Effect On Puget Sound Chinook Salmon Of NPDES Authorized Toxic Discharges As Permitted by Washington Department of Ecology

Combined Report by

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Purpose and Introduction

This report evaluates the effects on chinook salmon of National Pollutant Discharge Elimination System (NPDES) authorized toxic discharges into Puget Sound as permitted by Washington Department of Ecology. Two key components are brought together in this report. These are: 1) the environmental impact of toxic discharges into Puget Sound, and 2) the biological effects of toxic chemicals on chinook salmon in the Puget Sound. David LaLiberte is a professional engineer with Liberte Environmental Associates. In this report (Section I) he investigates the environmental impact of sources and toxic discharges into Puget Sound. Mr. LaLiberte's qualifications and experience are discussed below. Dick Ewing is a biologist with Biotech Research and Consulting. In this report (Section II) he addresses the biological effects of toxic chemicals on chinook salmon in the Puget Sound. Dr. Ewing's qualifications and experience are discussed below.

Qualifications and Experience of David LaLiberte, MSCE, Environmental Engineer

Mr. LaLiberte is a registered Professional Engineer in Civil and Environmental Engineering (Oregon), and holds a Master of Science degree in Civil Engineering from Portland State University. He is currently employed as the Principal Engineer of Liberte Environmental Associates ("LEA"), a private consulting company. Prior to LEA, he worked as a professional engineer at two large environmental engineering firms, Montgomery Watson Americas and Brown & Caldwell, for a combined total of eight years. In addition, he rose to the position of research assistant over the course of three years at Portland State University. He has over eighteen years of experience in: surface water quality analysis and evaluation (including extensive experience with wastewater characterization and dilution modeling); environmental quality control; pollution abatement, including analysis and evaluation of effluent treatment alternative and discharge requirements of NPDES permits; and environmental design. Clients have included the Oregon Department of Environmental Quality, numerous municipalities, several public utilities, industrial dischargers and non-governmental organizations. Mr. LaLiberte's curriculum vitae are attached as Appendix A.1.

Qualifications and Experience of Dick Ewing, Ph. D., Biologist

Dr. Ewing received his Ph. D. in cell and molecular biology from University of Miami, Coral Gables, Florida in 1968. After receiving his degree, he was a postdoctoral fellow in Oak Ridge National Laboratory, Oak Ridge, Tennessee and the Marine Biological Laboratory in Wood's Hole, Massachusetts where he worked on developmental biology and physiology of invertebrates. In 1971, he came to Oregon State University as a research associate and spent one year as a temporary assistant professor in zoology. In 1975, he joined the Oregon Department of Fish and Wildlife and spent the next 17 years as a fish physiologist and hatchery specialist. In 1992, he left Oregon Department of Fish and Wildlife and started his own business, Biotech Research and Consulting, Inc., where he specializes in performing enzyme and hormone analysis, food analysis, and water quality analysis for fisheries agencies. In 1998, he began performing enzyme immunoassays of pesticides for different organizations. Past contracts involving pollutants are those from Boise, Inc., Confederated Tribes of Siletz Indians, Devils Lake Watershed Enhancement Committee, Portland Department of Parks and Recreation, and Northwest Coalition for Alternatives to Pesticides. Dr. Ewing's curriculum vitae are attached as Appendix A.2.

Combined Report Summary

This combined report finds that toxic contamination of water, sediments and organisms in the Puget Sound region caused in substantial part by National Pollutant Discharge Elimination System (NPDES) permitted discharges is widespread and likely to be harmful to chinook salmon. Figures and tables presented in this report are at the end of this summary. Figure 1 shows the Puget Sound region of interest with Figures 2 through 6 showing circulation patterns in the sound. The Strait of Georgia and northern bays in the region, up to Canada, are also considered in this report because of their close proximity and the shared water quality concerns, which cross the international border.

At present, Puget Sound contains three species of federally listed salmonids, chinook salmon, chum salmon and bull trout. Chinook salmon in the Puget Sound area were listed as threatened in 1999.

Sources of toxic chemicals in Puget Sound are linked, in Section I, to State of Washington Department of Ecology (Ecology) authorized NPDES permits. These permits comprise 16 major industrial facilities, 56 additional industrial dischargers, 86 sewage treatment plants, 98 general industrial dischargers, and 1593 general stormwater dischargers. Table 1 lists the number and types of dischargers in the Puget Sound area of concern. Table 2 identifies the specific Ecology Water Resource Inventory Areas (WRIAs) comprising the Puget Sound area of concern.

Toxic contamination has been measured throughout the Puget Sound region by a number of state, federal, tribal, and local governments. Major waterbodies in the Puget Sound region experiencing impairment because of toxic contamination include Bellingham Bay, Fidalgo Bay, Skagit River, Snohomish River, Everett Harbor/Port Gardner, main basin of Puget Sound, Lake Union/Lake Washington Ship Canal, Duwamish River, Elliott Bay, East Passage, Dalco Passage, Poverty Bay, Puyallup River, Inner and Outer Commencement Bay, Squaxin Passages, Peale Passage, Pickering Passage, Carr Inlet, Eagle Harbor, Hale Passage, Case Inlet, Dana Passage, and additional locations.

Ecology is required, under the federal Clean Water Act, to conduct Total Maximum Daily Load (TMDL) assessments for waterbodies on the 303(d) list. Based on assessment in the Puget Sound region, Ecology has developed, or is developing, TMDLS for 12 waterbodies, originally contained in the state's 1998 and earlier 303(d) lists, and impaired for a range of toxic contaminants (Table 3). At least an additional 46 waterbodies are listed in the 2004 303(d) for impairment because of a range of toxic contaminants. This is a total of 58 impaired waterbodies when TMDLs and 303(d) listings for toxic contamination are added together. This is also a conservative number of toxic chemical impaired waters due to gaps in Ecology's ambient water quality data collection and a significant lack of identification of toxic chemicals discharged from NPDES permitted sources. Gaps also include unregulated discharges. For example, stormwater discharges from urbanized areas with less than 100,000 people are not currently regulated under Ecology's NPDES stormwater program. All of these gaps indicates that the number of Puget Sound waterbodies toxically impaired is much greater

than the 58 presently indicated by Ecology through the TMDL and 303(d) listing processes.

Toxic contaminants in Puget Sound waters, sediments and animals include heavy metals, polycyclic aromatic hydrocarbons (PAHs), polychlorinated hydrocarbons (PCHs), phthalates, phenols, other organics, ammonia, cyanide and hydrogen sulfide (see Tables 6 through 11 for types of sources).

Many of the toxic chemicals evaluated in this report are persistent (do not break down easily) and bioaccumulate at levels harmful. These persistent bioaccumulating toxins (PBTs) include; heavy metals, PAHs, phthalates and PCHs discharged from Ecology authorized NPDES permits. PBTs released at any concentration level are very probably harmful to chinook salmon, and other organisms, because of their of persistent and bioaccumulating characteristics. In the Puget Sound region PBTs have been found in mussels, sole, rockfish, salmon, chinook salmon, seals, and killer whales.

Many toxic contaminants discharged into Puget Sound concentrate in sediments and bioaccumulate in the tissues of organisms. Widespread toxic contamination in animals of the Puget Sound region is documented in Ecology's 303(d) listings for impaired waters due to contaminated organisms (see Table 12). Major waterbodies in the Puget Sound region experiencing impairment because of toxic contamination in organisms overlap with the waterbodies already listed above. Bioaccumulation of toxic contaminants occurs at levels harmful to animals including, among other organisms, mountain whitefish, bridgelip sucker, mussels, English sole, rockfish, chinook salmon and other salmonids, seals, and killer whales.

Ecology has issued NDPES permits that include limitations for conventional pollutants such as biological oxygen demand (BOD), temperature, total suspended solids (TSS), and oil and grease (O&G) and pH as well as metals and organic chemicals. In many NPDES permits, total suspended solids (TSS), and oil and grease (O&G) for which effluent limitations are established are in effect "catch-all" compounds that incorporate un-quantified and unidentified toxic contaminants. Metals, PAHs, phthalates and PCHs can be attached to permitted levels of effluent suspended solids in proportions about 33,000 to 6,250,000 times greater than safe levels for organisms. Additionally, PAHs, phthalates and PCHs may also be contained in authorized oil and grease discharges at levels about 400 to 670,000 times greater than presumably safe levels.

Puget Sound net flows and circulation are such that persistent toxic contaminants can remain in the system for long periods of time. The association of toxic contaminants with effluent suspended solids, combined with extended residence times in sound waters, allows contaminants to settle into sediments where organisms are exposed. Animals that rely on organisms associated with sediments are at risk of toxic contamination through this process.

Dissolved oxygen depletion in Puget Sound waters is an additional problem often occurring at the same time as toxic contamination. Discharges of oxygen demanding substances into Puget Sound include biochemical oxygen demand, chemical oxygen

demand, ammonia, and indirectly through algal dynamics, the nutrients phosphorus and nitrogen. Many areas of Puget Sound including Hood Canal, Budd Inlet, Deschutes River, Carr Inlet, Commencement Bay, Green River, Duwamish River, Everett Harbor, Snohomish River, Ebey Slough, Clover Creek, and others have periods of depleted oxygen, demonstrating water quality impairment, because of introduced oxygen demanding substances from NPDES permitted facilities as well as stormwater runoff, improperly operating on-site septic systems and ocean nutrients.

Generally, Ecology has not connected sources of toxic contamination with polluted waterbodies. This can be explained by inadequacies of Ecology's NPDES permit process that: 1) neglect or inaccurately performs the reasonable potential analyses meant to identify likely effluent concentrations; 2) overestimate natural instream dilution by neglecting tidal return of previously discharged effluent; 3) overestimate receiving water available for effluent dilution; 4) overestimate outfall mixing energy by inflating outfall port velocities; 5) permit Whole Effluent Toxicity (WET) testing on animals less sensitive than many Puget Sound animals including chinook salmon; 6) permit Whole Effluent Toxicity (WET) testing using inflated dilutions from inaccurate analyses identified in 2) through 4) above; 7) fail to account for additive and synergistic toxic effects of chemicals.

Chinook and other salmon use the Puget Sound as a waterway to and from the rivers and streams used for spawning. Chinook salmon adults feed extensively on the herrings and small fish that inhabit Puget Sound. In turn, sea lions and killer whales feed on the congregated salmon. As the salmon are urged on by hormones, they leave the estuary and travel up the rivers and streams to the spawning areas where they were born.

From evaluation of data of toxic contaminants in water, sediments, and tissues of chinook salmon from the Puget Sound, there is ample evidence of pollutant concentrations that may initiate many of the deleterious effects on salmon populations described in Section II by Ewing. The sublethal concentrations of these pollutants impair physiological functions at every stage in the life history of the salmon:

1) Interfering with the biochemical machinery of the cells.

2) Showing various neurotoxic effects that interfere with normal behavior.

3) Inhibiting the olfactory system in such a way to interfere with homing, predator avoidance, and spawning.

4) Interfering with the immune system, leading to increased mortality from diseases.

5) Increase the incidence of carcinogenesis through oxidized metabolites, DNA adducts and interference with DNA repair mechanisms.

6) Interfering with developmental processes, leading to reduced fertility, increased mortality of the young, and teratogenesis.

7) Act as endocrine disruptors, causing interference with the intricate balance of hormones needed for reproduction, osmoregulation, and homeostasis.

8) PBTs released at any concentration level are very probably harmful to chinook salmon, and other organisms, because of their persistent and bioaccumulating characteristics.

Combined Report Findings

- Toxic contamination is widespread in the Puget Sound region based on a review of water quality, sediment and organism tissue data.

- Ecology's own TMDL and 303(d) List assessments for waterbodies show toxic contamination in the Puget Sound is extensive. These assessments are limited by data gaps and much more contamination is possible.

- Toxic contamination in Puget Sound matches the types of chemicals that Ecology NPDES permits authorize for industrial, municipal, and stormwater discharges.

- Ecology authorized NPDES discharges are major sources of toxic chemicals on an ongoing basis.

- Ecology routinely overestimates effluent dilution in their NPDES permit evaluations resulting in the release of harmful concentrations of toxic contaminants.

- Ecology's existing NPDES process fails to identify many sources, and the magnitudes, of toxic contaminants they authorize for release.

- Ecology's NPDES Whole Effluent Toxicity testing on organisms fails to capture the synergistic effects of effluent toxic chemicals acting together, and does not characterize bioaccumulative effects of toxic contaminants.

- Total suspended solids (TSS) and oil and grease (O&G) allowances in effectively all Ecology NPDES permits very probably contain un-quantified toxic chemicals.

- Sublethal concentrations of toxic pollutants impair physiological functions of chinook and other salmon.

- Toxic chemicals, such as PAHs, PCHs and heavy metals, are persistent bioaccumulating toxins (PBTs) that are authorized for discharge by Ecology.

- PBTs released at any concentration level are very probably harmful to chinook salmon, and other organisms, because of their persistent and bioaccumulating characteristics.

- Toxic contamination adversely affects chinook salmon, other salmonids, whitefish, sucker, mussels, sole, rockfish, seals, killer whales and other organisms in the Puget Sound region.

