity of mammalian and avian wildlife, some of whose populations are believed to have declined over the recent past possibly due to pollution problems in the riverine ecosystem. Accurate assessment of the biological impacts of these pollution problems on higher trophic level wildlife is hampered by limited empirical knowledge regarding the toxicological effects of consuming contaminated prey. Toxicological studies elucidating the effects of, and effect levels for, various contaminants are necessary for evaluating impacts and health risks to higher trophic level wildlife in the river's ecosystem.

3. **Develop sediment bioassay procedures using endemic test species.**

The use of endemic, ecologically prominent species in sediment bioassays will provide a more realistic assessment of the biological significance of contaminated sediments in the river. Use of non-endemic bioassay species, although useful, suffers from the argument that such species may not accurately reflect contaminant impacts to species native to the study area. The sediment dwelling amphipods *Corophium* and *Eohaustorius* may serve as appropriate bioassay organisms in view of their ecological importance and abundance in the lower Columbia River.

4. **Conduct additional studies to determine the current status of migratory and resident fish populations in the river.**

Evaluating the health of the lower Columbia River will require assessing the current status (health and size) of resident and migratory fish populations. If this assessment is hampered by lack of sufficient and/or appropriate existing information, additional studies should be conducted to obtain this information.

5 **Determine the fundamental processes regulating fisheries production in the river.**

The lower Columbia River supports major fishery activities involving several fish and invertebrate species. However, very little is known on the processes regulating production of these species in the river. If population status characterization studies reveal impairment of fishery resources, studies should be conducted to both determine these fundamental processes and to determine the impact of the river's water quality on these processes.

6. **Sample the benthic boundary layer material and analyze for contaminants.**

Many of the water column suspended particulates and their bound contaminants may concentrate in a flocculent, semi-suspended layer a few centimeters above the river's bottom. This boundary layer particulate material may be a significant pathway of contaminant exposure for benthic invertebrates and bottom feeding fishes. The water-column and sediment sampling conducted as part of the reconnaissance survey did not sample this potentially important source of contaminants.

4.1.9 Water Quality Modeling

1. **Develop and/or evaluated existing water quality models for the lower Columbia River.**

The establishment of a predictive water quality model is a logical next step in the assessment of the health of the lower Columbia River Models that allow predictions of the fate and transport of environmental contaminants in the river will be useful to regulatory agencies for management of the lower river. The reconnaissance survey data and any additional data collected can be used to further calibrate EPA's steady-state SMPTOX 3 model to improve its reliability, or to establish a dynamic model such as TOXIWASP for more accurate predictions of the fate and transport of toxic contaminants in the river.

2. **Develop models for predicting contaminant accumulation around point sources in areas of the river subject to flow reversals.**

Numerous point sources discharge to the section of the lower river subject to flow reversals due to tidal changes. EPA-supported models commonly used by dischargers to predict effluent dilution for NPDES permits do not take this flow reversal into account. Estimates of effluent dilution derived using such models may be erroneous. For example, effluent released during the upstream flow would come down during the ebb flow and add to the effluent being released from the outfall. This would be a cyclic process which would result in elevated levels of ambient concentrations of effluent causing reduction in dilution ratios from what would have been expected using the traditional models. Models derived to predict contaminant dilution under flow reversal conditions could be calibrated with data obtained from localized field sampling that would be conducted around the larger outfalls.

5.0 RECOMMENDATIONS FOR STUDIES TO BE IMPLEMENTED BY THE BI-STATE PROGRAM

The studies listed below are suggested for implementation by the Bi-State Program over the next 2 years. The technical justification for these recommended studies has been provided as part of Section 4 0. The primary factors considered in selecting these studies were:

1. The importance of the studies for achieving the Bi-State Program's overall four-year goals

2. The scope of the studies in relation to the time frame and resources available to the Bi-State Program. For example, some of the long-term, biological process oriented research studies, although important, have not been included.

3. An assessment of whether the studies might most efficiently be accomplished by the Bi-State Program or by other agencies already conducting similar studies in the Columbia River or other river systems.

The studies are listed according to whether they might most appropriately be conducted in the 1992-1993 (Year 1 Studies) or 1993-1994 (Year 2 Studies) years of the Bi-State Program. The studies are also listed according to their recommended priority within each year Year 1 studies are generally those that:

1. Are a logical next step in that they complement and extend the information obtained by the reconnaissance survey

2. More completely fulfill the Bi-State Program's goals of identifying water quality problems in the lower Columbia River

3. Are deemed more urgent by the lower Columbia River Task 6 Review workshop participants.

4. Are necessary to provide the base information for optimal performance of Year 2 studies.

Year 2 studies are generally those that:

1. Might be better accomplished using data obtained from Year 1 studies; and

2. Were considered less urgent than Year 1 studies by the Task 6 review workshop participants.

A brief justification for recommending each study for implementation by the Bi-State Program is provided below.

5.1 YEAR 1 STUDIES

5.1.1 Problem Confirmation

1. **Conduct sampling to confirm and better define identified problem areas. Locate and sample additional depositional areas in the lower Columbia River. Conduct bioassays to assess toxicity of the sediments at problem areas.**

   This study is a logical next step in accomplishing the Bi-State Program's goal of identifying and characterizing problem areas in the river. The areas represented by the following stations are recommended for problem confirmation sampling.

Sediment	Tissue
D24 (St. Helens)	D28 (Sauvie Island)
E9[D] (Downstream of St. Helens)	D19 (Longview)
D35 (Camas)	D38[E] (Reed Island)
D22 (Kalama)	D10 (Clifton Channel)
E8 (Deer Island)	D24 (St Helens)
D19 (Longview)	D40 (Beacon Rock)
D6 (Grays Bay)	D29 (Vancouver Lake flushing channel)
	D3 (Astoria)

2. **A broad ranging and seasonal sampling program with replication should be conducted for fecal contamination indicator bacteria and parasitic protozoan pathogens, with emphasis on beneficial use areas and tributary mouths.**

   A more thorough characterization of bacterial conditions in the river was deemed important by workshop participants in view of the high bacterial levels observed during the reconnaissance survey. This study also contributes to the goals of identifying problem areas, assessing the water quality of the river, and determining if beneficial uses are likely to be impaired.

3. **Conduct additional sampling of potential problem chemicals (e.g., PCBs, pesticides and organotins).**

   This study is recommended as the next step in a more complete characterization of problem areas in the river. The study will also contribute towards the goal of assessing the water quality of the river.

5.1.2 Characterization

1. **Sample during other seasons and flow regimes.**

The dynamic nature of river systems suggests that the parameters measured during low flow may vary under different hydrological conditions. Sampling during other seasons and flow regimes is necessary to gain a comprehensive characterization of the water quality of the river.

2. **Conduct additional sampling of sediments and tissues in the wildlife refuge areas of the upper estuary.**

A more complete identification of problem areas in the wildlife refuges will require additional sampling in these areas. Reconnaissance survey sampling in these areas was limited.

3. **Summarize the status (e.g., population characteristics, potential problems, etc.) of migratory and resident fish.**

This study was recommended by workshop participants and will allow a determination of long-term trends in the status of the river's fish populations. The study will also contribute towards an assessment of whether beneficial uses are being impaired.

5.1.3 Bioaccumulation/Risk Assessment

1. **Estimate human and wildlife health risk using tissue data from the reconnaissance survey and other studies.**

Assessment of human and wildlife risk posed by tissue contaminants was deemed urgent by workshop participants. The study will also contribute towards the goal of evaluating whether beneficial uses are being impaired.

2. **Expand tissue contaminant analysis to other species, emphasizing those commonly consumed by humans and wildlife.**

This study will allow a more accurate assessment of risks posed to human and wildlife health, and also provide a more comprehensive characterization of the health of the river's biota.

5.1.4 Sources

1. **Sample water, sediment and tissue upstream of Bonneville.**

   Conducting this study will allow an assessment of the influence of upstream water quality conditions on the lower Columbia River, and provide information useful for the Bi-State's longer term goal of providing solutions to problems in the lower river.

2. **Characterize types and amounts of pollutants generated by various industries. Inventory use of pesticides and other toxic chemicals in the basin.**

   This study will allow identification of potential sources of contaminants observed in the river. The study will also contribute useful information towards providing longer-term solutions to water quality problems in the lower river.

5.1.5 Habitat

1. **Map/Inventory wetland and riparian habitats associated with the lower Columbia River.**

   This study will contribute towards a comprehensive characterization of the health of the lower river. The information obtained will also be useful for future management of wildlife resources utilizing these habitats.

5.1.6 Beneficial Uses

1. **Collect and evaluate information on the sensitivity of key fish and wildlife species to water quality conditions.**

   This information will play a key role in evaluating whether beneficial uses are being impaired. The information will also contribute towards an overall assessment of the health of the river's biota and help determine whether additional regulation of contaminant sources is necessary.

5.1.7 Protocols

1. **Develop or select a data information management system to store analytical data. Establish standardized data formats to allow sharing of data among agencies and investigators working on the lower Columbia River.**

   Establishing a standardized data reporting format and centralized data storage and management system will substantially improve the efficiency of data retrieval and analysis for future studies and regulatory and management decisions

5.1.8 Research

1. **Conduct basic biology studies for bioaccumulation target species.**

   Elucidating the influence of biological factors such as biota age, diet and dispersal range on bioaccumulation is crucial for the correct interpretation of tissue chemical burden data and assessment of ecological risks posed by environmental contaminants. Assessment of the biological significance of tissue contaminant data is, in turn, a major consideration in the delineation of problem areas and evaluation of the overall health of the river

5.1.9 Water Quality Modeling

1. **Develop new models and/or evaluate existing water quality models for the Columbia River.**

   The availability of accurate and reliable, predictive water quality models is an important component of the technical arsenal required for the development of solutions to identified water quality problems

5.2 YEAR 2 STUDIES

5.2.1 Characterization

1. **Collect sediment chemistry cores and analyze sediments from different sediment depths.**

   Analysis of historical sediment contamination will permit an assessment of long-term trends in contaminant input to the river, as well as assist in identifying historical problem areas that might need management solutions.