FIGURES

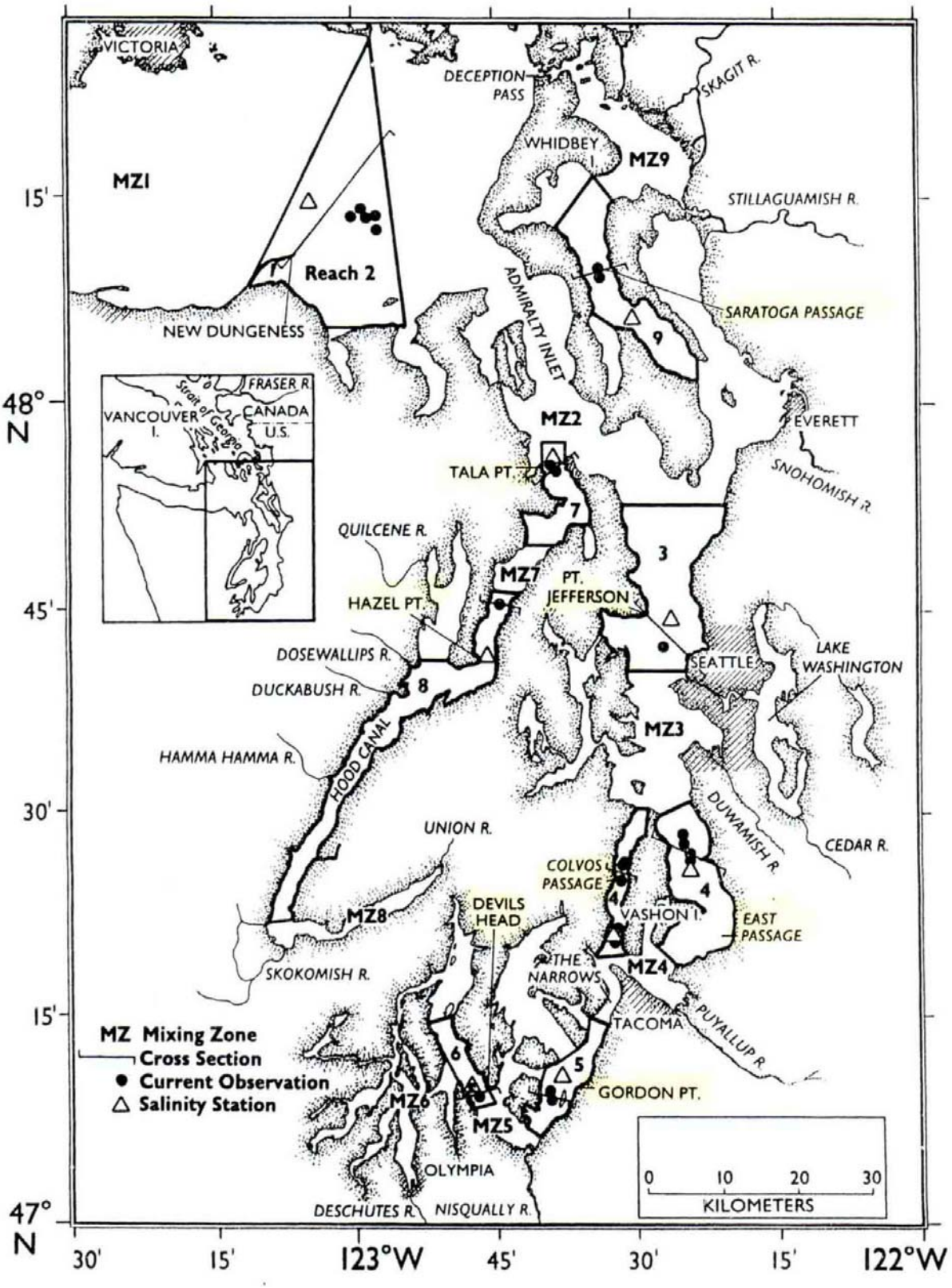

Figure 1. Map of Puget Sound region with reaches shown in bold outline.

NOAA study region identifying basin mixing zones, channel cross-sections, current observations and salinity stations. [From NOAA, 1990]

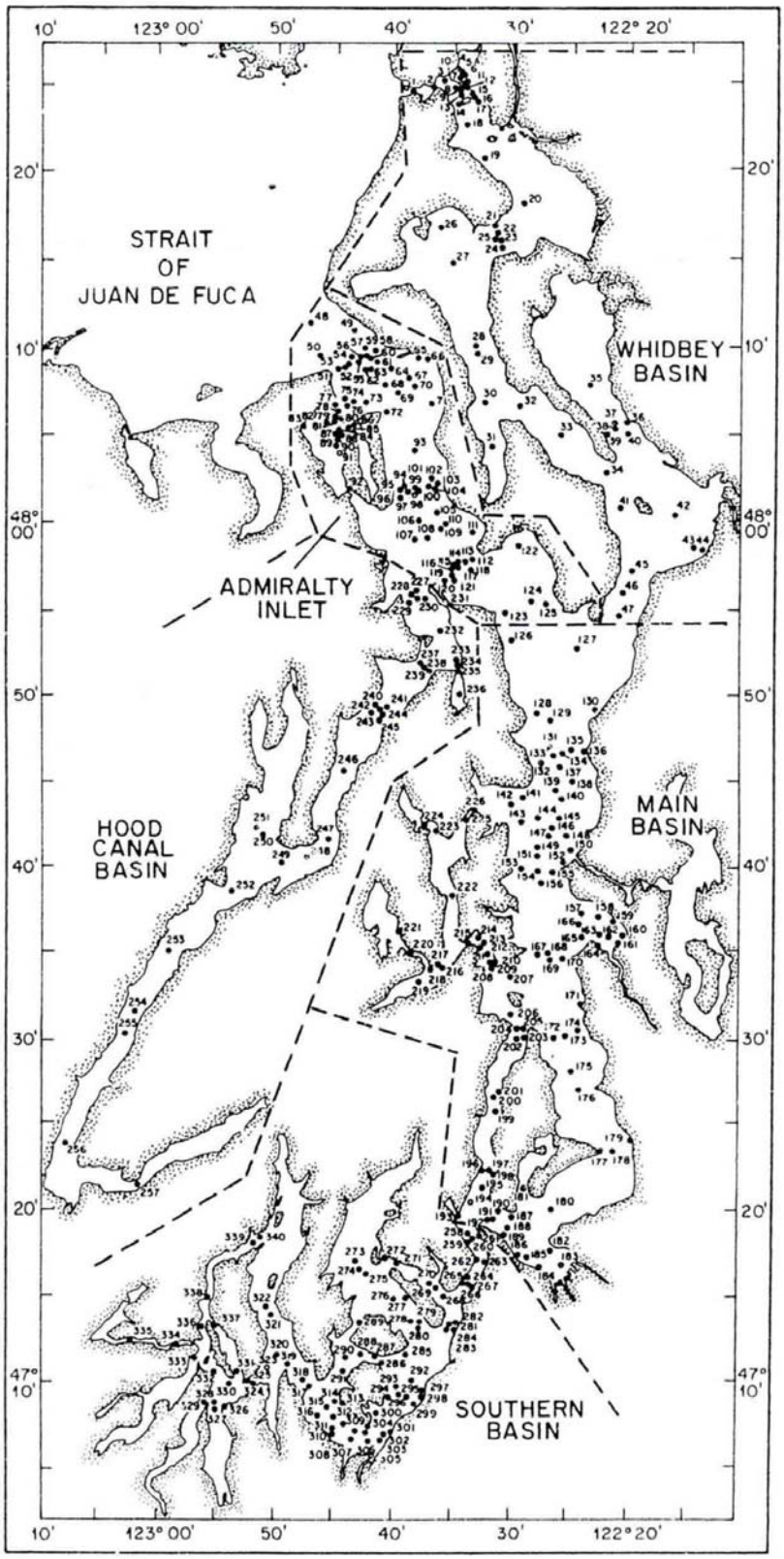

Figure 2. Sites of current measurements in the Puget Sound region.

NOAA study region showing Whidbey Basin, Main Basin, Southern Basin, Hood Canal Basin and Admiralty Inlet. [From NOAA Vol. 1, 1984a]

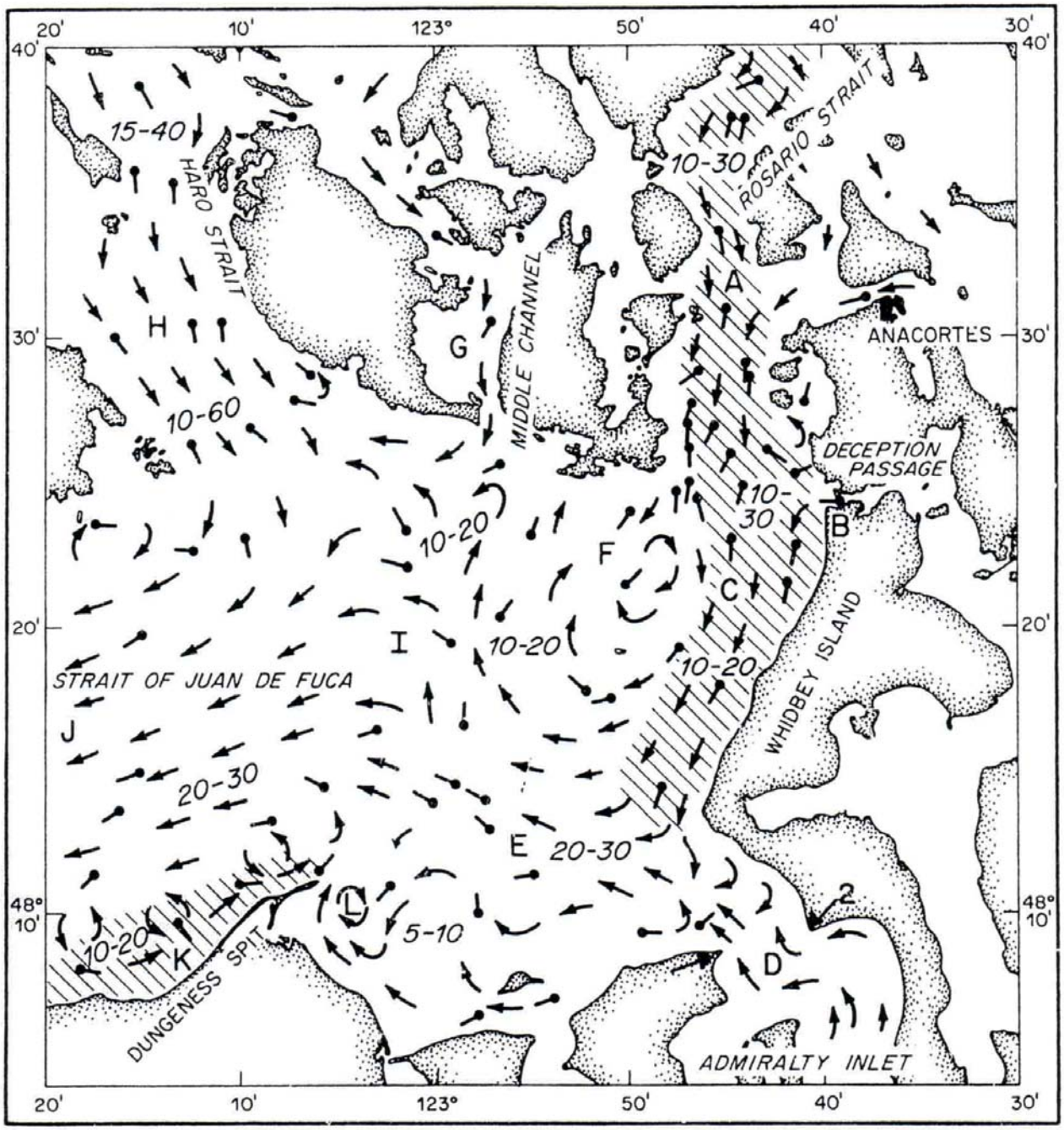

Figure 3. Plan view of net circulation in the upper layer (30m) Of the inner Strait of Juan de Fuca.

Current measurement and direction stations are shown by dot&line symbol. Numbers denote approximate current speed (centimeter per second, cm/s). The arrows represent the flow pattern based on observations. Hatched areas show where single layer net flow prevails. [From NOAA Vol. 3, 1984c, pg. 29]

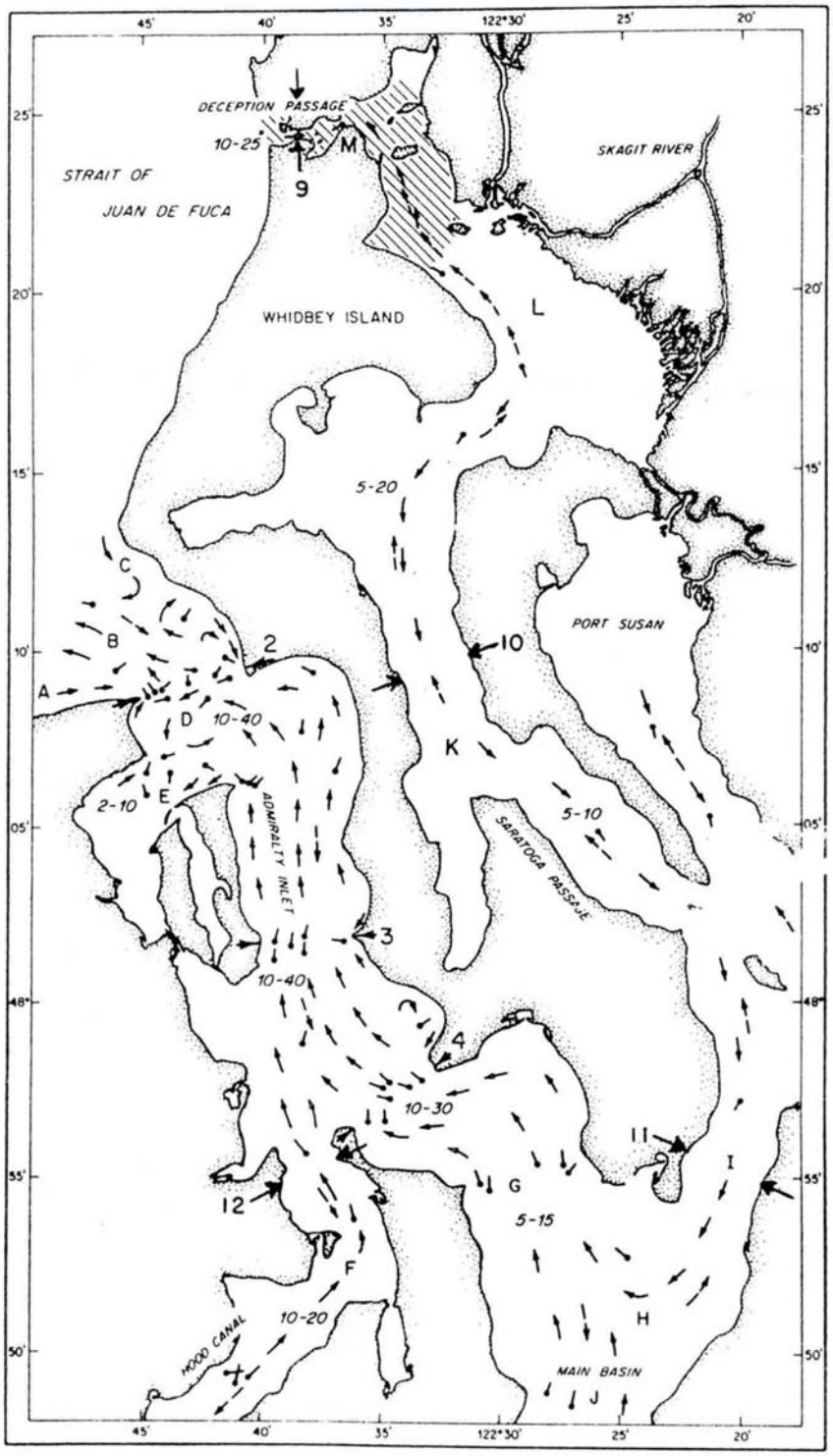

Figure 4. Plan view of net circulation in Admiralty Inlet and Whidbey Basin.