2. **Develop a long-term monitoring program, including establishment of a set group of stations for regular monitoring (with replication and a reduced analyte list) at different flow regimes.**

   A long-term monitoring program is necessary to determine if regulatory and management decisions implemented to solve water quality problems are achieving their desired effects

3. **Investigate induction of mixed-function oxygenase (MFO) enzymes in selected fish and avian species.**

   This study will 1) provide information on the biological significance of contaminants measured in the environmental media by indicating whether the exposed biota are stressed and 2) provide a surrogate, less expensive way to assess the extent of contaminant distribution and bioavailability in the river The results can be used towards an overall assessment of the health of the river's biota.

5.2.2 Bioaccumulation/Risk Assessment

1. **Conduct tissue contaminant analysis on vascular aquatic plants and algae, emphasizing those consumed by herbivores.**

   This study will contribute towards a more comprehensive characterization of the river's water quality, provide an estimate of the importance of contaminant transfer via organisms at the bottom of the food chain, and allow a more accurate assessment of risks to herbivorous wildlife

2. **Make recommendations for species to use for bioaccumulation monitoring of specific types of chemicals.**

   Development of an effective, long-term bioaccumulation monitoring program will require information on the most appropriate species to monitor for the different chemicals present in the river.

3. **Conduct tissue contamination analysis on salmonids, including juvenile fish migrating downstream.**

   This study is important for assessing risks to humans and wildlife resulting from fish consumption, and will assist in evaluating whether beneficial uses are being impaired

5.2.3 Sources

1. **Conduct additional and regular sampling of tributaries. Conduct tributary flow gauging.**

   Estimating the contribution of contaminants from tributaries is necessary for determining the relative importance of the different sources of contaminants to the lower Columbia River. This information will be a major consideration in the development of solutions to water quality problems.

2. **Conduct contaminant source-tracking studies near high priority problem areas.**

   Identifying the source of contaminants is necessary for effective implementation of solutions to water quality problems.

3. **Map and quantify land use in the lower Columbia River basin. Estimate types and amounts of pollutants generated by different land uses. Estimate nonpoint pollution loading for the basin. Assess relative importance of point and nonpoint sources.**

This study will permit identification of the most important nonpoint sources of contaminants to the lower river, and provide information necessary for regulatory and management decisions aimed at improving water quality conditions

4. **Inventory and characterize point sources to the Canadian border. Develop a database for this information.**

This study will permit an assessment of the potential influence of point sources upstream of the Bonneville Dam on water quality conditions in the lower reaches of the river. This information is necessary for the development of an integrated management plan for the lower river.

5.2.4 Habitat

1. **Document loss of habitat in areas where historical data (e.g, satellite imagery, aerial photographs) are available.**

This study will provide data on the direction of long-term changes in the terrestrial habitats associated with the river, and contribute towards an overall assessment of the health of the river basin.

5.2.5 Protocols

1. **Develop standard protocols for sample collection, handling, analysis, QA, etc., for all environmental studies conducted on the lower Columbia River.**

Development of standardized data collection protocols will ensure comparability of data obtained by different investigators and greatly facilitate analysis and identification of long-term trends in river water quality.

5.2.6 Research

1. **Develop sediment bioassay procedures using endemic test species.**

   This recommendation is based on achieving a more accurate assessment of the toxicological properties of sediments from problem areas in the lower river.

2. **Conduct additional studies to determine the current status of migratory and resident fish populations in the river.**

   These studies may be required for assessing longer-term changes to the river's fish populations, and determining if the river's health (as measured by the status of its fish populations) is declining.

5.2.7 Water Quality Modeling

1. **Develop models for predicting contaminant accumulation around point sources in areas of the river subject to flow reversals.**

   More accurate predictions of contaminant dispersion around point sources is necessary for the development of effective solutions to water quality problems that may occur in these areas.

6.0 REFERENCES

Barron, M.G 1990 Bioconcentration Env Sci Technol 24 1612-1618

Beak Consultants Incorporated 1989 Columbia River fish study fish collection, fish tissue sampling and age of fish sampled. Prepared for Northwest Pulp & Paper Assoc , Bellevue, Washington 30 pp

Bero, A.S and R.J Gibbs 1990 Mechanisms of pollutant transport in the Hudson estuary The Science of the Total Environment 97/98 9-22

Burton, G A , Jr 1991 Assessing the toxicity of freshwater sediments Environ Toxicol Chem 10 1585-1627

Cabelli, V J 1983 Health effects criteria for marine recreational waters EPA-600/1-80-031 Health Effects Research Laboratory, U S Environmental Protection Agency, Cincinnati, Ohio 98 pp

Cabelli, V J , A P Dufour, L J McCabe, and M A Levin 1983 A marine recreational water quality criterion consistent with indicator concepts and risk analysis Journal of the Water Pollution Control Federation 55:1306-1314

Callaway, R J , K.V Byram, and G R Ditsworth 1970 Mathematical Model of the Columbia River From Pacific Ocean to Bonneville Dam, Part I and II Pacific Northwest Water Laboratory, Corvallis, Oregon, 82 pp

Chapman, P M. and R. O Brinkhurst 1981 Seasonal changes in interstitial salinities and seasonal movements of subtidal benthic invertebrates in the Fraser River estuary, B C Estuarine, Coastal Shelf Sci 12 49-66

Christensen, E.R and S. Zhang 1993 Sources of polycyclic aromatic hydrocarbons to Lake Michigan determined from sedimentary records Environ Sci Technol 27 139-146

Columbia River Estuary Data Development Program (CREDDP) 1983 Bathymetric Atlas of the Columbia River Estuary

Conomos, T J 1968. Processes affecting suspended particulate matter in the Columbia River-effluent system, summer, 1965, 1966 Ph D thesis University of Washington, Seattle, Washington 141 pp

Conomos, T J and M G Gross 1972. River--Ocean suspended particulate matter relations in summer pp 176-202 In The Columbia River Estuary and Adjacent Ocean Waters A A Pruter and D L Alverson, eds. University of Washington Press, Seattle, Washington

Czuczwa, J M. and R.A Hites. 1984 Environmental fate of combustion-generated polychlorinated dioxins and furans. Environ Sci Technol 18 444-450

Dahm, C.N , S V Gregory, and P K Park 1981 Organic carbon transport in the Columbia River Estuarine, Coastal, and Shelf Science 13 645-658

Davis, P H , and R B Spies 1980 Infaunal benthos of a natural petroleum seep study of community structure Mar Biol 59 31-41

Dawley, E H , T Blahm, G Snyder, and W Ebel 1975 Studies of effects of supersaturation of dissolved gases on fish. Bonneville Power Administration, Bureau of Reclamation, U.S Army Corps of Engineers 84 pp

Dufour, A.P 1984 Health effects criteria for fresh recreational waters EPA-600/1-84-004 Health Effects Research Laboratory, U S Environmental Protection Agency, Research Triangle Park, N C 33 pp

Dufour, A P and V J Cabelli 1976 Characteristics of *Klebsiella* from textile finishing plant effluents Journal of Water Pollution Control Federation 48 872

Eriksen, K.W 21 July 1991. Personal communication (visit by Mr James Graham, Keystone/NEA, Inc., Tigard, Oregon) U S Army Corps of Engineers, Portland District, Portland, Oregon

Farrington, J.W 1991 Biogeochemical processes governing exposure and uptake of organic pollutant compounds in aquatic organisms Environmental Health Perspective 90 75-84

Ferraro, S P , R C Swartz, F A Cole, and D W Shultz, 1991 Temporal changes in the benthos along a pollution gradient discriminating the effects of natural phenomena from sewage-industrial wastewater effects. Estuarine, Coastal and Shelf Science 33 383-407

Forster, W O 1972. Radionuclide distribution in Columbia River and adjacent Pacific shelf sediments pp 701-754 In: The Columbia River Estuary and Adjacent Ocean Waters A A Pruter and D L Alverson, eds University of Washington Press, Seattle, Washington

Fox, D S , S Bell, W Nehlsen, and J Damron 1984 The Columbia River Estuary Atlas of physical and biological characteristics. Columbia River Estuary Data Development Program Astoria, Oregon 87 pp

Garrett, M., R.G. Anthony, J.W Watson, and K McGarigal 1988 Ecology of bald eagles on the lower Columbia River· Final Report to U S Army Corps of Engineers, Contract No DACW57-83-C-0100 Oregon State University, Dept. of Fisheries and Wildlife, Corvallis, Oregon 189 pp

Geldreich, E E. and E.W Rice. 1987 Occurrence, significance, and detection of *Klebsiella* in water systems. J AWWA 79(May) 74-80

Glenn, J L. 1973 Relations among radionuclide content and physical, chemical, and mineral characteristics of Columbia River sediments U S Geological Survey Professional Paper 433-M U S Government Printing Office, Washington, D C

Green, R. H., S. M. Singh, and R C Bailey 1985 Bivalve molluscs as response systems for modelling spatial and temporal environmental patterns Science of Total Environment 46.147-169

Haertel, L.S., C Osterberg, H Curl, Jr , and P K Park 1969 Nutrient and plankton ecology of the Columbia River estuary Ecology 50 962-978

Hamilton, P 1984 Hydrodynamic Modeling ot the Columbia River Estuary CREDDP Final Report, Astoria, Oregon.

Hedges, J I , H J Turin, and J R Ertel 1984 Sources and distributions of sedimentary organic matter in the Columbia River drainage basin, Washington and Oregon Limnol Oceanogr 29 35-46

Henny, C J., and R G Anthony 1989 Bald eagle and osprey National Wildlife Federation Scientific and Technical Series 12 66-82

Henny, C J , L J Blus, S T Gregory, and C J Stafford 1981 PCBs and organochlorine pesticides in wild mink and river otters trom Oregon In Worldwide Furbearers Conf Proc , Aug 3-11, 1980, Frostburg, Missouri, pp 1763-1780

Hoffman, E J., G L Mills, J S Latimer, and J G Quinn 1984 Urban runoff as a source of polycyclic aromatic hydrocarbons to coastal waters Environ Sci Technol 18 580-587

Holly, Jr , F M., and J L Rahuel 1990 New numerical/physical frame-work for mobile bed modelling. Journal of Hydraulic Research 28(4) 401-416

Holton, R L , D L Higley, M A Brzezinski K K Jones, and S L Wilson 1984 Final report on the benthic infauna work unit of the Columbia River College ot Oceanography, Oregon State University, Corvallis, Oregon. 179 pp + appendices

Huggett, R J , M A. Unger, P F Seligman, and A O Valkirs 1992 The marine biocide tributyltin Assessing and managing the environmental risks Environ Sci Technol 26 232-237

Jaquish, R E and R W Bryce 1990 Hanford Site environmental report for calendar year 1989 PNL-7346 Prepared for U S Department ot Energy Pacific Northwest Laboratory, Richland, Washington 355 pp.

Jay, D A , and J W Good. 1978. Columbia River Sediment and Sediment Transport. In· Columbia River Estuary Inventory of Physical and Biological Characteristics M H Seaman, ed Astoria, Oregon Columbia River Estuary Taskforce (Item not seen)

Jay, D A 1984. Columbia River Estuary Circulatory Process Final Report, Columbia River Data Development Program, 1984

Johnson, A , and D Norton 1988 Screening survey tor chemical contaminants and toxicity in sediments at five lower Columbia River ports - September 22-24, 1987 Washington State Department of Ecology, Olympia, Washington. 20 pp.

Johnson, A and B Hopkins 30 April 1991 Personal Communication (letter to Steve Saunders, WDOE) Washington Department of Ecology, Olympia, Washington

Kaniewska-Prus, M. 1983 Geological characteristics of polisaprobic section of the Vistula River below Warsaw Pol Arch Hydrobiol 30 149-163

Landrum, P F and J A Robbins 1990 Bioavailability of sediment-associated contaminants to benthic invertebrates pp 237-263 In. Sediments chemistry and toxicity of in-place pollutants R Bando, J P Geisy, and H Montan, eds Lewis Publishers, Inc , Wisconsin

Lara-Lara, J R , B E. Frey, and L F Small 1990a Primary production in the Columbia River estuary I Spatial and temporal variability of properties Pacific Science 44 17-37

Lara-Lara, J R , B E Frey, and L.F Small 1990b Primary production in the Columbia River estuary II. Grazing losses, transport, and a phytoplankton carbon budget. Pacific Science 44 38-50

Lincoln, J H and R F Foster 1943 Report on investigation of pollution in the Lower Columbia River Prepared for Washington State Pollution Commission and Oregon State Sanitary Authority 143 pp

Long, E.R., and L G Morgan 1990 The Potential of Biological Effects of Sediment-Sorbed Contaminants Tested in the National Status and Trends Program. NOAA Technical Memorandum NOS OMA 52. NOAA, Seattle, Washington

McAnally, W H., J Noble, R Brogdon, Jr , J V Letter, Jr , J P Stewart, and W A Thomas 1983 Columbia River Estuary Hybrid Model Studies Report 1 Verification of hybrid modeling of the Columbia River mouth Hydraulic, Laboratory, U S Army Engineer Waterways Experiment Station, Vicksburg, Mississippi

McGarigal, K., R G Anthony, and F B Isaacs 1991 Interactions of humans and bald eagles on the Columbia River Estuary Wildlife Monographs No 115 1-47

McKenzie, S 12 February 1991 Personal Communication (phone by Tad Deshler, Tetra Tech, Inc , Bellevue, Washington) U S Geological Survey, Portland, Oregon

Menzie, C A., B B Potocki, and J Santodonato 1992 Exposure to carcinogenic PAHs in the environment. Environ. Sci Technol 26 1278-1284

Myers, M S., L.D Rhodes, and B B McCain 1987 Pathologic anatomy and patterns of occurrence of hepatic neoplasms, putative preneoplastic lesions, and other idiopathic hepatic conditions in English sole *(Parophrys vetulus)* from Puget Sound, Washington J Natl Cancer Inst 72(2) 333-363

Näf, C , D Broman, H Pettersen, C Rolff, and Y Zebuhr 1992 Flux estimates and pattern recognition of particulate polycyclic aromatic hydrocarbons, polychlorinated dibenzo-p-dioxins, and dibenzofurans in the waters outside various emission sources on the Swedish Baltic Coast Environ Sci Technol 26 1444-1457

Nalepa, T F , and P F Landrum 1988 Benthic invertebrates and contaminant levels in the Great Lakes: effects, fates and role in cycling pp 77-102. In Toxic Contaminants and Ecosystem Health A Great Lakes Focus M S Evans, ed John Wiley and Sons, New York

National Council of the Paper Industry for Air and Stream Improvement, Inc. (NCASI). 1972 *Klebsiella pneumoniae* infection A review with reference to the water-borne epidemiologic significance of *K. pneumonia* presence in the natural environment Stream Improvement Technical Bulletin No 254 NCASI, New York 24 pp

National Council of the Paper Industry for Air and Stream Improvement, Inc (NCASI) 1975 Further studies of the sanitary significance of *Klebsiella pneumoniae* occurrence in mill effluents and surface waters: Part 1 The distribution and densities of *Klebsiella* in receiving waters Part 2 Biochemical, antimicrobial susceptibility, virulence and serological type characterization of *Klebsiella* isolates from natural receiving waters Stream Improvement Technical Bulletin No 279 NCASI, New York 49 pp + appendices

Newell, A J , D W Johnson, and L K Allen 1987 Niagara river biota contamination project Fish flesh criteria for piscivorous wildlife New York State Department of Environmental Conservation, Division of Fish and Wildlife, Bureau of Environmental Protection

Niemelä, S I and P Vaatanen 1982 Survival in lake water of *Klebsiella pneunoniae* discharged by a paper mill Applied and Environmental Microbiology 44 264-269

Ogden Beeman & Associates 1984 Preliminary Report on Columbia River Shoaling Study, submitted to Portland District, U S Army Corps of Engineers Portland, Oregon

Park, P K., M Catalfomo, G.R. Webster, and B H Reid 1970 Nutrients and carbon dioxide in the Columbia River Limnol Oceanogr 15 70-79

Park, P K., C.L. Osterberg, and W O Forster 1972 Chemical budget of the Columbia River pp 123-134 In: The Columbia River Estuary and Adjacent Ocean Waters A A Pruter and D L Alverson, eds. University of Washington Press, Seattle, Washington

Park, P K , G R. Webster, and R. Yamamoto 1969 Alkalinity budget of the Columbia River Limnol Oceangr 14 559-567

Pearson, T H. and R Rosenberg 1978. Macrobenthic succession in relation to organic enrichment and pollution of the marine environment. Oceanogr Mar Biol Ann Rev 16:229-311

Persaud, D., R. Jaagumagi, and A. Hayton 1991 Draft The Provincial Sediment Quality Guidelines Water Resources Branch, Ontario Ministry of the Environment, Toronto, Ontario, Canada

Portland General Electric Co 1990 Trojan Nuclear Plant, Operational Environmental Radiological Surveillance Program. Portland General Electric Co . Portland, Oregon

Rao, B.V S.S.R.S., and T V Rao 1980 Aquatic oligochaetes as indicators of organic pollution in Visakhapatnam Harbor Indian J. Mar Sci 9 222-223

Reinert, R.E., B.A Knuth, M.A. Kamrin, and Q.J Stober 1991 Risk assessment, risk management, and fish consumption advisories in the United States Fisheries 16 5-12

Robeck, G G , C Henderson, and R C Palange 1954 Water quality studies on the Columbia River U S Department of Health, Education, and Welfare, Public Health Service, Robert A. Taft Sanitary Engineering Center, Cincinnati, Ohio

Robertson, D E and J J Fix 1977 Association of Hanford origin radionuclides with Columbia River sediment BNWL-2305 Battelle-Pacific Northwest Laboratory, Richland, Washington 36 pp + appendices

Robey, D L , and L J Lower 1991 A time-varying, three-dimensional hydrodynamic and water quality model of Chesapeake Bay The Military Engineer 544 50-51

Schmitt, C J and W G Brumbaugh 1990 National contaminant biomonitoring program Concentrations of arsenic, cadmium, copper, lead, mercury, selenium, and zinc in U S freshwater fish, 1976-1984 Arch. Environ Contam Toxicol 19 731-747

Schmitt, C , J Zajicek, and P Peterman 1990 National Contaminant Biomonitoring Program Residues of organochlorine chemicals in U S freshwater fish, 1976-1984 Arch Environ Contam Toxicol. 19 748-781

Sheng, Y P 1986. A three-dimensional mathematical model of coastal, estuarine, and lake currents using boundary fitted grid Report No 585 ARAP Group of Titan Systems, New Jersey, Princeton, New Jersey

Sherwood, C R , J S Creager, E H Roy, G Geltenbaun, and T Dempsey 1984 Sedimentary processes and evironments in the Columbia River estuary Final report on the Sedimentation and Shoaling Work Unit of the Columbia River Estuary Data Development Program Columbia River Estuary Study Taskforce, Astoria, Oregon 318 pp

Sherwood, C R , and J S Craeger 1990 Sedimentary Geology of Columbia River Estuary Progress in Oceanography, v 25, no 1-4

Simenstad, C.A , L F Small, C D McIntire, D A Jay and C Sherwood 1990 Columbia River estuary studies. an introduction to the estuary, brief history, and prior studies Prog Oceanog. 25 1-13

Sternberg, R.W , J.S. Creager, W Glassley, and J Johnson. Aquatic disposal field investigations, Columbia River disposal site, Oregon Appendix A Investigation of the hydraulic regime and physical nature of bottom sedimentation. U S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi.