Current measurement and direction stations in the upper layer (30m) are shown by dot&line symbol. Numbers denote approximate current speed (centimeter per second, cm/s). The solid arrows represent the flow pattern in the upper layer based on observations. The dashed arrows represent the flow in the lower layer. Hatched areas show where single layer net flow prevails. [From NOAA Vol. 3, 1984c, pg33]

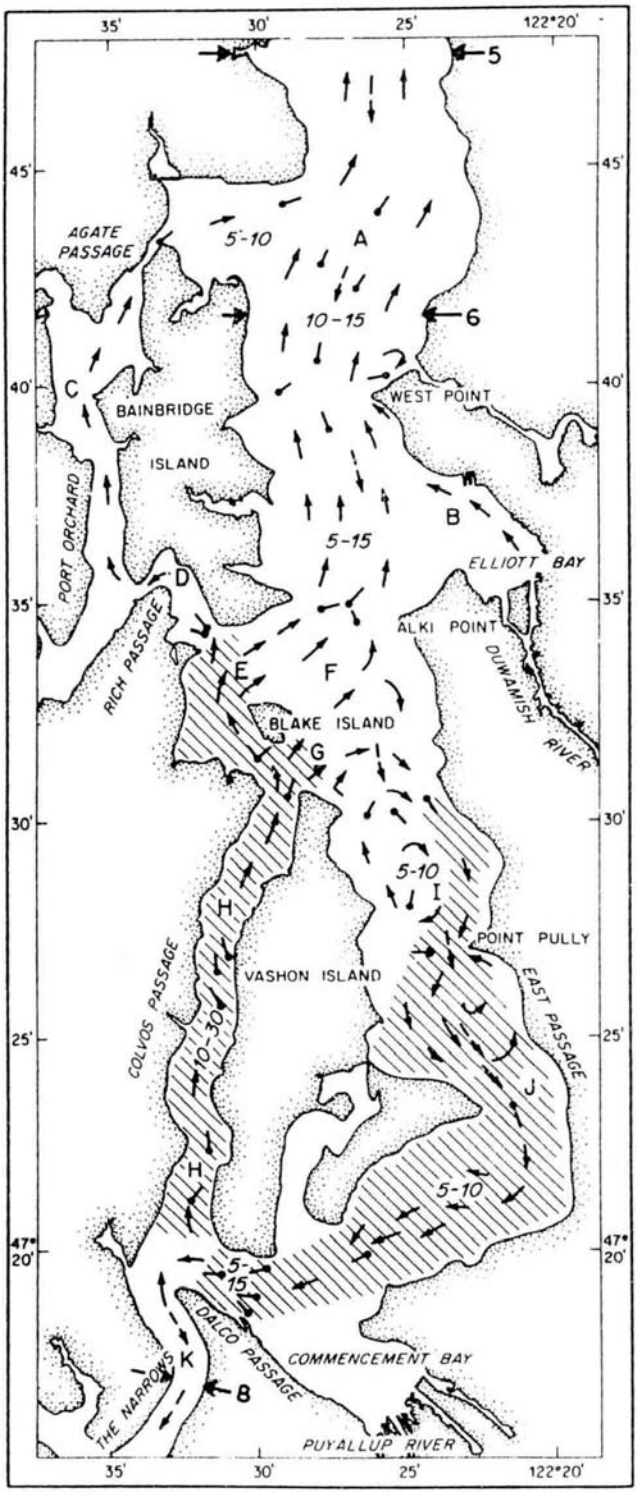

Figure 5. Plan view of net circulation in Main Basin.

Current measurement and direction stations in the upper layer are shown by dot&line symbol. Numbers denote approximate current speed (centimeter per second, cm/s). The solid arrows represent the flow pattern in the upper layer based on observations. The dashed arrows represent the flow in the lower layer. Hatched areas show where single layer net flow prevails. [From NOAA Vol. 3, 1984c, pg34]

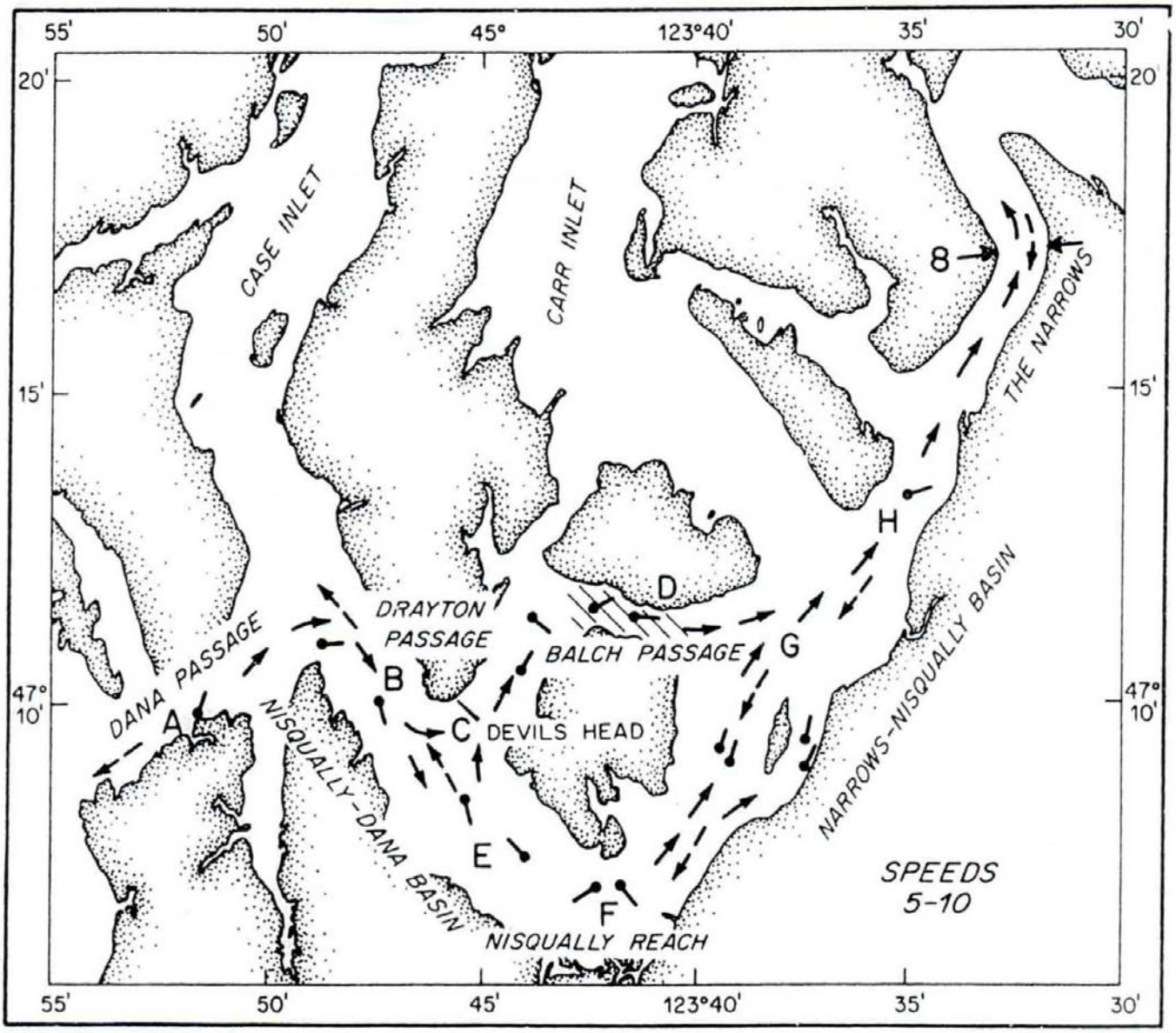

Figure 6. Plan view of net circulation in a portion of the Southern Basin.

Current measurement and direction stations in the upper layer are shown by dot&line symbol. Numbers denote approximate current speed (centimeter per second, cm/s). The solid arrows represent the flow pattern in the upper layer based on observations. The dashed arrows represent the flow in the lower layer. Hatched areas show where single layer net flow prevails. [From ref. NOAA Vol. 3, 1984c, pg34]

TABLES

Table 1. Number of NPDES Permits Authorized by Ecology as of January 2006 To Discharge Toxic Pollutants into the Puget Sound Region Identified in this Study

Ecology Authorized NPDES Wastewater Permits [A]	
Major Individual Industrial [B]	16
Additional Individual Industrial [C]	56
Individual Sewage Treatment Plant (STP) [D]	86
General Industrial [E]	98
General Stormwater [F]	1593

[A] Facility data summarized here was developed from the Ecology database, Information on Ecology's Water Quality Permit Life Cycle System. [Ecology WPLCS, 2004b] Compiled information for these summarized permits is detailed in Appendix B.

[B] The 16 Major Individual Industrial discharger permits and fact sheets were obtained from Ecology through, Information on Ecology's Water Quality Permit Life Cycle System. [Ecology WPLCS, 2004b] These dischargers are listed by receiving water (i.e., by WRIA) in Table 12. The evaluated Major Industrial Permits typically contained provisions for discharge of industrial stormwater into the process wastewater outfall and/or to additional outfalls.

[C] Permits include operations such as cement and asphalt manufacturing, chemical manufacturing, petroleum storage, shipyard, solid waste sites, transportation facilities, wood preserving and others. All the evaluated Individual Industrial Permits contained provisions for discharge of industrial stormwater into the process wastewater outfall and/or to additional outfalls.

[D] The sewage treatment plant (i.e., municipal STP) permits that were compiled contained provisions for discharge of facility stormwater, including combined storm and sewage discharge (i.e., CSOs), into the process wastewater outfall and/or to additional permitted outfalls.

[E] General Industrial Permits compiled include 90 for Boatyards, and 8 for Drinking Water Treatment Plants.

[F] See Appendix B for a listing of General Stormwater for 11 Municipal (MS4 Phase I, comprised by 11 unique permits), 788 Industrial, and 794 Construction Permits. The General Stormwater Permit for Municipal is comprised of 11 unique permits in Ecology's facilities database and appear to constitute MS4 Phase I permitting. The General Stormwater Permit for Industrial includes discharges from 12 landfills. The General Stormwater Permit for Construction includes discharges from 2 landfills.

Table 2. Ecology Identified Water Resource Inventory Areas (WRIAs) In the Puget Sound Region Highlighting Key WRIAs Identified in this Study

WRIA No.	WRIA Name By River Basin	Additional Important Waterbodies in WRIA
01	Nooksack	Bellingham Bay; Strait of Georgia
03	Lower Skagit-Samish	Fidalgo and Padilla Bays; Guemes Channel; Samish Bay
05	Stillaguamish	Port Susan
06	Island (County)	Holmes Harbor; Penn Cove; Saratoga Passage
07	Snohomish	Everett Harbor; Port Gardiner
08	Cedar-Sammamish	Elliott Bay; Lake Washington Ship Canal; Puget Sound (North- Central)
09	Duwamish-Green	Elliott Bay; Puget Sound (South-Central)
10	Puyallup-White	Commencement Bay; East Passage; Puget Sound (South-Central)
11	Nisqually	Nisqually Reach; Puget Sound (South)
12	Chambers-Clover	Leach Creek
13	Deschutes	Budd Inlet; Squaxin, Peale & Pickering Passages
14	Kennedy-Goldsborough	Oakland Bay; Hammersley Inlet; Squaxin, Peale & Pickering Passages; Case Inlet & Dana Passage
15	Kitsap (county & nearby areas)	Case Inlet & Dana Passage; Hood Canal; Carr Inlet; Eagle Harbor; Hale Passage; Puget Sound (South); Tacoma Narrows
Less Urbanized Basins Draining to Puget Sound and Surrounding Straits		
02	San Juan	Juan de Fuca Strait & Strait of Georgia
04	Upper Skagit	Lower Skagit
16	Skokomish-Dosewallips	Hood Canal; The Great Bend; Annas Bay
17	Quilcene-Snow	Admiralty Inlet,
18	Elwha-Dungeness	Juan de Fuca Strait
19	Lyre-Hoko	Juan de Fuca Strait

See Appendix D for water quality assessment for each WRIA.