Sylvester, R.O and D A. Carlson. 1961 A report on Lower Columbia River, basic water quality data analysis for the year 1960 Prepared for the Cooperative Water Quality Basic Data Program Oregon State Sanitary Authority, Northwest Pulp and Paper Association, and Washington State Pollution Control Commission. University of Washington, Seattle, Washington

Tetra Tech. 1991a. Reconnaissance Survey of the lower Columbia River Task 1 List of materials to evaluate. Prepared for Lower Columbia River Bi-State Committee Tetra Tech, Inc., Bellevue, Washington.

Tetra Tech 1991b Reconnaissance Survey of the lower Columbia River Task 1 Problem area and data gap identification ranking framework Prepared for Lower Columbia River Bi-State Committee Tetra Tech, Inc , Bellevue, Washington.

Tetra Tech. 1991c Reconnaissance Survey of the lower Columbia River Task 2 List of sources of information to evaluate Prepared for Lower Columbia River Bi-State Committee Tetra Tech, Inc , Bellevue, Washington.

Tetra Tech. 1991d Reconnaissance Survey of the lower Columbia River. Task 5· Definition of beneficial uses Prepared for Lower Columbia River Bi-State Committee Tetra Tech, Inc , Bellevue, Washington

Tetra Tech 1991e Reconnaissance Survey of the lower Columbia River Cruise Report Prepared for Lower Columbia River Bi-State Committee Tetra Tech, Inc . Bellevue, Washington

Tetra Tech. 1991f Reconnaissance Survey of the lower Columbia River QA/QC Plan. Prepared for Lower Columbia River Bi-State Committee Tetra Tech, Inc , Bellevue, Washington

Tetra Tech. 1991g Reconnaissance Survey of the lower Columbia River Sampling Plan. Prepared for Lower Columbia River Bi-State Committee Tetra Tech, Inc., Bellevue, Washington

Tetra Tech 1992a Reconnaissance Survey of the lower Columbia River Task 1 Summary of existing data and preliminary identification of problem areas and data gaps Prepared for Lower Columbia River Bi-State Committee. Tetra Tech, Inc , Bellevue, Washington

Tetra Tech. 1992b Reconnaissance Survey of the lower Columbia River Task 1 Summary report Prepared for Lower Columbia River Bi-State Committee Tetra Tech, Inc., Bellevue, Washington

Tetra Tech. 1992c Reconnaissance Survey of the lower Columbia River Task 2 data analysis report Inventory and characterization of pollutants Prepared for Lower Columbia River Bi-State Committee Tetra Tech, Inc , Bellevue, Washington

Tetra Tech. 1992d. Reconnaissance Survey of the Lower Columbia River Task 2 summary report Inventory and characterization of pollutants Prepared for Lower Columbia River Bi-State Committee Tetra Tech, Inc., Bellevue, Washington

Tetra Tech 1992e Reconnaissance Survey of the lower Columbia River Task 3. Review of hydraulic, hydrologic, sediment transport, and geomorphic characteristics of the lower Columbia River Prepared for Lower Columbia River Bi-State Committee Tetra Tech, Inc., Bellevue, Washington.

Tetra Tech. 1992f Reconnaissance Survey of the lower Columbia River Task 3 Recommendations on conceptual modeling approaches and numerical models Prepared for Lower Columbia River Bi-State Committee. Tetra Tech, Inc. Bellevue, Washington

Tetra Tech 1992g Reconnaissance Survey of the lower Columbia River. Task 3· Final task report and recommendations Prepared for Lower Columbia River Bi-State Committee Tetra Tech, Inc , Bellevue, Washington

Tetra Tech 1992h Reconnaissance Survey of the lower Columbia River Task 4 Review of biological indicators to support recommendations on a biological monitoring approach Prepared for Lower Columbia River Bi-State Committee Tetra Tech, Inc , Bellevue, Washington

Tetra Tech 1992i Reconnaissance Survey of the lower Columbia River· Task 4 Recommended biological indicators for the lower Columbia River Prepared for Lower Columbia River Bi-State Committee Tetra Tech, Inc., Bellevue, Washington

Tetra Tech. 1992j. Reconnaissance Survey of the lower Columbia River Task 5 Beneficial use descriptions and locations Prepared for Lower Columbia River Bi-State Committee Tetra Tech, Inc , Bellevue, Washington

Tetra Tech 1992k. Reconnaissance Survey of the lower Columbia River Task 5 summary report Beneficial uses and sensitive areas Prepared for Lower Columbia River Bi-State Committee Tetra Tech, Inc., Bellevue, Washington

Tetra Tech. 1993. Reconnaissance Survey of the lower Columbia River Task 6 Reconnaissance report. Prepared for Lower Columbia River Bi-State Committee Tetra Tech, Inc , Bellevue, Washington.

Thomas, W A , and W H McAnally, Jr 1985 User's manual for generalized computer program system, open channel flow and sedimentation, TABS-2 Instruction Report HL-85-1 U S Army Engineer, Waterways Experiment Station, Vicksburg, Mississippi (Item not seen)

Thorp, J H and A P Covich (eds) 1991 Ecology and classification of North American Freshwater Invertebrates Academic Press, San Diego, California 911 pp

U S Army Corps of Engineers 1980 Columbia River Sediment Database, Estuarine and Riverine Portland District Corps of Engineers, Portland Oregon

U S Army Corps of Engineers 1986 Investigation of Bank Erosion at Sauvie Island, Oregon Planning Division Technical Report. COE. Portland District, Portland,.Oregon

U.S. Army Corps of Engineers 1987 Columbia River, Downstream of Bonneville Dam, Maintenance Disposal Plan. COE, Portland District, Portland, Oregon

U S Army Corps of Engineers 1988. Columbia River Water Management Report for Water Year 1987 Columbia River Water Management Group, Portland, Oregon

U S Army Corps of Engineers 1991 Channel Status Columbia River U S Army Corps of Engineers, Portland District, Portland Oregon

U S. Environmental Protection Agency 1990 Environmental monitoring and assessment programs Ecological indicators EPA/600/3-90/060 Office ot Research and Development, U S. Environmental Protection Agency

U S Environmental Protection Agency 1991a Bioaccumulation ot selected pollutants in fish - A National Study Vols I and II EPA 506/6-90/001a Assessment and Watershed Protection Division, Office of Water Regulations and Standards, U S Environmental Protection Agency, Washington, D C

U S. Environmental Protection Agency 1991b Assessment and control of bioconcentratable contaminants in surface waters Office of Water, U S Environmental Protection Agency, Washington, D C

U.S. Environmental Protection Agency 1991c Proposed sediment quality criteria for the protection of benthic organisms Dieldrin Draft EPA document Office of Science and Technology, Health and Ecological Criteria Division, U S. Environmental Protection Agency, Washington, D C.

U S Environmental Protection Agency 1991d Proposed sediment quality criteria for the protection of benthic organisms Acenaphthene Draft EPA document Office of Science and Technology, Health and Ecological Criteria Division, U S Environmental Protection Agency, Washington, D C

U S Environmental Protection Agency 1991e Proposed sediment quality criteria for the protection of benthic organisms Endrin Draft EPA document Office of Science and Technology, Health and Ecological Criteria Division, U S Environmental Protection Agency, Washington, D C

U S Environmental Protection Agency 1991f Proposed sediment quality criteria for the protection of benthic organisms Fluoranthene Draft EPA document Office of Science and Technology, Health and Ecological Criteria Division, U S Environmental Protection Agency, Washington, D C

U S. Environmental Protection Agency 1991g Proposed sediment quality criteria for the protection of benthic organisms: Phenanthrene Draft EPA document Office ot Science and Technology, Health and Ecological Criteria Division, U S Environmental Protection Agency, Washington, D C

U S Environmental Protection Agency 1991h Total maximum daily load (TMDL) for 2,3,7,8-TCDD in the Columbia River Basin Decision Document U S Environmental Protection Agency, Region X, Seattle, Washington

U S Environmental Protection Agency 1991i Dioxin loadings to waters in the Columbia River Basin Region 10 Fact Sheet

U S Fish and Wildlife Service 1991 Unpublished data

Van Winkle, W 1914. Quality of surface waters ot Washington Geological Survey Water-Supply Paper 363 U S. Geological Survey, Washington. D C

Weston, D P 1990 Hydrocarbon bioaccumulation from contaminated sediment by the deposit-feeding polychaete *Abarenicola pacifica*. Mar Biol 107 159-169

Whetten, J T , J C Kelley, and L G Hanson 1969 Characteristics of Columbia River sediment and sediment transport. J Sediment Petrol 39 1149-1166

Williams, L.G 1964 Possible relationships between plankton-diatom species numbers and water-quality estimates Ecology 45 809-823

Williams, L G 1972 Plankton diatom species biomasses and the quality of American rivers and the Great Lakes Ecology 53 1038-1050

Williams, L.G and C. Scott. 1962. Principal diatoms of major waterways of the United States Limnol Oceanogr 7:365-375

Windom, H L., J T Byrd, R.G Smith, Jr , and F Huan 1991 Inadequacy of NASQUAN data for assessing metal trends in the nation's rivers Environ. Sci Technol 25:1137-1142

Appendix A. Crayfish Metals Ranking Scores

Station	*Crayfish* Barium rank	*Crayfish* Cadmium rank	*Crayfish* Copper rank	*Crayfish* Lead rank	*Crayfish* Mercury rank	*Crayfish* Nickel rank	*Crayfish* Silver rank	*Crayfish* Zinc rank	Metals Rank sum	Adjusted Metals Rank sum
D3										
D6	12.5	10	14	9.5	15.5	1	1	9	72.5	50.3
D8	9.5	10	12	9.5	10	1	16	11	79	54.9
D10	7.5	7.5	17	9.5	1	1	11	7	61.5	42.7
D12	7.5	4	2	16	6	1	10	5	51.5	35.8
D15	15	16.5	9	9.5	7.5	1	12	4	74.5	51.7
D16	1	2	3	1	11.5	1	14	6	39.5	27.4
D19	6	7.5	16	1	9	1	1	14	55.5	38.5
D20	18	10	8	1	7.5	1	18	15.5	79	54.9
D22	12.5	4	1	17.5	13	1	6	3	58	40.3
D23	9.5	6	5	9.5	18	1	5	1	55	38.2
D24	12.5	4	4	9.5	11.5	1	4	2	48.5	33.7
D26	17	13	18	14	1	18	1	18	100	69.4
D28	5	13	13	5.5	17	1	8	10	72.5	50.3
D29	3.5	15	6	1	1	1	13	12	52.5	36.5
D31	2	13	15	14	14	1	7	8	74	51.4
D35	3.5	1	7	5.5	15.5	17	9	13	71.5	49.7
D38	12.5	16.5	11	14	5	1	15	15.5	90.5	62.8
D40	16	18	10	17.5	4	1	17	17	100.5	69.8

* Adjusted Metals Rank Sum equals the Metals Rank Sum divided by the maximum possible score (8 metals x 18 stations = 144) times 100

* A rank of 1 was assigned for non-detected values

Appendix A Crayfish Pesticide Ranking Scores

Station	Crayfish p,p'-DDT rank	Crayfish o,p'-DDT rank	Crayfish p,p'-DDE rank	Crayfish o,p'-DDE rank ND	Crayfish p,p'-DDD rank	Crayfish o,p'-DDD rank ND	Crayfish Heptachlor rank	Crayfish Aldrin rank ND	Crayfish Dieldrin rank	Crayfish Mirex rank ND	Crayfish Dacthal rank ND	Crayfish Methyl Parathion rank	Crayfish Parathion rank ND
D3													
D6	1.0	1.0	5.0	0.0	1.0	0.0	1.0	0.0	1.0	0.0	0.0	18.0	0.0
D8	1.0	1.0	6.0	0.0	1.0	0.0	1.0	0.0	1.0	0.0	0.0	1.0	0.0
D10	1.0	1.0	11.0	0.0	18.0	0.0	1.0	0.0	1.0	0.0	0.0	1.0	0.0
D12	1.0	1.0	3.0	0.0	1.0	0.0	1.0	0.0	1.0	0.0	0.0	1.0	0.0
D15	1.0	1.0	8.0	0.0	17.0	0.0	1.0	0.0	1.0	0.0	0.0	1.0	0.0
D16	1.0	1.0	4.0	0.0	1.0	0.0	1.0	0.0	1.0	0.0	0.0	16.0	0.0
D19	1.0	1.0	13.0	0.0	1.0	0.0	1.0	0.0	1.0	0.0	0.0	1.0	0.0
D20	18.0	1.0	14.5	0.0	1.0	0.0	1.0	0.0	1.0	0.0	0.0	1.0	0.0
D22	1.0	1.0	9.0	0.0	1.0	0.0	1.0	0.0	1.0	0.0	0.0	1.0	0.0
D23	1.0	18.0	16.0	0.0	1.0	0.0	1.0	0.0	1.0	0.0	0.0	1.0	0.0
D24	1.0	1.0	12.0	0.0	1.0	0.0	1.0	0.0	1.0	0.0	0.0	17.0	0.0
D26	1.0	1.0	10.0	0.0	1.0	0.0	1.0	0.0	1.0	0.0	0.0	1.0	0.0
D28	1.0	1.0	1.0	0.0	1.0	0.0	1.0	0.0	1.0	0.0	0.0	1.0	0.0
D29	1.0	1.0	14.5	0.0	1.0	0.0	1.0	0.0	1.0	0.0	0.0	1.0	0.0
D31	1.0	1.0	17.5	0.0	1.0	0.0	1.0	0.0	18.0	0.0	0.0	1.0	0.0
D35	1.0	1.0	1.0	0.0	1.0	0.0	1.0	0.0	1.0	0.0	0.0	1.0	0.0
D38	1.0	1.0	17.5	0.0	1.0	0.0	18.0	0.0	1.0	0.0	0.0	1.0	0.0
D40	1.0	1.0	7.0	0.0	1.0	0.0	1.0	0.0	1.0	0.0	0.0	1.0	0.0

* Adjusted Pesticides Rank Sum equals the Pesticides Rank Sum divided by the maxiumum possible score (12 pesticides x 18 stations = 216) times 100

* A rank of 1 was assigned for non-detected values

Station	*Crayfish* Malathion rank ND	*Crayfish* Iso-phorone rank	*Crayfish* Endosulfan II rank	*Crayfish* Endosulfan sulfate rank	*Crayfish* Endrin rank ND	*Crayfish* Endrin aldehyde rank ND	*Crayfish* Meth-oxychlor rank	*Crayfish* alpha BHC rank ND	*Crayfish* beta BHC rank	*Crayfish* delta BHC rank ND	*Crayfish* gamma BHC rank ND	Pesticide Sum rank	Adjusted Pesticide Sum rank
D3													
D6	0.0	1.0	1.0	1.0	0.0	0.0	1.0	0.0	1.0	0.0	0.0	33.0	15.3
D8	0.0	13.0	1.0	1.0	0.0	0.0	1.0	0.0	1.0	0.0	0.0	29.0	13.4
D10	0.0	1.0	1.0	1.0	0.0	0.0	1.0	0.0	1.0	0.0	0.0	39.0	18.1
D12	0.0	1.0	1.0	1.0	0.0	0.0	1.0	0.0	1.0	0.0	0.0	14.0	6.5
D15	0.0	1.0	1.0	1.0	0.0	0.0	17.0	0.0	1.0	0.0	0.0	51.0	23.6
D16	0.0	1.0	1.0	18.0	0.0	0.0	1.0	0.0	18.0	0.0	0.0	64.0	29.6
D19	0.0	18.0	1.0	1.0	0.0	0.0	1.0	0.0	1.0	0.0	0.0	41.0	19.0
D20	0.0	1.0	1.0	1.0	0.0	0.0	1.0	0.0	1.0	0.0	0.0	42.5	19.7
D22	0.0	1.0	1.0	1.0	0.0	0.0	1.0	0.0	1.0	0.0	0.0	20.0	9.3
D23	0.0	1.0	1.0	1.0	0.0	0.0	1.0	0.0	1.0	0.0	0.0	44.0	20.4
D24	0.0	14.0	1.0	1.0	0.0	0.0	18.0	0.0	1.0	0.0	0.0	69.0	31.9
D26	0.0	15.0	1.0	1.0	0.0	0.0	1.0	0.0	1.0	0.0	0.0	35.0	16.2
D28	0.0	17.0	1.0	1.0	0.0	0.0	1.0	0.0	1.0	0.0	0.0	28.0	13.0
D29	0.0	1.0	18.0	1.0	0.0	0.0	1.0	0.0	1.0	0.0	0.0	42.5	19.7
D31	0.0	16.0	1.0	1.0	0.0	0.0	1.0	0.0	1.0	0.0	0.0	60.5	28.0
D35	0.0	1.0	1.0	1.0	0.0	0.0	1.0	0.0	1.0	0.0	0.0	12.0	5.6
D38	0.0	1.0	1.0	1.0	0.0	0.0	1.0	0.0	17.0	0.0	0.0	61.5	28.5
D40	0.0	1.0	1.0	1.0	0.0	0.0	1.0	0.0	1.0	0.0	0.0	18.0	8.3

Appendix A. Crayfish Dioxin/Furan Ranking Scores

Station	Adjusted TEC Score	Dioxin/ Furan TEC Conc (pg/g)	NYS Criteria Exceedance Score	*CRAYFISH* FINAL ADJUSTED TEC RANK
D06	34.7	1.307	0	34.7
D08	33.5	1.261	0	33.5
D10	34.7	1.307	0	34.7
D12	NM	NM	0	NM
D15	29.8	1.124	0	29.8
D16	NM	NM	0	NM
D19	97.7	3.68	20	117.7
D20	33.8	1.274	0	33.8
D22	NM	NM	0	NM
D23	41.1	1.55	0	41.1
D24	66.2	2.493	0	66.2
D26	NM	NM	0	NM
D28	100.0	3.767	20	120.0
D29	NM	NM	0	NM
D31	NM	NM	0	NM
D35	41.5	1.562	0	41.5
D38	38.4	1.445	0	38.4
D40	31.7	1.193	0	31.7

* Adjusted TEC score equals the TEC concentration divided by the maximum TEC score (3.767) times 100