Table 3. Comparison of Puget Sound Area TMDLs for Toxic Contaminants

Waterbody	Location	Toxic Pollutant Parameter [A]
Bellingham Bay	WRIA01	Sediment bioassay; Metals: Arsenic, Copper, Lead, Mercury, Zinc; Phenol, PCBs; & Wood waste
Sumas River	WRIA01	Ammonia –N Chlorine
Stillaguamish River	WRIA05	Mercury Arsenic
Snohomish River	WRIA07	Dioxin; Metals: Arsenic, Mercury
Snoqualmie River	WRIA07	Ammonia –N
Duwamish River & Lower Green River	WRIA09	Ammonia –N
Green River	WRIA09	Ammonia –N (under development) Metals (under development)
Puyallup River	WRIA10	Ammonia –N
Commencement Bay	WRIA10	Dioxin
Chambers Creek & Steilacoom Lake	WRIA12	Copper
Budd Inlet	WRIA13	PCB (under development)
Other Nearby Waterbodies:		
Strait of Juan de Fuca	WRIA18	Dioxin

[A] Source: Ecology 2005a, Washington State Ecology - Approved TMDLs; and Ecology, 2005b, Washington State Ecology – TMDLs Under Development.

Table 4. Residence Time Comparisons for the Puget Sound Southern Basin

	Budd Inlet	Eld Inlet	Totten Inlet	Hammersley Inlet	Puget Sound Southern Basin
Waterbody Volume (V, 10^8 m^3) [B]	2.52	1.59	2.13	1.48	158
Residence Time (day)					
Salt/mass balance	0.9-12	N/A	N/A	N/A	28-174
Transport model [C]	6.5	8.4	4.0	46.3	124
Mass Transport (m^3 /s)	450	220	620	37	1480

[A] Residence times as evaluated in "Investigation of the Mean Flow in a Complex Multi-Connected Estuary: South Puget Sound", Albertson, S. L, Newton, J. and Reynolds, R., and Ebbesmeyer, C., Puget Sound Research 2001 Proceedings, see Puget Sound Action Team (PSAT) website.

[B] Water surface elevation at mean high water (MHW)

[C] Residence times as determined by Albertson, et al., from application of the mass transport model, SPASM.

N/A - values not available.

Table 5. Upwelling Time Scales in Puget Sound Basins

Puget Sound Region (See Figure 2 for Basin Locations)	**Upwelling Time Scale** [A] (T, days)	**Volume** (V, 10^9 m^3)	**Upwelling Transport** (Q, m^3 /s)
Puget Sound- Southern Basin	10	16	20,000
Main Basin	60	77	15,000
Whidbey Basin	110	29	3,000
Hood Canal	120	25	2500

A Sources: Ebbesmeyer, et al., 1998; and NOAA, 1990.

Table 6. List of Important Toxic Compounds Authorized for Discharge or Affected by Ecology's NPDES Program

	PAHs		Metals	Additional
Aromatic Hydrocarbons Benzene Ethylbenzene Toluene Xylenes (m,p,o) ***Phenolic Compounds*** 2-Methyl Phenol 2,4-Dimethylphenol 3/4 -Methylphenol **Phthalates** Di-n-butyl phthalate Benzyl butyl phthalate (Pesticide, other) Bis(2-ethylhexyl) phthalate (Pesticide, other) **Pesticides** Dieldrin Chlordane Lindane Alpha-hexachlorocyclohexane Alpha-endosulfane	***LPAHs*** Acenaphthene Acenaphthylene Anthracene Fluorene Phenanthrene Naphthalene ***HPAHs*** Benzo(a)anthracene Benzo(a)pyrene Benzo(b)fluoranthene Benzo(ghi)perylene Benzo(j)fluoranthene Benzo(k)fluoranthene Chrysene Dibenzo(a,h)anthracene Fluoranthene Indeno(1,2,3-cd)pyrene Pyrene PAH compounds 2-Methylnaphthalene 3-Methylcholanthrene 5-Methylchrysene 1-Nitropyrene 7H-Dibenzo(e,g)carbazole 7,12-Dimethylbenz(a)anthracene	***Adsorbable Organic Halides (AOX)*** (Contains toxic contaminants - chlorinated organics) ***Dioxins*** 2,3,7,8-tetrachlorodibenzo-p-dioxin 1,2,3,7,8-pentachlorodibenzo-p-dioxin 1,2,3,4,7,8-hexachlorodibenzo-p-dioxin 1,2,3,6,7,8-hexachlorodibenzo-p-dioxin 1,2,3,7,8,9-hexachlorodibenzo-p-dioxin 1,2,3,4,6,7,8-heptachlorodibenzo-p-dioxin 1,2,3,4,6,7,8,9-octachlorodibenzo-p-dioxin ***Furans*** 2,3,7,8-tetrachlorodibenzofuran 1,2,3,7,8-pentachlorodibenzofuran 2,3,4,7,8-pentachlorodibenzofuran 1,2,3,4,7,8-hexachlorodibenzofuran 1,2,3,6,7,8-hexachlorodibenzofuran 1,2,3,7,8,9-hexachlorodibenzofuran 2,3,4,6,7,8-hexachlorodibenzofuran 1,2,3,4,6,7,8-heptachlorodibenzofuran 1,2,3,4,7,8,9-heptachlorodibenzofuran 1,2,3,4,6,7,8,9-octachlorodibenzofuran ***Other Polychlorinated Hydrocarbons*** Chlorobenzene 1,2-Dichlorobenzene 1,3-Dichlorobenzene 1,4-Dichlorobenzene PCBs ***Chlorinated Phenolic Compounds*** Pentachlorophenol (Pesticide, other) Trichlorophenols Trichloroguaiacols	Arsenic Cadmium Chromium Copper Lead Mercury Nickel Selenium Zinc	Ammonia Chlorine Hydrogen Sulfide Cyanide

Table 7. Oil Refining
Effluent Chemicals Discharged to Natural Waters

	PAHs	Metals	Additional
Total Suspended Solids (TSS) (With toxic contaminants attached) ***Oil and Grease (O&G)*** (Containing toxic contaminants) ***Aromatic Hydrocarbons*** Benzene Ethylbenzene Toluene Xylenes (m,p,o) ***Phenolic Compounds*** 2-Methyl Phenol 2,4-Dimethylphenol 3/4 -Methylphenol **Phthalates** Di-n-butyl phthalate Bis(2-ethylhexyl) phthalate ***Polychlorinated Hydrocarbons*** Chlorobenzene 1,2-Dichlorobenzene 1,3-Dichlorobenzene 1,4-Dichlorobenzene Dibenzofuran	***LPAHs*** Acenaphthene Acenaphthylene Anthracene Fluorene Phenanthrene Naphthalene 2-Methylnaphthalene (PAH compound) ***HPAHs*** Benzo(a)anthracene Benzo(a)pyrene Benzo(b)fluoranthene Benzo(g,h,i)perylene Benzo(j)fluoranthene Benzo(k)fluoranthene Chrysene Dibenzo(a,h)anthracene Fluoranthene Indeno(1,2,3-cd)pyrene Pyrene	Arsenic Cadmium Chromium Copper Lead Mercury Nickel Selenium Zinc	Ammonia Chlorine Hydrogen Sulfide Cyanide

Table 8. Pulp & Paper Mill
Effluent Chemicals Discharged to Natural Waters

	PAHs and Compounds		Metals	Additional
Total Suspended Solids (TSS) (With toxic contaminants attached) ***Oil and Grease (O&G)*** (Containing toxic contaminants) **Phthalates** Bis(2-ethylhexyl) phthalate [defoamer] ***Phenolic Compounds*** 2-Methyl Phenol 2,4-Dimethylphenol 3/4 –Methylphenol ***Aromatic Hydrocarbons*** Benzene Ethylbenzene Toluene Xylenes (m,p,o)	Benzo(a)anthracene Benzo(a)phenanthrene (chrysene) Benzo(a)pyrene Benzo(b)fluoranthene Benzo(j)fluoranthene Benzo(k)fluoranthene Benzo(j,k)fluorene (fluoranthene) Benzo(r,s,t)pentaphene Dibenzo(a,h)acridine Dibenzo(a,j)acridine Dibenzo(a,h)anthracene Dibenzo(a,e)fluoranthene Dibenzo(a,e)pyrene Dibenzo(a,h)pyrene Dibenzo(a,l)pyrene Naphthalene Indeno(1,2,3-cd)pyrene 3-Methylcholanthrene 5-Methylchrysene 1-Nitropyrene7H- Dibenzo(e,g)carbazole 7,12-Dimethylbenz(a)anthracene	***Adsorbable Organic Halides (AOX)*** (Contains toxic contaminants - chlorinated organics) ***Dioxins*** 2,3,7,8-tetrachlorodibenzo-p-dioxin 1,2,3,7,8-pentachlorodibenzo-p-dioxin 1,2,3,4,7,8-hexachlorodibenzo-p-dioxin 1,2,3,6,7,8-hexachlorodibenzo-p-dioxin 1,2,3,7,8,9-hexachlorodibenzo-p-dioxin 1,2,3,4,6,7,8-heptachlorodibenzo-p-dioxin 1,2,3,4,6,7,8,9-octachlorodibenzo-p-dioxin ***Furans*** 2,3,7,8-tetrachlorodibenzofuran 1,2,3,7,8-pentachlorodibenzofuran 2,3,4,7,8-pentachlorodibenzofuran 1,2,3,4,7,8-hexachlorodibenzofuran 1,2,3,6,7,8-hexachlorodibenzofuran 1,2,3,7,8,9-hexachlorodibenzofuran 2,3,4,6,7,8-hexachlorodibenzofuran 1,2,3,4,6,7,8-heptachlorodibenzofuran 1,2,3,4,7,8,9-heptachlorodibenzofuran ***1,2,3,4,6,7,8,9-octachlorodibenzofuran*** ***Other Polychlorinated Hydrocarbons*** Chlorobenzene 1,2-Dichlorobenzene 1,3-Dichlorobenzene 1,4-Dichlorobenzene ***Chlorinated Phenolic Compounds*** Pentachlorophenol Trichlorophenols Trichloroguaiacols	Arsenic Copper Mercury Vanadium	Ammonia Chlorine Hydrogen Sulfide

Table 9. Other Major and Additional Individual Industrial Dischargers Effluent Chemicals Discharged to Natural Waters

Discharge [A]	PAHs	Metals	Additional
Total Suspended Solids (TSS) (With toxic contaminants attached) ***Oil and Grease (O&G)*** (Containing toxic contaminants) ***Aromatic Hydrocarbons*** Benzene Ethylbenzene Toluene Xylenes (m,p,o) ***Phenolic Compounds*** 2-Methyl Phenol 2,4-Dimethylphenol **Phthalates** Di-n-butyl phthalate Bis(2-ethylhexyl) phthalate Benzyl butyl phthalate ***Chlorinated Phenolic Compounds*** Pentachlorophenol ***Polychlorinated Hydrocarbons*** Chlorobenzene 1,2-Dichlorobenzene__ 1,3-Dichlorobenzene__ 1,4-Dichlorobenzene Dibenzofuran Chloroform	***LPAHs*** Acenaphthene Acenaphthylene Anthracene Fluorene Phenanthrene Naphthalene 2-Methylnaphthalene (PAH compound) ***HPAHs*** Benzo(a)anthracene Benzo(a)pyrene Benzo(b)fluoranthene Benzo(ghi)perylene Benzo(j)fluoranthene Benzo(k)fluoranthene Chrysene Dibenzo(a,h)anthracene Fluoranthene Indeno(1,2,3-cd)pyrene Pyrene	Arsenic Cadmium Chromium Copper Lead Mercury Nickel Selenium Zinc	Ammonia Chlorine Hydrogen Sulfide Cyanide

[A] Other major dischargers include aluminum smelters, power cogeneration facilities and chemical manufacturing. Additional industrial dischargers include operations such as cement and asphalt manufacturing, chemical manufacturing, petroleum storage, shipyard, solid waste sites, transportation facilities, wood preserving and others.

Table 10. Municipal Sewage Treatment Plant Wastewater Effluent Chemicals Discharged to Natural Waters

Discharge [A]	PAHs	Metals	Additional
Total Suspended Solids (TSS) (With toxic contaminants attached) ***Oil and Grease (O&G)*** (Containing toxic contaminants) ***Aromatic Hydrocarbons*** Benzene Ethylbenzene Toluene Xylenes (m,p,o) ***Phenolic Compounds*** 2-Methyl Phenol 2,4-Dimethylphenol **Phthalates** Di-n-butyl phthalate Bis(2-ethylhexyl) phthalate Benzyl butyl phthalate ***Chlorinated Phenolic Compounds*** Pentachlorophenol (Pesticide) ***Polychlorinated Hydrocarbons*** Chlorobenzene 1,2-Dichlorobenzene__ 1,3-Dichlorobenzene__ 1,4-Dichlorobenzene Dibenzofuran Chloroform	***LPAHs*** Acenaphthene Acenaphthylene Anthracene Fluorene Phenanthrene Naphthalene 2-Methylnaphthalene (PAH compound) ***HPAHs*** Benzo(a)anthracene Benzo(a)pyrene Benzo(b)fluoranthene Benzo(ghi)perylene Benzo(j)fluoranthene Benzo(k)fluoranthene Chrysene Dibenzo(a,h)anthracene Fluoranthene Indeno(1,2,3-cd)pyrene Pyrene	Arsenic Cadmium Chromium Copper Lead Mercury Nickel Selenium Zinc	Ammonia Chlorine Hydrogen Sulfide

[A] These permits include discharges to STP systems for operations such as landfills, metal finishing, printing, shipyards, petroleum storage, seafood processing, wood treating, and others. This Municipal STP category includes combined sewer overflows (CSOs).

Table 11. General Stormwater for Industrial, Construction and Municipal Effluent Chemicals Discharged to Natural Waters

	PAHs	Metals	Additional
Total Suspended Solids (TSS) (With toxic contaminants attached) ***Oil and Grease (O&G)*** (Containing toxic contaminants) ***Aromatic Hydrocarbons*** Benzene Ethylbenzene Toluene Xylenes (m,p,o) **Phthalates** Benzyl butyl phthalate (Pesticide, other) Bis(2-ethylhexyl) phthalate (Pesticide, other) ***Polychlorinated Hydrocarbons*** Chlorobenzene 1,3-Dichlorobenzene PCBs Pentachlorophenol **Pesticides** Dieldrin Chlordane Lindane Alpha-hexachlorocyclohexane Alpha-endosulfane	***LPAHs*** Acenaphthene Acenaphthylene Anthracene Fluorene Phenanthrene Naphthalene 2-Methylnaphthalene (PAH compound) ***HPAHs*** Benzo(a)anthracene Benzo(a)pyrene Benzo(b)fluoranthene Benzo(ghi)perylene Benzo(j)fluoranthene Benzo(k)fluoranthene Chrysene Dibenzo(a,h)anthracene Fluoranthene Indeno(1,2,3-cd)pyrene Pyrene	Antimony Arsenic Beryllium Cadmium Chromium Copper Lead Mercury Nickel Selenium Silver Thallium Zinc	Ammonia Chlorine Hydrogen Sulfide Cyanide Phenolic Compounds Other Volatile Organics

Table 12 and Continued. Correlation of Ecology Authorized NPDES Permits With Puget Sound Toxic Contamination and Locations

WRIA No.	Facilities Description	Discharger Type	Ecology Authorized Discharge Chemicals	Receiving Waterbody	Waterbody Status - Ecology 303(d) Category 5 Listings		
				Direct Discharge	WQ	Tissue [A]	Sediment (from SEDQUAL)
WRIA 01	Intalco Works, Ferndale (near Cherry Point) [WA-000295-0]	Aluminum Smelter	Total Suspended Solids; Fluoride; Aluminum; Antimony; Arsenic; Cadmium; Copper; Nickel; Zinc; Cyanide, free; Benzo(a)pyrene (i.e., PAHs); Oil & Grease; Chlorine; Total PCBs (found and allowed at Kaiser Aluminum Tacoma).	Strait of Georgia	Except where indicated for this WRIA, no apparent assessment by Ecology for likely toxic chemicals in water (see Appendix D).	Except where indicated for this WRIA, no apparent assessment by Ecology for likely toxic chemicals in tissue (see Appendix D).	PAHss, as follows: Indeno(1,2,3-cd)pyrene; (other compounds): 1,2,4-Trichlorobenzene; 1,2-Dichlorobenzene; Hexachlorobenzene
WRIA 01	ConocoPhillips Refinery, Ferndale (also known as TOSCO) [WA-000298-4]	Oil Refinery	Phenolic Compounds, Total Ammonia, Sulfide, Total Chromium, Hexavalent Chromium, Cyanide, BOD5, COD, O&G, TSS, Solvents, Phthalates, PAHs, Other Metals.	Strait of Georgia & Trib. to Lummi Bay			
WRIA 01	Tenaska, Ferndale [WA-003129-1]	Cogeneration Power	Total Suspended Solids; Oil & Grease; Total Chromium; Total Zinc; Total Residual Chlorine; Priority Pollutant Organics, Other Metals.	Strait of Georgia (via TOSCO's outfall)			[Sediment data from Ecology's SEDQUAL summary in 303(d) listings does not indicate what other likely contaminants were monitored or assessed.]
WRIA 01	BP Cherry Point Refinery, Blaine [WA-002290-0]	Oil Refinery	Phenolic Compounds, Total Ammonia, Sulfide, Total Chromium, Hexavalent Chromium, Chlorine, BOD5, COD, O&G, TSS, Solvents, Phthalates, PAHs, Other Metals.	Strait of Georgia			
WRIA 01	Georgia Pacific West, Inc.; and Econgen cogeneration plant; Bellingham [WA-000109-1]	Pulp and Paper Mill	Mercury; BOD5, TSS Other likely contaminants allowed by Ecology are: ammonia, landfill leachate, phenols, PCH including pentachlorophenol, sulfides, surfactants, phtahaltes, and additional metals including chromium, copper, nickel and zinc. Contaminants from Econgen are also effectively non-monitored.	Bellingham Bay			Bellingham Bay TMDLs because imparied based on sediments for: Sediment bioassay; Metals: Arsenic, Copper, Lead, Mercury, Zinc; Phenol, PCBs, & Wood waste
				Baker Creek	Pentachlorophenol, Zinc		
				Fever Creek	Pentachlorophenol, Copper, Zinc		
				Squalicum Creek	Pentachlorophenol, Zinc		Sediment Bioassay
				Toad Lake Creek	Pentachlorophenol, Zinc		
		For this WRIA there are additional industrial, general stormwater and municipal STP dischargers (See Appendix B).	Also, for this WRIA, the toxic contaminants in Tables 9 through 11 are likely from additional industrial, stormwater and municipal STP dischargers.				
WRIA 03	Tesoro, Anacortes [WA-000076-1]	Oil Refinery	Phenolic Compounds, Total Ammonia, Sulfide, Total Chromium, Hexavalent Chromium, Chlorine, BOD5, COD, O&G, TSS, Solvents, Phthalates, PAHs, Other Metals.	Fidalgo Bay	Except where indicated for this WRIA, no apparent assessment by Ecology for likely toxic chemicals in water (see Appendix D).	PAHss, as follows: Benzo(A)anthracene; Chrysene (Littleneck Clam) [Johnson, 2000]A	Hexachlorobutadiene; 4-Methylphenol; 2-Methylphenol; Phenol; Pentachlorophenol; Benzyl alcohol; Benzoic acid; 2,4- Dimethylphenol; 1,2,4- Trichlorobenzene; 1,2-Dichlorobenzene
	Shell Oil Products US, Anacortes (also known as, Equilon) [WA-000294-1	Oil Refinery	Phenolic Compounds, Total Ammonia, Sulfide, Total Chromium, Hexavalent Chromium, Chlorine, BOD5, COD, O&G, TSS, Solvents, Phthalates, PAHs, Other Metals.	Fidalgo Bay		Except where indicated for this WRIA, no apparent assessment by Ecology for likely toxic chemicals in tissue (see Appendix D).	
WRIA 03				Samish Bay			2,4- Dimethylphenol; 1,2,4- Trichlorobenzene; 1,2-Dichlorobenzene

Table 12 and Continued. Correlation of Ecology Authorized NPDES Permits With Puget Sound Toxic Contamination and Locations

WRIA No.	Facilities Description	Discharger Type	Ecology Authorized Discharge Chemicals	Receiving Waterbody	Waterbody Status - Ecology 303(d) Category 5 Listings		
				Direct Discharge	WQ	Tissue [A]	Sediment (from SEDQUAL)
WRIA 03				Skagit River		Total PCBs (Mountain whitefish & bridgelip sucker) [Hopkins, et al., 1985];	[Sediment data from Ecology's SEDQUAL summary in 303(d) listings does not indicate what other likely contaminants were monitored or assessed.]
WRIA 03		For this WRIA there are additional industrial, general stormwater and municipal STP dischargers (See Appendix B).	Also, for this WRIA, the toxic contaminants in Tables 9 through 11 are likely to be discharged from additional industrial, stormwater and municipal STP dischargers.	Swinomish Channel		PAHss, as follows: Benzo(A)anthracene; Chrysene (Littleneck Clam) [Johnson, 2000]	
WRIA 06				Holmes Harbor	No apparent assessment by Ecology for likely toxic chemicals in water.	No apparent assessment by Ecology for likely toxic chemicals in tissue.	Hexachlorobenzene; Hexachlorobutadiene; 1,2,4- Trichlorobenzene; Benzyl alcohol; 1,2-Dichlorobenzene
WRIA 06		For this WRIA there are additional industrial, general stormwater and municipal STP dischargers (See Appendix B).	Also, for this WRIA, the toxic contaminants in Tables 9 through 11 are likely to be discharged from additional industrial, stormwater and municipal STP dischargers.	Saratoga Passage			2-Methylphenol; 2,4-Methylphenol; Methylphenol; 1,2,4- Trichlorobenzene; 1,2-Dichlorobenzene; Benzoic Acid; Pentachlorophenol; Benzyl alcohol _____ [Sediment data from Ecology's SEDQUAL summary in 303(d) listings does not indicate what other likely contaminants were monitored or assessed.]
WRIA 07	Kimberly-Clark, Everett Harbor [WA-000062-1]	Pulp and Paper Mill	2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD); 2,3,7,8-tetrachlorodibenzofuran (TCDF); Tetrachlorocatechol; Tetrachloroguaiacol; Trichlorosyringol; 4,5,6-trichloroguaiacol; 3,4,6-trichlorocatechol; 3,4,5-trichlorocatechol; 3,4,5-trichloroguaiacol; 2,3,4,6-tetrachlorophenol; 3,4,6-trichloroguaiacol; Pentachlorophenol; 2,4,6-trichlorophenol; 2,4,5-trichlorophenol; Chloroform (not monitored in permit); AOX; BOD5, COD, O&G, TSS, other Phenols, Phthalates, Metals.	Everett Harbor & Port Gardner (also East Waterway)	Except where indicated for this WRIA, no apparent assessment by Ecology for likely toxic chemicals in water (see Appendix D).	Except where indicated for this WRIA, no apparent assessment by Ecology for likely toxic chemicals in tissue (see Appendix D).	2-Methylphenol; 2,4-Dimethylphenol; Bis(2-ethylhexyl)phthalate; Phenol; Pentachlorophenol; 4-Methylphenol; Benzoic acid; Benzyl alcohol Sediment Bioassay _____ [Sediment data from Ecology's SEDQUAL summary in 303(d) listings does not indicate what other likely contaminants were monitored or assessed.]
WRIA 07				Snohomish River			1,2,4-Trichlorobenzene; 4- Hexachlorobenzene
WRIA 07				Allen Creek			1,2,4-Trichlorobenzene; 4- Hexachlorobenzene
WRIA 07				Swan Trail Slough	Ammonia-N		

Table 12 and Continued. Correlation of Ecology Authorized NPDES Permits With Puget Sound Toxic Contamination and Locations

WRIA No.	Facilities Description	Discharger Type	Ecology Authorized Discharge Chemicals	Receiving Waterbody	Waterbody Status - Ecology 303(d) Category 5 Listings		
				Direct Discharge	WQ	Tissue [A]	Sediment (from SEDQUAL)
		For this WRIA there are additional industrial, general stormwater and municipal STP dischargers (See Appendix B).	Also, for this WRIA, the toxic contaminants in Tables 9 through 11 are likely to be discharged from additional industrial, stormwater and municipal STP dischargers.				
WRIA 08				Puget Sound (N-Central) & Useless Bay	Except where indicated for this WRIA, no apparent assessment by Ecology for likely toxic chemicals in water (see Appendix D).	Except where indicated for this WRIA, no apparent assessment by Ecology for likely toxic chemicals in tissue (see Appendix D).	2,4-Dimethylphenol; Hexachlorobenzene; 1,2,4-Trichlorobenzene; N-nitrosodiphenylamine; 1,2-Dichlorobenzene; Bis(2-ethylhexyl)phthalate
WRIA 08				Puget Sound	Ammonia-N		
WRIA 08				Puget Sound (Central)	Ammonia-N	Dieldrin (discontinued pesticide)	
WRIA 08				Elliott Bay	No apparent assessment by Ecology for likely toxic chemicals in water.	No apparent assessment by Ecology for likely toxic chemicals in tissue.	PAHss, as follows: Acenaphthalene; Benzo(a)anthracene; Phenanthrene; Fluorene; Naphthalene; 2-methylnaphthalene; LPAHs; (other compounds): Hexachlorobenzene; Hexachlorobutadiene; Dibensofuran; 2-Methylphenol; 2,4-Dimethylphenol; 2,4- Dimethylphenol; 1,2,4- Trichlorobenzene; 1,2-Dichlorobenzene Benzoic acid; Benzyl alcohol; Mercury; Silver; Sediment Bioassay _____ [Sediment data from Ecology's SEDQUAL summary in 303(d) listings does not indicate what other likely contaminants were monitored or assessed.]
		For this WRIA there are additional industrial, general stormwater and municipal STP dischargers (See Appendix B).	Also, for this WRIA, the toxic contaminants in Tables 9 through 11 are likely to be discharged from additional industrial, stormwater and municipal STP dischargers.				
WRIA 09				Elliott Bay	Except where indicated for this WRIA, no apparent assessment by Ecology for likely toxic chemicals in water (see Appendix D).	Except where indicated for this WRIA, no apparent assessment by Ecology for likely toxic chemicals in tissue (see Appendix D).	PAHss, as follows: Dibenzo(a,h)anthracene (other compounds): Pentachlorophenol; 1,2-Dichlorobenzene; 1,4-Dichlorobenzene; 1,2,4-Trichlorobenzene; Butylbenzyl phthalate; Dimethyl phthalate; Bis(2-ethylhexyl)phthalate; 2-Methylphenol; 4-Methylphenol; 2,4-Dimethylphenol; Hexachlorobenzene; Hexachlorobutadiene; N-nitrosodiphenylamine; Pentachlorophenol; Total PCBs _____ [Sediment data from Ecology's SEDQUAL summary in 303(d) listings does not indicate what other likely contaminants were monitored or assessed.]