* NM = Not Measured

Appendix A. Crayfish Total Ranking Scores

Station	*CRAYFISH* Adjusted Metals Rank Sum	*CRAYFISH* Adjusted Pesticide Rank Sum	*CRAYFISH* Adjusted TEC Score	*CRAYFISH* Sum of Adjusted ranks	Number of Chemical Categories	Rank Sum Adjusted for Number of Categories	*CRAYFISH* TOTAL RELATIVE RANKING SCORE
D06	50.3	15.3	34.7	100.3	3	33	55
D08	54.9	13.4	33.5	101.8	3	34	56
D10	42.7	18.1	34.7	95.5	3	32	52
D12	35.8	6.5	NM	42.2	2	21	35
D15	51.7	23.6	29.8	105.2	3	35	57
D16	27.4	29.6	NM	57.1	2	29	47
D19	38.5	19.0	117.7	175.2	3	58	96
D20	54.9	19.7	33.8	108.4	3	36	59
D22	40.3	9.3	NM	49.5	2	25	41
D23	38.2	20.4	41.1	99.7	3	33	54
D24	33.7	31.9	66.2	131.8	3	44	72
D26	69.4	16.2	NM	85.6	2	43	70
D28	50.3	13.0	120.0	183.3	3	61	100
D29	36.5	19.7	NM	56.1	2	28	46
D31	51.4	28.0	NM	79.4	2	40	65
D35	49.7	5.6	41.5	96.7	3	32	53
D38	62.8	28.5	38.4	129.7	3	43	71
D40	69.8	8.3	31.7	109.8	3	37	60

Appendix A Largescale Sucker Metals Ranking Scores*

Station	Sucker Barium rank	Sucker Cadmium rank	Sucker Copper rank	Sucker Lead rank	Sucker Mercury rank	Sucker Nickel rank	Sucker Zinc rank	Metals Rank sum	Adjusted Metals Rank sum**
D06	8	7.8	17 5	15	11	1	10	70.3	55 8
D08	10	5 5	14	6	13	1	13	62 5	49 6
D10	5	15	15	13.5	15	1	8	72 5	57 5
D12	13 5	7 8	16	10	8 5	1	3 5	60 3	47.9
D15	12	15	9	7	6	1	16	66	52.4
D16	2	2 5	6	8 5	4	1	2	26	20 6
D19	1	2.5	8	1	5	1	1	19 5	15 5
D20	8	7 8	11	12	10	1	14	63 8	50 7
D22	4	2.5	17 5	18	14	16	17	89	70 6
D23	15 5	2 5	5	1	17 5	1	7	49 5	39 3
D24	8	15	10	8 5	2	1	5	49 5	39 3
D26	11	7 8	4	5	17 5	1	3 5	49 8	39 6
D28	6	7 8	13	13 5	8 5	18	18	84 8	67.3
D29	13 5	15	12	16	1	17	9	83 5	66 3
D31	18	15	1	1	12	1	11	59	46 8
D35	3	5 5	7	1	7	15	6	44 5	35 3
D38	15 5	7 8	2 5	17	3	1	12	58.8	46 7
D40	17	18	2 5	11	16	1	15	80.5	63 9

* A rank of 1 was assigned for non-detected values
* Metals which were not detected at any station were not included in the ranking
** Adjusted Metals Rank Sum equals the Metals Rank Sum divided by the maximum possible score (7 x 18 = 162) times 100

Appendix A. Largescale Sucker Semivolatile Ranking Scores*

Station	Sucker 2-Methyl Naphthalene rank		Semi-Volatile Rank sum	Adjusted Semi-Volatile Rank sum
D06	1		1	5.6
D08	1		1	5.6
D10	1		1	5.6
D12	1		1	5 6
D15	1		1	5.6
D16	1		1	5.6
D19	1		1	5.6
D20	1		1	5.6
D22	1		1	5.6
D23	1		1	5.6
D24	1		1	5.6
D26	1		1	5.6
D28	1		1	5.6
D29	1		1	5.6
D31	1		1	5.6
D35	18		18	100.0
D38	1		1	5.6
D40	1		1	5.6

* A rank of 1 was assigned for non-detected compounds

** Adjusted Semi-Volatile Rank Sum equals the Semi-Volatile Rank Sum divided by the maximum possible score (1 semi-volatile x 18 stations = 18) times 100

Appendix A Largescale Sucker Pesticide Ranking Scores*

Station	Sucker o,p'-DDD rank	Sucker o,p'-DDE rank	Sucker p,p'-DDD rank	Sucker p,p'-DDE rank	Sucker p,p'-DDT rank	Sucker Aldrin rank	Sucker Dieldrin rank	Sucker Parathion rank	Sucker Endosulfan I rank	Sucker Endosulfan sulfate rank	Sucker Endrin rank	Sucker Endrin aldehyde rank
D03	1	1	1	1	9	1	1	1	1	1	1	1
D08	1	1	3	18	1	1	1	17	1	1	1	1
D10	1	1	13.5	1	15.5	17	1	1	18	1	1	1
D12	1	1	1	1	1	18	1	1	1	1	1	18
D15	15.5	17	15.5	1	18	1	1	1	1	1	1	1
D16	1	11	7.5	1	8	1	1	16	1	1	1	1
D19	1	16	9	1	1	1	1	1	1	1	1	1
D20	1	1	7.5	1	12	1	1	18	1	1	1	1
D22	15.5	12.5	6	1	13	1	1	1	1	1	1	1
D23	15.5	15	13.5	1	15.5	1	1	1	1	1	18	1
D24	1	10	12	1	1	1	1	1	1	1	1	1
D26	1	1	18	1	17	1	18	1	1	1	1	1
D28	1	14	10.5	1	10	1	1	1	1	1	1	1
D29	15.5	12.5	4	1	7	1	1	1	1	1	17	1
D31	18	18	17	1	1	1	1	1	1	1	1	1
D35	13	1	5	1	6	1	1	1	1	18	1	1
D38	1	1	15.5	1	11	1	1	1	1	1	1	1
D40	1	1	10.5	1	14	16	1	1	1	1	1	1

* A rank of 1 was assigned for non-detected values

** Adjusted Pesticide Rank Sum equals the Pesticides Rank Sum divided by the max poss. score (16 pesticides x 18 stations = 288) times 100

Appendix A Largescale Sucker Pesticide Ranking Scores*

Station	Sucker Methoxy-chlor rank	Sucker alpha-BHC rank	Sucker beta-BHC rank	Sucker gamma-BHC rank	Pesticide Rank sum	Adjusted Pesticide Rank sum	# Exceed of NY Criteria (Pesticides)	NY Criteria Exceed Score	SUCKER FINAL ADJUSTED PESTICIDE Score
D06	1	1	1	1	24	8 3	0	0	8 3
D08	1	1	1	1	51	17 7	0	0	17 7
D10	1	1	1	1	76	26 4	0	0	26 4
D12	1	1	1	1	50	17.4	0	0	17 4
D15	18	1	1	1	95	33 0	0	0	33 0
D16	1	1	1	17	70.5	24 5	0	0	24 5
D19	1	1	1	18	56	19 4	0	0	19 4
D20	1	1	1	1	50 5	17 5	0	0	17 5
D22	1	1	1	1	59	20 5	0	0	20 5
D23	1	17	1	1	104 5	36 3	0	0	36 3
D24	1	1	1	16	51	17 7	0	0	17 7
D26	1	18	1	1	83	28 8	0	0	28 8
D28	1	1	1	1	47 5	16 5	0	0	16 5
D29	1	1	18	1	84	29 2	0	0	29 2
D31	1	1	1	1	66	22 9	0	0	22 9
D35	1	1	1	1	54	18 8	0	0	18 8
D38	1	1	1	1	40 5	14 1	0	0	14 1
D40	1	1	1	1	53 5	18 6	0	0	18 6

Appendix A Largescale Sucker PCB Ranking Scores*

Station	Sucker Aroclor 1254 rank	Sucker Aroclor 1260 rank	PCB Rank sum	Adjusted PCB Rank sum**	# Exceed. of NY Criteria (PCB)	NY Criteria Exceed. Score	SUCKER FINAL ADJUSTED PCB Score
D06	8.5	1	9 5	26.4	1	20	46 4
D08	6	1	7	19 4		0	19 4
D10	16 5	1	17.5	48 6	1	20	68 6
D12	8.5	1	9 5	26 4	1	20	46 4
D15	5	1	6	16 7		0	16 7
D16	7	1	8	22 2		0	22 2
D19	4	1	5	13 9		0	13 9
D20	11 5	1	12 5	34 7	1	20	54 7
D22	3	1	4	11.1		0	11 1
D23	14 5	1	15 5	43.1	1	20	63 1
D24	10	1	11	30 6	1	20	50 6
D26	13	1	14	38.9	1	20	58 9
D28	18	1	19	52.8	1	20	72 8
D29	14 5	1	15.5	43.1	1	20	63 1
D31	16 5	1	17.5	48 6	1	20	68 6
D35	2	1	3	8.3		0	8 3
D38	11.5	1	12.5	34.7	1	20	54 7
D40	1	18	19	52 8	1	20	72 8

* A rank of 1 was assigned for non-detected values
** Adjusted PCB Rank Sum equals the PCBs Rank Sum divided by the maximum possible score (2 Aroclors x 18 stations = 36) times 100

Appendix A. Largescale Sucker Dioxin/Furan Ranking Scores

Station	Adjusted TEC Score*	Dioxin/ Furan TEC Conc. (pg/g)	# Exceed. of NY Criteria (Dioxin)	NY Criteria Exceedance Score	SUCKER FINAL ADJUSTED DIOXIN/FURAN Score
D06	47.7	1.814		0	47.7
D08	70.6	2.685		0	70.6
D10	99.8	3.795	1	20	119.8
D12	NM	NM		0	NM
D15	59.2	2.251		0	59.2
D16	NM	NM		0	NM
D19	86.8	3.299	1	20	106.8
D20	40.7	1.548		0	40.7
D22	NM	NM		0	NM
D23	56.5	2.147		0	56.5
D24	67.7	2.575		0	67.7
D26	NM	NM		0	NM
D28	94.2	3.582	1	20	114.2
D29	NM	NM		0	NM
D31	NM	NM		0	NM
D35	51.6	1.962		0	51.6
D38	100.0	3.802	1	20	120.0
D40	71.9	2.735		0	71.9

* Adjusted TEC score equals the TEC concentration divided by the maximum TEC score (3.802) times 100

NM = Not measured

Appendix A. Largescale Sucker Total Ranking Scores

Station	*SUCKER* Adjusted Metals Rank sum**	*SUCKER* Adjusted Semi-Volatile Rank sum	*SUCKER* Adjusted Pesticide Rank sum	*SUCKER* Adjusted PCB Rank sum**	*SUCKER* Adjusted TEC/NY Criteria Rank sum	*SUCKER* Sum of Adjusted ranks	Number of Chemical Categories	Rank Sum Adjusted for Number of Categories	*SUCKER* TOTAL RELATIVE RANKING SCORE
D06	55 8	5.6	8 3	26 4	47.7	143.8	5	29	60
D08	49 6	5.6	17.7	19 4	70.6	162.9	5	33	68
D10	57 5	5 6	26 4	48 6	99.8	237.9	5	48	99
D12	47 9	5 6	17 4	26.4	NM	97.2	4	24	51
D15	52 4	5.6	33 0	16 7	59.2	166 8	5	33	70
D16	20 6	5 6	24 5	22 2	NM	72.9	4	18	38
D19	15 5	5 6	19 4	13 9	86.8	141.1	5	28	59
D20	50 7	5 6	17 5	34.7	40.7	149.2	5	30	62
D22	70 6	5 6	20 5	11 1	NM	107 8	4	27	56
D23	39 3	5 6	36 3	43 1	56 5	180 7	5	36	75
D24	39 3	5 6	17 7	30 6	67.7	160 8	5	32	67
D26	39 6	5 6	28 8	38 9	NM	112 8	4	28	59
D28	67 3	5 6	16 5	52 8	94 2	236 4	5	47	99
D29	66 3	5 6	29 2	43 1	NM	144 0	4	36	75
D31	46 8	5 6	22 9	48 6	NM	123 9	4	31	65
D35	35 3	100 0	18 8	8.3	51.6	214 0	5	43	89
D38	46 7	5 6	14 1	34 7	100 0	201.0	5	40	84
D40	63 9	5 6	18 6	52.8	71.9	212.7	5	43	89

Station	*SUCKER* Adjusted Metals Rank sum	*CRAYFISH* Adjusted Metals Rank sum	*TOTAL* Adjusted Metals Rank sum	*SUCKER* Adjusted Semi-Volatile Rank sum	*CRAYFISH* Adjusted Semi-Volatile Rank sum	*TOTAL* Adjusted Semi-Volatile Rank sum	*SUCKER* Adjusted Pesticide Rank sum	*CRAYFISH* Adjusted Pesticide Rank sum	*TOTAL* Adjusted Pesticide Rank sum
D06	55 8	50 3	106 1	5 6	0	5 6	8 3	15 3	23 6
D08	49 6	54.9	104.5	5 6	0	5 6	17.7	13 4	31 1
D10	57 5	42.7	100 2	5 6	0	5 6	26 4	18.1	44 5
D12	47 9	35 8	83 7	5 6	0	5 6	17 4	6 5	23 9
D15	52 4	51 7	104.1	5 6	0	5 6	33.0	23 6	56 6
D16	20 6	27 4	48 0	5 6	0	5 6	24 5	29 6	54 1
D19	15 5	38 5	54.0	5 6	0	5 6	19 4	19 0	38 4
D20	50 7	54 9	105 6	5 6	0	5 6	17 5	19 7	37 2
D22	70 6	40 3	110 9	5 6	0	5 6	20 5	9 3	29 8
D23	39 3	38 2	77 5	5 6	0	5 6	36 3	20 4	56 7
D24	39 3	33 7	73 0	5 6	0	5 6	17 7	31 9	49 6
D26	39 6	69 4	109 0	5 6	0	5 6	28 8	16 2	45 0
D28	67 3	50 3	117 6	5 6	0	5 6	16 5	13 0	29 5
D29	66 3	36 5	102 8	5 6	0	5 6	29 2	19 7	48 9
D31	46 8	51 4	98 2	5 6	0	5 6	22 9	28 0	50 9
D35	35 3	49 7	85 0	100 0	0	100 0	18 8	5 6	24 4
D38	46 7	62 8	109 5	5 6	0	5 6	14 1	28.5	42.6
D40	63 9	69 8	133 7	5 6	0	5 6	18 6	8 3	26 9

Appendix A Combined Crayfish and Largescale Sucker Total Ranking Scores (Page 2 of 2)

SUCKER Adjusted PCB Rank sum	*CRAYFISH* Adjusted PCB Rank sum	*TOTAL* Adjusted PCB Rank sum	*SUCKER* Adjusted TEC/NY Criteria Rank sum	*CRAYFISH* Adjusted TEC/NY Criteria Rank sum	*TOTAL* Adjusted TEC/NY Criteria Rank sum	*TOTAL* Sum of Adjusted ranks	Number of Chemical Categories	*TOTAL* Rank Sum Adjusted for Number of Categories	*TOTAL* Relative Ranking Score
26.4	0	26.4	47 7	34 7	82 4	244 1	5	49	58
19 4	0	19.4	70.6	33 5	104 1	264 7	5	53	63
48.6	0	48 6	99 8	34 7	134 5	333 4	5	67	79
26 4	0	26.4	NM	NM	NM	139 5	4	35	42
16 7	0	16 7	59 2	29 8	89 0	271 9	5	54	65
22 2	0	22.2	NM	NM	NM	129.9	4	32	39
13 9	0	13 9	86 8	117 7	204 5	316 3	5	63	75
34.7	0	34 7	40 7	33 8	74.5	257 6	5	52	61
11.1	0	11 1	NM	NM	NM	157 4	4	39	47
43 1	0	43 1	56 5	41 1	97 6	280 4	5	56	67
30 6	0	30 6	67 7	66 2	133 9	292 6	5	59	70
38 9	0	38 9	NM	NM	NM	198 4	4	50	59
52 8	0	52 8	94 2	120 0	214.2	419 7	5	84	100
43 1	0	43 1	NM	NM	NM	200 2	4	50	60
48 6	0	48 6	NM	NM	NM	203 3	4	51	61
8 3	0	8 3	51 6	41 5	93.1	310 8	5	62	74
34.7	0	34 7	100.0	38 4	138.4	330.7	5	66	79
52 8	0	52 8	71.9	31 7	103.6	322.5	5	65	77

Appendix A. Carp Metals Ranking Scores

Station	Carp Barium rank	Carp Cadmium rank	Carp Copper rank	Carp Lead rank	Carp Mercury rank	Carp Nickel rank	Carp Zinc rank	Metals Rank sum	Adjusted Metals Rank Sum**
D24	5	1	5	3	1	1	2	18	25 0
D26	3	8	8	4	8	1	7	39	54 2
D28	7	5	4	6 5	4	7	8	41 5	57 6
D29	6	4	1	2	2	1	1	17	23 6
D31	2	2	3	1	7	1	4	20	27.8
D35	4	3	2	5	3	6	5	28	38 9
D38	8	7	7	6 5	6	8	6	48 5	67 4
D40	1	6	6	8	5	1	3	30	41 7

* A rank of 1 was assigned for non-detected values
* Metals which were not detected at any station were not included in the ranking
** Adjusted Metals Rank Sum equals the Metals Rank Sum divided by the maximum possible score (7 x 8 = 56) times 100

Appendix A Carp Semivolatiles Ranking Scores

Station	*CARP* Phenol rank	*CARP* 2-Chloro-phenol rank	*CARP* 4-Chloro-3-methyl-phenol rank	*CARP* 4-Nitro-phenol rank	*CARP* 2,4-Dinitro-toluene rank	*CARP* N-Nitroso-di-n-propyl-amine rank	*CARP* Acenaphthene rank	*CARP* Naphthalene rank	*CARP* Pyrene rank
D23	1	1	1	1	1	1	1	1	1
D24	1	1	1	1	1	1	1	1	1
D26	1	1	1	1	1	1	1	1	1
D28	1	1	1	1	1	1	1	1	1
D29	9	9	9	9	9	9	9	1	9
D31	1	1	1	1	1	1	1	1	1
D35	1	1	1	1	1	1	1	9	1
D38	1	1	1	1	1	1	1	1	1
D40	1	1	1	1	1	1	1	1	1

Appendix A Carp Semivolatiles Ranking Scores

Station	*CARP* 1,4-Dichloro-benzene rank	*CARP* 1,2,4-Tri-chloro-benzene rank	*CARP* Di-n-butyl phthalate rank	*CARP* Semivolatiles Rank sum	Adjusted Semivolatiles Rank sum	Number of NYS Exceed. (Trichlorobenzenes)	NYS Exceedance Score	FINAL SEMIVOLATILE RANKING SCORE
D23	1	1	1	12	11.1	-	0	11 1
D24	1	1	1	12	11.1	-	0	11 1
D26	1	1	1	12	11.1	-	0	11 1
D28	1	1	8	19	17.6	-	0	17 6
D29	9	9	1	92	85.2	1	20	105 2
D31	1	1	1	12	11.1	-	0	11 1
D35	1	1	1	20	18.5	-	0	18 5
D38	1	1	9	20	18.5	-	0	18 5
D40	1	1	1	12	11.1	-	0	11 1

Appendix A Carp Pesticide Ranking Scores

Station	CARP o,p-DDD rank	CARP o,p-DDE rank	CARP o,p-DDT rank	CARP 4,4'-DDD rank	CARP 4,4'-DDE rank	CARP 4,4'-DDT rank	CARP Aldrin rank	CARP Dieldrin rank
D23	1	1	1	7	3	1	1	1
D24	1	1	1	5	4	1	1	1
D26	1	9	1	9	1	9	1	1
D28	1	7.5	9	4	6	1	1	1
D29	9	1	1	1	5	5	9	1
D31	1	7.5	1	1	9	8	1	9
D35	1	1	1	1	7	1	1	1
D38	1	1	1	6	8	7	1	8
D40	1	1	1	8	1	6	1	1