Table 12 and Continued. Correlation of Ecology Authorized NPDES Permits With Puget Sound Toxic Contamination and Locations

WRIA No.	Facilities Description	Discharger Type	Ecology Authorized Discharge Chemicals	Receiving Waterbody	Waterbody Status - Ecology 303(d) Category 5 Listings		
				Direct Discharge	WQ	Tissue [A]	Sediment (from SEDQUAL)
WRIA 09				Puget Sound (Central)		Total Dioxins (Seals) [Transboundary Georgia Basin-Puget Sound Working Group on Environmental Indicators, 2002]; Total Dioxins (Killer Whales, i.e., Orcinus orca) [Ross, et al. 2000]; Total Furans (Seals) [TGB-PS WGEI, 2002]; Total PCBs (Seals) [TGB-PS WGEI, 2002]	
WRIA 09				Duwamish River & Water Way		PAHss (Sole) [Myers, et al., 1998]; 4,4'-DDD and 4,4'-DDE and Alpha-BHC (Mountain whitefish & bridgelip sucker) [Hopkins et al. 1985]; Total PCBs (Mussel) [Johnson & Davis, 1996]; Total PCBs (Eng. Sole) Total PCBs (coho salmon) [WA Dept. Fish & Wildlife PSAMP, 1992-2000]	PAHss, as follows: Dibenzo(a,h)anthracene; Fluoranthene; (other compounds): 1,2-Dichlorobenzene; 1,4-Dichlorobenzene; 1,2,4-Trichlorobenzene; Butylbenzyl phthalate; 4-Methylphenol; 2,4-Dimethylphenol; Phenol; Hexachlorobenzene; Hexachlorobutadiene; N-nitrosodiphenylamine; Pentachlorophenol; Total PCBs; Sediment Bioassay
WRIA 09		For this WRIA there are additional industrial, general stormwater and municipal STP dischargers (See Appendix B).	Also, for this WRIA, the toxic contaminants in Tables 9 through 11 are likely to be discharged from additional industrial, stormwater and municipal STP dischargers.	Puget Sound (South, S-Central, East Passage)		Total PCBs (Seals) [Simms, et al., 2000]	1,2,4-Trichlorobenzene; Hexachlorobenzene; Dichlorobenzene (all South). Benzyl alcohol; 2-Methylphenol; 2,4-Dimethylphenol (all South Central and East Passage)
WRIA 10	Kaiser Aluminum, Tacoma (Port of Tacoma) [WA-000093-1]	Aluminum Smelter	Total Suspended Solids; Fluoride; Aluminum; Antimony; Arsenic; Cadmium; Copper; Nickel; Zinc; Cyanide, free; Benzo(a)pyrene (i.e., PAHs); Oil & Grease; Total PCBs.	Inner Bay - Commencement -Hylebos WW -Blair Waterway	Except where indicated for this WRIA, no apparent assessment by Ecology for likely toxic chemicals in water (see Appendix D).	Dieldrin, Total PCBs (Mussel) [Johnson and Davis, 1996]	Sediment Bioassay (Hylebos); Copper (Inner); N-nitrosodiphenylamine; 1,2-Dichlorobenzene; 2,4-Dimethylphenol; 1,4-Dichlorobenzene; 1,2,4-Trichlorobenzene; Hexachlorobutadiene; Benzoic acid (all Inner)
WRIA 10	Pacific Functional Fluids, LLC, Tacoma (formerly know as Lilyblad Petroleum) [WA-003867-9]	Chemical	Copper, Lead, Zinc, pentachlorophenol, O&G, acetone, Methylene Chloride, arsenic, other metals.	Inner Bay - Commencement -Blair Waterway (via Lincoln Avenue Ditch)		Except where indicated for this WRIA, no apparent assessment by Ecology for likely toxic chemicals in tissue (see Appendix D).	[Sediment data from Ecology's SEDQUAL summary in 303(d) listings does not indicate what other likely contaminants were monitored or assessed.]
WRIA 10	US Oil & Refining, Tacoma [WA-000178-3]	Oil Refinery	Phenolic Compounds, Total Ammonia, Sulfide, Total Chromium, Hexavalent Chromium, Chlorine (not monitored in this permit), BOD5, COD, O&G, TSS, Solvents, Phthalates, PAHs, Other Metals.	Inner Bay - Commencement -Blair Waterway			
WRIA 10	Sound Refining, Tacoma [WA-000320-4]	Oil Refinery	Phenolic Compounds, Total Ammonia, Sulfide, Total Chromium, Hexavalent Chromium, Chlorine, BOD5, COD, O&G, TSS, Solvents, Phthalates, PAHs, Other Metals.	Inner Bay - Commencement Hylebos Waterway			

Table 12 and Continued. Correlation of Ecology Authorized NPDES Permits With Puget Sound Toxic Contamination and Locations

WRIA No.	Facilities Description	Discharger Type	Ecology Authorized Discharge Chemicals	Receiving Waterbody	Waterbody Status - Ecology 303(d) Category 5 Listings		
				Direct Discharge	WQ	Tissue [A]	Sediment (from SEDQUAL)
	Simpson Kraft Co., Tacoma [WA-000085-0]	Pulp and Paper Mill	2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD); 2,3,7,8-tetrachlorodibenzofuran (TCDF); Tetrachlorocatechol; Tetrachloroguaiacol; Trichlorosyringol; 4,5,6-trichloroguaiacol; 3,4,6-trichlorocatechol; 3,4,5-trichlorocatechol; 3,4,5-trichloroguaiacol; 2,3,4,6-tetrachlorophenol; 3,4,6-trichloroguaiacol; Pentachlorophenol; 2,4,6-trichlorophenol; 2,4,5-trichlorophenol; Chloroform; AOX; BOD5, COD, O&G, TSS, other Phenols, Phthalates, Metals.	Inner (Hylebos Waterway)		Dieldrin, Total PCBs (Mussel) [Johnson and Davis, 1996]	
WRIA 10				Outer Commencement Bay		Total PCBs and Bis(2-ethylhexyl)phthalate (sole) [1993 and 1995, Washington Department of Fish and Wildlife PSAMP database]	Total PCBs; Bis(2-ethylhexyl)phthalate
WRIA 10	Sonoco, Sumner [WA-000088-4]	Pulp and Paper Mill	Ammonia; BOD5, TSS Other likely contaminants allowed by Ecology are: ammonia, phenols, PCH including pentachlorophenol, sulfides, surfactants, phthalates, and additional metals including mercury, chromium, copper, nickel and zinc.	White River			
WRIA 10				Puyallup River	Mercury		
WRIA 10				Dalco Passage & Poverty Bay		Total PCBs and Bis(2-ethylhexyl)phthalate (sole, mussels, rockfish) [1993 and 1995, (1992-1995,1996 for rockfish) Washington Department of Fish and Wildlife PSAMP database]	Total PCBs; Bis(2-ethylhexyl)phthalate
		For this WRIA there are additional industrial, general stormwater and municipal STP dischargers (See Appendix B).	Also, for this WRIA, the toxic contaminants in Tables 9 through 11 are likely to be discharged from additional industrial, stormwater and municipal STP dischargers.				
WRIA 12	Abitibi Consolidated, Steilacoom [WA-000104-0]	Pulp and Paper Mill	TSS, BOD5 Other likely contaminants allowed by Ecology are: ammonia, phenols, PCH including pentachlorophenol, surfactants, phthalates, and additional metals including mercury, chromium, copper, nickel and zinc.	Puget Sound & Chambers Creek	Except where indicated for this WRIA, no apparent assessment by Ecology for likely toxic chemicals in water (see Appendix D).	Except where indicated for this WRIA, no apparent assessment by Ecology for likely toxic chemicals in tissue (see Appendix D).	2,4-Dimethylphenol; Hexachlorobenzene; 1,2,4-Trichlorobenzene; N-nitrosodiphenylamine; 1,2-Dichlorobenzene; Bis(2-ethylhexyl)phthalate

Table 12 and Continued. Correlation of Ecology Authorized NPDES Permits With Puget Sound Toxic Contamination and Locations

WRIA No.	Facilities Description	Discharger Type	Ecology Authorized Discharge Chemicals	Receiving Waterbody	Waterbody Status - Ecology 303(d) Category 5 Listings		
				Direct Discharge	WQ	Tissue [A]	Sediment (from SEDQUAL)
WRIA12				Leach Creek	Mercury [Ecology EIM database, 1992-1993]		[Sediment data from Ecology's SEDQUAL summary in 303(d) listings does not indicate what other likely contaminants were monitored or assessed.]
WRIA12		For this WRIA there are additional industrial, general stormwater and municipal STP dischargers (See Appendix B).	Also, for this WRIA, the toxic contaminants in Tables 9 through 11 are likely to be discharged from additional industrial, stormwater and municipal STP dischargers.	Puget Sound (South)		Total PCBs (Copper Rock Fish) [WDFW PSAMP, 1992-1993]	
WRIA13				Budd Inlet	Except where indicated for this WRIA, no apparent assessment by Ecology for likely toxic chemicals in water (see Appendix D).	Except where indicated for this WRIA, no apparent assessment by Ecology for likely toxic chemicals in tissue (see Appendix D). PAHss (as follows, for Shellfish) [Norton, et al., 1986] Benzo(a)anthracene Benzo(b)fluoranthene Benzo(k)fluoranthene Chrysene	[Sediment data from Ecology's SEDQUAL summary in 303(d) listings does not indicate what other likely contaminants were monitored or assessed.]
WRIA13		For this WRIA there are additional industrial, general stormwater and municipal STP dischargers (See Appendix B).	Also, for this WRIA, the toxic contaminants in Tables 9 through 11 are likely to be discharged from additional industrial, stormwater and municipal STP dischargers.	Squaxin & Dana Passages		Total PCBs (English Sole) [WDFW PSAMP, 1993&1996]	
WRIA14				Case Inlet & Dana Passage	Except where indicated for this WRIA, no apparent assessment by Ecology for likely toxic chemicals in water (see Appendix D).	Except where indicated for this WRIA, no apparent assessment by Ecology for likely toxic chemicals in tissue (see Appendix D). Bis(2-ethylhexyl)phthalate (English sole) [WDFW PSAMP, 1993]	[Sediment data from Ecology's SEDQUAL summary in 303(d) listings does not indicate what other likely contaminants were monitored or assessed.]
WRIA14		For this WRIA there are additional industrial, general stormwater and municipal STP dischargers (See Appendix B).	Also, for this WRIA, the toxic contaminants in Tables 9 through 11 are likely to be discharged from additional industrial, stormwater and municipal STP dischargers.	Squaxin, Peale and Pickering Passages		Bis(2-ethylhexyl)phthalate (English sole) [WDFW PSAMP, 1993] Total PCBs (English Sole) [WDFW PSAMP, 1993&1996]	
WRIA15				Carr Inlet		Bis(2-ethylhexyl)phthalate (English sole) [WDFW PSAMP, 1993] Total PCBs (English Sole) [WDFW PSAMP, 1993&1996]	[Sediment data from Ecology's SEDQUAL summary in 303(d) listings does not indicate what other likely contaminants were monitored or assessed.]
WRIA15				Clear Creek		Total PCBs (Oncorhyncus clarkii) [Davis, et al., 1998]	

Table 12 and Continued. Correlation of Ecology Authorized NPDES Permits With Puget Sound Toxic Contamination and Locations

WRIA No.	Facilities Description	Discharger Type	Ecology Authorized Discharge Chemicals	Receiving Waterbody	Waterbody Status - Ecology 303(d) Category 5 Listings		
				Direct Discharge	WQ	Tissue [A]	Sediment (from SEDQUAL)
WRIA15				Dyes Inlet &Port Washington Narrows		Mercury (Crab) [EA Engineering, 1995]	Dibenzo(a,h)anthracene (other compounds): 2-Methylphenol; 2,4-Dimethylphenol; 1,2-Dichlorobenzene; 1,4-Dichlorobenzene; 1,2,4-Trichlorobenzene; Hexachlorobutadiene; Hexachlorobenzene; N-nitrosodiphenylamine; Pentachlorophenol
WRIA15				Eagle Harbor		PAHss (as follows, for Shellfish) [Yake, et al., 1984] Benzo(a)anthracene Benzo(a)pyrene Benzo(b)fluoranthene Benzo(k)fluoranthene Chrysene Dibenzo(a,h)anthracene Indeno(1,2,3-cd)pyrene Also, Total PCBs	[Sediment data from Ecology's SEDQUAL summary in 303(d) listings does not indicate what other likely contaminants were monitored or assessed.]
WRIA15				Hale Passage (South)		Total PCBs (English Sole) [WDFW PSAMP, 1993&1996]	
WRIA15				Puget Sound (South)		Bis(2-ethylhexyl)phthalate (English sole) [WDFW PSAMP, 1993] Total PCBs (English Sole) [WDFW PSAMP, 1993-1997]	
WRIA15				Case Inlet & Dana Passage		Bis(2-ethylhexyl)phthalate (English sole) [WDFW PSAMP, 1993]	
WRIA15		For this WRIA there are additional industrial, general stormwater and municipal STP dischargers (See Appendix B).	Also, for this WRIA, the toxic contaminants in Tables 9 through 11 are likely to be discharged from additional industrial, stormwater and municipal STP dischargers.	Sinclair Inlet			2-Methylphenol; 2,4-Dimethylphenol; 1,2-Dichlorobenzene; 1,4-Dichlorobenzene; 1,2,4-Trichlorobenzene; Benzyl Alcohol; Benzoic Acid; Hexachlorobutadiene; Hexachlorobenzene; N-nitrosodiphenylamine; Pentachlorophenol Mercury
WRIA 17	Port Townsend Paper, Port Townsend [WA-000092-2]	Pulp and Paper Mill	BOD5, TSS, Total chlorine residual Other likely contaminants allowed by Ecology are: ammonia, phenols, PCH including pentachlorophenol, sulfides, surfactants, phthalates, and additional metals including mercury, chromium, copper, nickel and zinc.	Port Townsend Bay (Glen Cove)	Except where indicated for this WRIA, no apparent assessment by Ecology for likely toxic chemicals in water (see Appendix D).	Except where indicated for this WRIA, no apparent assessment by Ecology for likely toxic chemicals in tissue (see Appendix D).	[Sediment data from Ecology's SEDQUAL summary in 303(d) listings does not indicate what other likely contaminants were monitored or assessed.]
WRIA 18				Admiralty Inlet	Except where indicated for this WRIA, no apparent assessment by Ecology for likely toxic chemicals in water (see Appendix D).	Except where indicated for this WRIA, no apparent assessment by Ecology for likely toxic chemicals in tissue (see Appendix D).	1,2-Dichlorobenzene; 1,2,4-Trichlorobenzene; Hexachlorobenzene; [Sediment data from Ecology's SEDQUAL summary in 303(d) listings does not indicate what other likely contaminants were monitored or assessed.]

Table 12 and Continued. Correlation of Ecology Authorized NPDES Permits With Puget Sound Toxic Contamination and Locations

WRIA No.	Facilities Description	Discharger Type	Ecology Authorized Discharge Chemicals	Receiving Waterbody	Waterbody Status - Ecology 303(d) Category 5 Listings		
				Direct Discharge	WQ	Tissue [A]	Sediment (from SEDQUAL)

[A] **References** for contamination of organism tissue related to ambient WQ concentrations, as cited by Washington Ecology (based on National Toxics Rule):

Johnson, A., 2000, *Results of a Screening Analysis for Metals and Organic Compounds in Shellfish from Padilla Bay and Vicinity* , by Art Johnson, Washington Ecology Publication No. 00-03-008, May 2000.

Hopkins, B. S., D. K. Clark, M. Schlender, and M. Stinson, 1985, *Basic Water Monitoring Program: Fish Tissue and Sediment Sampling for 1984* , Washington State Department of Ecology, Olympia, WA. Pub. No. 85-7.

TGB-PS WGEI, 2002, Transboundary Georgia Basin – Puget Sound Working Group on Environmental Indicators, *Georgia Basin-Puget Sound Ecosystem Indicators Report Technical Backgrounders Contaminants in Harbour Seals* , Spring 2002.

Ross, et al., 2000, *High PCB Concentrations in Free-Ranging Pacific Killer Whales, Orcinus orca: Effects of Age, Sex and Dietary Preference* , by P. S. Ross, G. M. Ellis, M. G. Ikonomou, L. G. Barrett-Lennard and R. F. Addison, Marine Pollution

Myers, et al., 1998a, Toxicopathic hepatic lesions as biomarkers of chemical contaminant exposure and effects in marine bottomfish species from the Northeast and Pacific Coasts, USA, by Myers, M. S., L. L. Johnson, O. P. Olson, C. M. Stehr, B. H.

Myers, 1998b, Toxicopathic hepatic lesions in subadult English sole (Pleuronectes vetulus) from Puget Sound, Washington, USA: Relationships with other biomarkers of contaminant exposure, Marine Environmental Research, by Myers, M. S., L. L. Johnson,

Johnson, A., and Davis, D., 1996. Washington State Pesticide Monitoring Program: Pesticides and PCBs in Marine Mussels, 1995. Washington State Department of Ecology, Olympia, WA., Pub. No. 96-303.

Simms, et al., 2000, Contaminant-related disruption of vitamin A dynamics in free-ranging harbor seal (Phoca vitulina) pups from British Columbia, Canada and Washington State, USA, by Simms, W., S. Jeffries, M. Ikonomou, and P. S. Ross, Environmental

Norton, D., 1986, Results of Priority Pollutant Analyses on Water, Sediment, and Clam Samples in Lower Budd Inlet near McFarland/Cascade, Washington Dept. of Ecology, Olympia, WA.

Yake, et al., 1984, Chemical Contaminants in Clams and Crabs from Eagle Harbor, Washington State, with Emphasis on Polynuclear Aromatic Hydrocarbons, by Yake, B., J. Joy, and A. Johnson, Washington State Dept. Ecology, Olympia, WA,

EA Engineering, 1995, Draft Remedial Investigation/Feasibility Study: Jackson Park Housing Complex/Naval Hospital Operable Unit 2 - Marine Areas. Prepared for Engineering Field Activity, Northwest Naval Facilities Engineering Command. December

I. NPDES Authorized Toxic Discharges into Puget Sound Permitted by Washington Ecology

Report Section by David LaLiberte, MSCE, Environmental Engineer

I.1. Review of NPDES Permits

This is a review of records concerning Ecology issued NPDES permits likely to result in discharge of toxic chemicals into Puget Sound waters. In Section II of this report by Ewing, the effects of toxic chemicals on chinook salmon are discussed. Section II discussions are referenced where appropriate, throughout this section.

I.1.1. Permit Review

The number of discharge permits by type is listed in Table 1 for major industrial, additional industrial, sewage treatment plants (STPs), general industrial, and general stormwater. The number of permits by type is based on available information developed through Information on Ecology's Water Quality Permit Life Cycle System. [Ecology WPLCS, 2006i] These permitted dischargers are listed by receiving water basin (i.e., by WRIA) in Table 12. Discharger facility data is detailed and summarized in Appendix B.

The universe of Ecology-issued NPDES permits in the Puget Sound basin comprises 16 major industrial facilities such as petroleum refining, pulp and paper mills, aluminum smelting, chemical manufacturing and power cogeneration; 56 additional individual industrial dischargers including cement and asphalt manufacturing, chemical manufacturing, petroleum storage, shipyard, solid waste sites, transportation facilities, wood preserving and others; 86 sewage treatment plants (STPs) from municipal dischargers; 98 general industrial dischargers made up of boatyard and water treatment facilities; and 1593 general stormwater dischargers from industrial, commercial, transportation, construction and municipal sources. [Ecology NPDES permits, 2006a-e]

I.1.2. Puget Sound and Receiving Waters

Ecology has organized monitoring data into Water Resource Inventory Areas (WRIA) to support its 303(d) List requirements. [Ecology 303(d) list, 2004a] The areas evaluated are listed in Table 2 and comprise the Puget Sound region of interest for this report. In the 303(d) assessment process, Ecology does not take into account the total effect of all the impaired WRIAs that comprise Puget Sound. This has resulted in a lack of consideration of Puget Sound as a whole, or even consideration of reaches within Puget Sound itself. Appendix C summarizes criteria used by Ecology in assessing the impairment status of waterbodies within the Puget Sound region based on water quality, sediment and organism. [Ecology, 2006f-g; EPA, 2002b] Detailed assessments for Puget Sound region waterbodies, for the range of chemical parameters examined by Ecology, is presented in Appendix D. [Ecology Assessment, 2004b]

Available waterbody monitoring and impairment data were obtained from the 2004 *Washington State's Water Quality Assessment 303(d) List*, for water quality, tissue and

sediments. [Ecology 303(d) List, 2004a] Ecology lists criteria for determining impairment in *Water Quality Standards for Surface Waters of the State of Washington*, WAC Chapter 173-201a; and in *Sediment Management Standards*, WAC Chapter 173-204. [Ecology, 2006f-g.] Ecology's assessment procedures are described in *Water Quality Program Policy- Assessment of Water Quality for the Section 303(d) List*. [Ecology Assessment, 2002] Ecology also uses the EPA's National Toxics Rule, for organisms exposed to toxic chemicals in ambient water and reflecting human health risk because of bioconcentration of toxic chemicals in fish tissue. [EPA, 2002b]

Ecology has also developed and maintains the Environmental Information Management System (EIM) database website. [Ecology, 2006h] The EIM is intended to contain environmental data from Ecology and other verified contributors for Washington's air, water, soil, aquatic animals, and plants. In addition EIM provides links to detailed studies that include monitoring location information and monitoring results. WRIA monitoring data was obtained from EIM for a number of basins in the Puget Sound area. Examples of sediment data obtained from EIM are detailed and summarized in Appendix E. This report represents an extensive examination of toxic contamination in the Puget Sound study area based on these data. However, the database was not comprehensive, particularly as it related to monitoring data for sediments. This is especially apparent in sediment study data conducted as a requirement of NPDES discharge and never updated to EIM.

I.1.3. Toxic Discharges into Toxically Impaired Receiving Waters

Total maximum daily loads (TMDL) documents developed by Ecology for the Puget Sound area are evaluated. [Ecology, 2005a-b] Table 3 summarizes waterbodies having established TMDLs for toxic contaminants including metals, phenols, ammonia, Dioxins and PCBs. Ecology continues to allow discharges of toxic substances into at least 12 Puget Sound area TMDL basins, impaired for toxic contaminants, at concentrations harmful to organisms, specifically, chinook salmon (see Section II by Ewing, subsections II.3.3 through II.3.5, for chemical specific discussion of harm to chinook salmon). In addition, an even greater number of toxically impaired water bodies, i.e., there are at least 46 listed (in the 2004 303(d)) in the Puget Sound region, also receive toxic discharges. This is a total of 58 impaired waterbodies when TMDLs and 303(d) listings for toxic contamination are added together.

I.2. Ecology's NPDES Permit Requirements

Approximately 20 NPDES permits were reviewed, with associated permit evaluations, to assess the extent of toxic contaminants continuing to be discharged into Puget Sound. Ecology purports to have performed "reasonable potential" analyses for all these permits to demonstrate that discharge of individual specific pollutants in compliance with permit conditions will not result in exceedances of water quality standards. [Ecology, 2006f-g] Effluent characterization and monitoring requirements in the permits also omit obvious pollutants such as PAH and phthalates, which show widespread contamination in Puget Sound area waters. Mixing zone dilutions in the permit are also routinely over-estimated in Ecology's evaluations and are not representative of toxic discharges that cause water

quality violations in Puget Sound area waters. These over-estimated dilutions are used as the basis for WET testing; therefore the results of such testing lead to under-protective conclusions.

I.2.1. Reasonable Potential Analysis

The majority of Ecology's NPDES permit evaluations include reasonable potential analysis (RPA) to determine whether a discharge will violate water quality or sediment criteria. However, review of the details of these permit evaluations indicates that no RPA was performed for key toxic chemicals known to be in the effluent, as would be required for consistency with EPA guidance [EPA TSD, 1991] and Ecology's own guidance. [Ecology Permit Manual, 2004d] NPDES permit evaluations did not include toxic pollutants across a range of categories including oil refineries, pulp and paper mills, industrial and municipal stormwater dischargers, additional industrial dischargers and STP dischargers. Key toxic chemicals not receiving reasonable potential analysis were PAHs, PCHs, phthalates, and metals particularly lead, mercury, and copper.

NPDES permits for the 6 oil refineries, all major facilities, did not include limitations for polynuclear hydrocarbons (PAHs) and phthalates. The uncertainty introduced by infrequent effluent monitoring, usually once per permit cycle (i.e., every 5 years) as part of an EPA Priority Pollutant Scan, is not reflected in Ecology's reasonable potential analysis and is not consistent with EPA guidance.

Similarly, NPDES permits for the 6 pulp and paper mills, did not include limitations for polynuclear hydrocarbons (PAHs) and phthalates. The uncertainty introduced by infrequent effluent monitoring, in many instances once per permit cycle (i.e., once every 5 years) as part of an EPA Priority Pollutant Scan, is not reflected in Ecology's reasonable potential analysis and is not consistent with EPA guidance. [EPA TSD, 1991]

A review of 6 of the 56 "additional industrial" Puget Sound NPDES permits, showed that effluent limitations were not included for polynuclear hydrocarbons (PAHs) and phthalates although the compounds are likely present in the permitted effluent. The uncertainty introduced by infrequent effluent monitoring, usually once per permit cycle (i.e., every 5 years) as part of an EPA Priority Pollutant Scan, is not reflected in Ecology's reasonable potential analysis and is not consistent with EPA guidance. [EPA TSD, 1991]

A review of 6 of the 86 Puget Sound sewage treatment plants discharging showed that effluent limitations were not included for polynuclear hydrocarbons (PAHs) and phthalates although likely in the permitted effluent. The uncertainty introduced by infrequent effluent monitoring, usually once per permit cycle (i.e., every 5 years) as part of an EPA Priority Pollutant Scan, is not reflected in Ecology's reasonable potential analysis and is not consistent with EPA guidance. [EPA TSD, 1991]

For the 1593 general stormwater permits in the Puget Sound region, which include industrial, construction and municipal facilities, no monitoring of toxic chemicals such as PAHs, phthalates, PCHs or heavy metals (except zinc) is typically required.

I.2.2. Monitoring requirements

The more infrequent the monitoring required by NPDES permit, the larger the uncertainty associated with adverse effects on aquatic biota. The EPA recognized this, in the *Technical Support Document for Water Quality-Based Toxics Control* [EPA TSD, 1991], indicating a multiplier should be used to be more representative of actual chemical concentrations being discharged.

This review of selected NPDES permits in the Puget Sound region reveals that monitoring and attainment of numeric effluent limitations are not required for specific discharge toxicants that are likely to be present in the authorized discharges. For example, PAHs contained in effluent are consistently neglected in Ecology's NPDES permit development although several EPA investigations show PAHs are present in industrial, municipal and stormwater discharges. [EPA 2005a; EPA 2005b; EPA 1983]

Sediment Monitoring

While Ecology's standard language related to reasonable potential analysis, presented in permit evaluation reports, states that the Department relies on sediment monitoring for assessing waterbody conditions, significant omissions exist in Ecology's reporting of toxic contaminants in their 303(d) assessment compared to the supporting EIM database. [Ecology 303(d) List, 2004a; Ecology, 2006h]

Ecology staff state in the permit Fact Sheets that they have done reasonable potential analysis on sediments but this does not seem to be the case. Of the 20 NPDES permits and Fact Sheets reviewed, all refer to sediment monitoring that was performed but none of this data appears in the 303(d) List database. Sediment data from outfall vicinities affect RPA but was not considered and does not appear in Ecology's WQ assessment databases, i.e., EIM and SEDQUAL.