Station	CARP Mirex rank	CARP Endrin rank	CARP gamma-BHC rank	Pesticides Rank sum	Adjusted Pesticides Rank sum	# Exceed. of NY Criteria	FINAL PESTICIDES ADJUSTED TOTAL
D23	1	1	1	19	19 2	0	19 2
D24	1	1	1	18	18 2	0	18 2
D26	9	1	9	51	51 5	0	51 5
D28	1	1	1	33 5	33.8	0	33 8
D29	1	1	1	35	35 4	0	35 4
D31	1	1	1	40 5	40 9	0	40 9
D35	1	1	1	17	17 2	0	17.2
D38	1	9	1	44	44.4	0	44 4
D40	1	1	1	23	23 2	0	23 2

Appendix A. Carp PCB Ranking Scores

Station	*CARP* Aroclor-1254 rank	*CARP* Aroclor-1260 rank	*CARP* PCB Rank sum	Adjusted PCB Rank sum	*CARP* No. NYS Criteria Exceed.	*CARP* NYS Exceed. Score	*CARP* FINAL ADJUSTED RANK
D23	1	7	8	44.4	0	0	44.4
D24	1	6	7	38.9	0	0	38.9
D26	1	9	10	55.6	0	0	55.6
D28	9	1	10	55.6	1	20	75.6
D29	7	1	8	44.4	1	20	64.4
D31	8	1	9	50.0	1	20	70.0
D35	5	1	6	33.3	1	20	53.3
D38	6	1	7	38.9	1	20	58.9
D40	1	8	9	50.0	1	20	70.0

Appendix A. Carp Dioxin/Furan Ranking Scores

Station	CARP Dioxin/Furan TEC Conc. (pg/g)	CARP Adjusted TEC Score	CARP No. NYS Criteria Exceed.	CARP NYS Exceed. Score	CARP FINAL ADJUSTED RANK
D23	NM	NM	0	0	NM
D24	5.203	100.0	1	20	120.0
D26	NM	NM	0	0	NM
D28	4 875	93.7	1	20	113.7
D29	NM	NM	0	0	NM
D31	NM	NM	0	0	NM
D35	3 591	69.0	1	20	89.0
D38	2.890	55 5	0	0	55 5
D40	5.063	97 3	1	20	117 3

Appendix A. Carp Total Ranking Scores

Station	*CARP* FINAL METALS RANKING SCORE	*CARP* FINAL SEMIVOLATILE RANKING SCORE	*CARP* FINAL PESTICIDES ADJUSTED TOTAL	*CARP* FINAL PCB ADJUSTED RANK	*CARP* FINAL DIOXIN/FURAN ADJUSTED RANK	Sum of Final Ranks	Number of Chemical Categories	Rank Sum Adjusted for No. of Categories	FINAL RELATIVE RANKING SCORE
D23	NM	11.1	19.2	44 4	NM	74.7	3	24.9	43.6
D24	25.0	11 1	18 2	38.9	100.0	193 2	5	38 6	67 6
D26	54.2	11.1	51 5	55 6	NM	172.3	4	43 1	75 4
D28	57 6	17 6	33 8	75 6	93 7	278 3	5	55 7	97.4
D29	23.6	105 2	35 4	64.4	NM	228 6	4	57.1	100 0
D31	27.8	11.1	40.9	70.0	NM	149 8	4	37 4	65.5
D35	38.9	18 5	17.2	53 3	69 0	196 9	5	39 4	68.9
D38	67.4	18 5	44 4	58 9	55 5	244 8	5	49 0	85.7
D40	41.7	11 1	23 2	70 0	97 3	243 3	5	48 7	85.2

Appendix A. Peamouth Metals Ranking Scores

Station	Peamouth Barium rank	Peamouth Cadmium rank	Peamouth Copper rank	Peamouth Lead rank	Peamouth Mercury rank	Peamouth Nickel rank	Peamouth Zinc rank	Metals Rank sum	Adjusted Metals Rank sum**
D03	5	3	5	8	10	1	3	35	50.0
D10	4	9	7	5	7	1	4	37	52.9
D12	7	6.5	4	6.5	6	1	8	39	55.7
D15	10	10	10	10	1	9	10	60	85.7
D16	3	3	1	2	8	1	2	20	28.6
D19	6	3	3	6.5	4	1	1	24.5	35.0
D21	2	3	6	4	5	1	5	26	37.1
D23	1	3	2	3	3	1	7	20	28.6
D24	8.5	8	9	9	9	10	6	59.5	85.0
D28	8.5	6.5	8	1	2	1	9	36	51.4

* A rank of 1 was assigned for non-detected values
* Metals which were not detected at any station were not included in the ranking
** Adjusted Metals Rank Sum equals the Metals Rank Sum divided by the maximum possible score (7 x 10 = 70) times 100

Appendix A Peamouth Pesticide Ranking Scores

Station	*PEAMOUTH* o,p-DDD rank	*PEAMOUTH* o,p-DDE rank	*PEAMOUTH* 4,4'-DDD rank	*PEAMOUTH* 4,4'-DDE rank	*PEAMOUTH* Aldrin rank	*PEAMOUTH* Dieldrin rank	*PEAMOUTH* Dacthal rank	*PEAMOUTH* Malathion rank	*PEAMOUTH* Endosulfan I rank
D03	10	10	1	9	1	1	1	1	8
D10	1	1	1	1	1	1	1	10	1
D12	1	1	1	1	1	1	1	1	1
D15	1	1	8 5	5	9	1	1	1	1
D16	1	1	1	1	8	1	10	1	1
D19	1	1	8.5	6	1	1	1	1	1
D21	1	1	1	7	10	10	1	1	9
D23	1	1	10	8	1	9	1	1	10
D24	1	1	1	10	1	1	1	9	1
D28	1	1	1	4	1	1	1	1	1

Appendix A. Peam[illegible] Pesticide Ranking Scores

Station	*PEAMOUTH* Endrin aldehyde rank	*PEAMOUTH* beta-BHC rank	*PEAMOUTH* gamma-BHC rank	Pesticide Rank sum	Adjusted Pesticide Rank Sum	# NYS Exceed. (DDE)	# NYS Exceed. (BHC)	# NYS Exceed. (TOTAL)	NYS Exceed. Score	Final Peamouth Ranking Score
D03	1	1	1	45	37.5	1	-	1	20	57.5
D10	1	1	1	21	17.5	-	-	0	0	17.5
D12	1	9	1	20	16.7	-	-	0	0	16.7
D15	1	1	10	40.5	33.8	-	-	0	0	33.8
D16	1	1	1	28	23.3	-	-	0	0	23.3
D19	1	1	1	24.5	20.4	-	-	0	0	20.4
D21	10	10	1	62	51.7	-	1	1	20	71.7
D23	1	1	1	45	37.5	1	-	1	20	57.5
D24	1	1	1	29	24.2	1	-	1	20	44.2
D28	1	1	1	15	12.5	-	-	0	0	12.5

Appendix A   Peamouth PCB Ranking Scores

Station	*PEAMOUTH* Aroclor-1242 rank	*PEAMOUTH* Aroclor-1260 rank	PCB Rank sum	Adjusted PCB Rank sum	# NYS Exceed. (PCBs)	NYS Exceed. Score	Final Peamouth Ranking Score
D03	10	9	19	95	1	20	115
D10	1	1	2	10	-	0	10
D12	1	4	5	25	1	20	45
D15	1	6 5	7 5	37 5	1	20	57 5
D16	1	3	4	20	1	20	40
D19	1	8	9	45	1	20	65
D21	1	5	6	30	1	20	50
D23	1	6 5	7 5	37 5	1	20	57 5
D24	1	10	11	55	1	20	75
D28	9	2	11	55	1	20	75

Appendix A. Peamouth Dioxin/Furan Ranking Scores

Station	*PEAMOUTH* Dioxin/ Furan TEC Conc. (pg/g)	*PEAMOUTH* Adjusted TEC Score	# NYS Exceed. (Dioxin)	NYS Exceed. Score	Final Peamouth Ranking Score
D03	NM	NM	-	0	NM
D10	7 012	52.7	1	20	73
D12	NM	NM	-	0	NM
D15	4 229	31 8	1	20	52
D16	NM	NM	-	0	NM
D19	9.498	71.5	1	20	91
D21	7 933	59.7	1	0	60
D23	8.795	66.2	1	20	86
D24	13.293	100.0	1	20	120
D28	6.239	46.9	1	20	67

Appendix A Peam , Total Ranking Scores

Station	*Peamouth* Final Metals Rank Score	*Peamouth* Final Pesticide Ranking Score	*Peamouth* Final PCB Ranking Score	*Peamouth* Final Dioxin/Furan Ranking Score	Sum of Final Ranks	Number of Chemical Categories	Rank Sum Adjusted for No. of Categories	FINAL RELATIVE RANKING SCORE
D03	50.0	57 5	115 0	NM	222 5	3	74.2	91.5
D10	52.9	17.5	10 0	52 7	133 1	4	33 3	41 1
D12	55.7	16 7	45 0	31 8	149 2	4	37.3	46 0
D15	85.7	33 8	57.5	71 5	248 4	4	62 1	76 6
D16	28 6	23 3	40 0	NM	91.9	3	30 6	37 8
D19	35 0	20 4	65 0	44 8	165 2	4	41 3	51 0
D21	37 1	71.7	50 0	59 7	218 5	4	54.6	67 4
D23	28 6	57.5	57 5	86 2	229 7	4	57 4	70 9
D24	85 0	44.2	75 0	120 0	324 2	4	81.0	100 0
D28	51 4	12 5	75 0	46 9	185 9	4	46 5	57 3

APPENDIX A:

Chemical Ranking Tables for Crayfish, Largescale Sucker, Carp, and Peamouth