Appendix E presents example sediment database information from Ecology's EIM for Fidalgo Bay and Elliott Bay. While the SEDQUAL database reports some contamination in each of the of the bays in the 2004 303(d) List for sediments, the EIM database demonstrates that contamination is more extensive than indicated. For example, the 303(d) List based on SEDQUAL for Elliott Bay omits reporting standards violations for the metals chromium, copper, lead, and zinc; and the PAHs chrysene, fluoranthene, dibenzo(a,h)anthracene, indeno(1,2,3-cd)pyrene and HPAHs. An additional example is Fidalgo Bay where the 303(d) List based on SEDQUAL omits reporting standards violations for the PAHs phenanthrene, chrysene and fluoranthene. Lastly, while the EIM and SEDQUAL databases for sediments are used in Ecology's assessments and 303(d) listings, it does not include data for toxic contaminated sediment that is developed from NPDES required outfall monitoring. This pattern of omission of known data is repeated in additional Puget Sound WRIAs. Of the 20 permits and Fact Sheets evaluated, all omitted updating the results of sediment monitoring into the EIM database used for assessment of waterbody impairment for 303(d) List determinations.

Individual oil refinery industrial permits, and fact sheets, acknowledge contaminated outfall sediments for mercury, cadmium and bis(2-ethylhexyl)phthalate in toxic amounts. However, a detailed review of Ecology's 303(d) assessment and listings do not include this monitoring data in the EIM or SEDQUAL databases. Accordingly, despite known discharges associated with contaminated sediments, no 303(d) listings exist for oil refinery generated mercury, cadmium, and bis(2-ethylhexyl)phthalate.

Sediment contamination is widespread in areas affected by industrial, CSO and stormwater discharges that have been authorized, or left un-quantified, by Ecology's NPDES permits. [EPA LDW, 2001, 2003-05; EPA Commencement Bay; Ecology, Bellingham Bay, 1998, 2001, 2006] These discharges have historically resulted in environmental contamination and many continue to be authorized through current permits. Contaminated water and sediments in Bellingham Bay, Fidalgo Bay, Everett Harbor, Elliott Bay, and Commencement Bay have received and continue to receive effluent discharges from permits allowing discharges of inadequately treated wastewater from industry and municipalities. For example, Elliott Bay has historic contamination requiring cleanup [King County CSO, 2006]. However, ongoing discharges into Elliott Bay, and the Duwamish River upstream, continue from at least 7 industrial dischargers with individual permits for: bulk petroleum storage and distribution; cement manufacturing; ship building, repair and conversions; steel manufacturing; and steam heating utility (see Appendix B). Additionally, about 93 industrial stormwater general permits authorized by Ecology allow continued discharges of toxic contaminants into Elliott Bay, and the Duwamish and Green Rivers upstream (see Appendix B). Lastly, urban stormwater runoff authorized under Ecology's NPDES permit for the Seattle municipal separate stormwater sewer system (MS4 Phase I) discharges contribute still more toxic contaminants.

I.2.3. Sensitivity of Whole Effluent Toxicity Testing

The combined, or synergistic, effect of a number of chemicals acting together often causes significantly greater harm than individual chemicals acting separately. [EPA TSD, 1991] Whole Effluent Toxicity (WET) testing required in Ecology's NPDES permits, and EPA guidance, is intended to capture this combined chemical condition. [EPA TSD, 1991; Ecology Permit Manual, 2004d] However, the reasonable potential analyses employed by Ecology for WET testing shows combined effluent effects will not cause harm to less sensitive species, such as rainbow trout, than chinook salmon (see Section II.2. by Ewing). [Also EPA TSD 1991] The WET testing approved by Ecology also routinely allows unrepresentative, minimal effluent concentrations to be used when evaluating an organism's exposure to total effluent effects. Minimal effluent concentrations are derived based on inflated dilutions resulting from inaccurate mixing zone analyses as described in the next subsection. WET testing is routinely conducted for a maximum of seven days, and therefore fails to account for longer-term effects, such as bioaccumulation, exhibited by many of the toxic chemicals discussed in this report. [Ecology WET, 1995, also know as the "Canary Book"; Ecology NPDES Permits, 2006a-e]

I.2.4 Effect of Mixing Zone Dilution Allowances

A review of a sample of Ecology NPDES permits, and fact sheets, shows that outfall mixing zone dilutions are routinely over-estimated for a significant number of permits. One example of a systematic error in Ecology permit evaluations is the omission of accounting for tidal conditions that return previously discharged effluent into the outfall mixing zone area. This tidal return rate has the effect of raising background concentrations of effluent pollutants and significantly reduces dilution. Additionally, ambient velocities in the Puget Sound are typically overestimated in Ecology's NPDES permit evaluations resulting in inflated dilution. [Ecology Permits, 2006a-e; NOAA, 1990; NOAA 1984a-c; Cannon; 1990; Albertson, 2001; Fischer, et al., 1979; White, 1986; Baumgartner, et al., 1993] This leads to Ecology's conclusion, in many instances, that there are no undesirable effects from discharge of toxic chemicals and other contaminants. However, this is despite known adverse effects of human caused, and widespread, toxic contamination in Puget Sound waters, sediments, and organisms. Over-estimated Puget Sound dilutions also result in less monitoring, fewer effluent limitations and less wastewater treatment being required in the permits. Inaccurate and underestimation of effluent dilution factors create harm to Puget Sound organisms by distorting the results of the reasonable potential analysis as performed under EPA and NPDES permit requirements and guidance. [EPA TSD, 1991; Baumgartner, 1993; Ecology NPDES Permits 2006a-e]

Effective acute toxicity assessment for organisms is substantially neglected by Ecology, and was not performed consistent with EPA guidance for mixing zones. This is because determination of acute toxicity based on discharge length scale was typically not conducted by Ecology. The discharge length scale is crucial to mixing zone analyses because it relates outfall physical conditions to the extent of acute toxicity in the zone around the outfall. Inaccuracies in acute toxicity extent, coupled with the routine tendency of mixing zone analysts to overestimate available dilution water and outfall port velocities, causes significant under-estimation of chronic toxicity at the mixing zone boundary. This under-estimation of toxicity is a factor in Ecology's failure to explain the connection of known source discharges with impaired waterbodies.

Many instances exist where Ecology allows the discharge of persistent toxic chemicals, such as PAHs, some metals (such as mercury) and phthalates [Ecology Permits 2006a-e] known to bioaccumulate in organisms such as chinook salmon (see Sections II.2.2, II.2.3, and II.3.3-Mercury by Ewing). [Also EPA Criteria, 1986] For example, the discharge of metals, such as mercury, are typically justified based on meeting short-term mixing zone criteria in the water column near the outfall or, as in the case of stormwater, based on un-quantified metals discharges from storm piping and runoff. However, metals are persistent and do not breakdown beyond the mixing zone. Importantly, metals are typically associated with suspended solids and settle out of the water column in, and beyond, the permitted mixing zone. Accumulation of metals, PAH and PCHs in sediments occurs in outfall mixing zone vicinities, and these toxic contaminants remain perennially available to organisms where they bioaccumulate.

The six-mile long Lower Duwamish Waterway superfund site regrettably demonstrates the fate of PCBs, PAHs, phthalates, metals (mercury and arsenic), and other organic contaminants, which have accumulated in estuary sediments. The current and historic sources of these contaminants are industrial, combined sewer overflows, and urban stormwater.EPA LDW, 2001; EPA LDW, 2003-05] Additional examples are: the Commencement Bay - Nearshore Tideflats Superfund site [EPA Commencement Bay], and Bellingham Bay sediment contamination. [Ecology, Bellingham Bay, 1998, 2001 and 2006]

The present tendency of dischargers is to obtain approval from Ecology for expanded mixing zones, and hence increased total toxic pollutant load, through engineered changes to effluent outfalls (i.e., lengthening of their discharge outfall by adding diffuser ports). Engineered changes are arbitrarily limited to effluent outfalls only, and do not extend to wastewater treatment levels commensurate with state-of-the-art outfall design. For example, while the addition of outfall diffusers may improve some of the short-term effects of toxic discharges on the aquatic ecosystem, resulting increased discharges of persistent toxic pollutants including metals, PAH and PCHs is a worsened condition. This problem is routinely not addressed in NPDES permits issued by Ecology. Wastewater treatment design levels, commensurate with the advanced outfall designs now typically implemented, are not evaluated in Ecology's NPDES process. However, these technologies would reduce exposure of Puget Sound organisms to lower and presumably safe levels of persistent, bioaccumulative toxic contaminants.

The present trend is to move outfalls, and their NPDES permitted mixing zones, into areas of Puget Sound not as intensively contaminated with toxic chemicals. This has occurred in the bays of the Puget Sound region including Bellingham Bay, Fidalgo Bay, Everett Harbor, Commencement Bay and others. Toxic contaminants presently allowed for discharge under Ecology's NPDES permits would result in expanded contamination into new areas of Puget Sound bays and estuaries. This will cause increased harm to dependent organisms such as mussels, sole, salmon, seals, and killer (Orcas) whales as already documented in Ecology's 303(d) listings for animal tissue for existing conditions, and harm as discussed in Section II.2 by Ewing. Combined with the shortcomings of Ecology's reasonable potential analysis (RPA) for determining harm to organisms, expanding the area of toxic chemicals in the sediment is highly threatening to salmon, specifically chinook salmon.

I.3 Puget Sound Hydrodynamic Conditions

This section examines scientific reports associated with Puget Sound bathymetry, water velocities, tidal conditions and flow circulation. [NOAA, 1990; NOAA 1984a-c; Cannon; 1990; Albertson, 2001; USGS Hood Canal, 2004; USGS Hood Canal, 2005] The primary exchange of waters between the Strait of Juan de Fuca (i.e., Pacific Ocean saltwater) and Puget Sound occurs through Admiralty Inlet (see Figure 3). The prevailing annual net circulation through Admiralty Inlet into the sound is dominated by two-layer flow (see Figures 2-6). The net annual transport of heavier density seawater into the sound occurs via the bottom layer. Whereas, the net annual transport of lighter density seawater out of the sound occurs via the upper layer. Admiralty Inlet bathymetry affects

the depth of the surface layer, with the approximately 200-foot sill depth controlling the surface layer depth.

Based on review of the scientific studies of circulation in the Puget Sound, it is apparent that contaminants discharged into the sound can remain for extended periods. Discharges into the sound are generally laden with total suspended solids (TSS) that have toxic contaminants attached, or contain toxic chemicals in oil and grease (O&G). [Ecology NPDES Permits, 2006a-e]

In the Strait of Juan de Fuca the annual transport flow average is about 100,000 m^3/s in each layer off Pillar Point, and it decreases to about 40,000 m^3/s at the entrance to Puget Sound off New Dungeness. In the Main Basin of Puget Sound, transport flow decreases to about 14,000 m^3/s off Point Jefferson but then rises to 32,000 m^3/s in East and Colvos Passages before decreasing again to 15,000 m^3/s off Gordon Point and to 5000 m^3/s of Devils Head.

Transport flow in the Hood Canal and Saratoga Pass side channels of Puget Sound are small, being less than 7,000 m^3/s. [NOAA, 1990] USGS evaluations of transport flows in Hood Canal have shown weak mixing and sluggish circulation. [USGS Hood Canal, 2004; USGS Hood Canal, 2005]

As contaminants adsorb onto particles, and settle, they can travel further into the side channels of the Puget Sound including the Southern, Whidbey and Hood Canal Basins (see Figures 2-6). In these side channels, discharged particles have ample time to be deposited into Puget Sound sediments. For example, Puget Sound circulation patterns cause discharged effluent to remain in the Southern Basin of Puget Sound for extended periods, on the order of 100 days, considerable time for particle settlement. Extended periods allow mixed effluent from industrial, municipal and storm facilities, to settle out suspended solids such that sediment contamination is widespread in Puget Sound. [Ecology 303(d) List – Sediments, 2004a; Ecology SEDQUAL, 2004c]

I.3.1. Surface versus Bottom Layer Flows

Currents in Puget Sound are tidally mixed with estuarine circulation as two-layered over the entrance sill at Admiralty Inlet, and in the main basin from Seattle northward. Observations [Cannon, et al., 1990] show the onset of saltwater intrusions is associated with the neap tides and horizontal density gradient across the sill. These bottom layer intrusions are one of the major circulation features of Puget Sound. However, tidal mixing, particularly during spring tides, may impede or stop density currents in the bottom layer. These effects cause a net flow into Puget Sound in the lower layer, and a net flow out of the sound through the surface layer over the sill. [Cannon, et al., 1990]

Cokelet, et al. [NOAA, 1990] used fresh water and salt as tracers to deduce the annual mean volume flow in 18 reaches of the Puget Sound region. This application of the conservation of mass used Knudsen's equations based on freshwater runoff and flux-weighted salinities. Computed fresh water runoff was related to river inflows into the

Puget Sound area. Recorded estuarine currents and salinity were evaluated in the NOAA study to calculate the transport flow rates in cubic meters per second (m^3/s).

I.3.2. Puget Sound Residence Times

Albertson, et al., has determined residence times in various waterbodies of the Southern Basin of Puget Sound 2001. These times are summarized in Table 4 based on waterbody volume and mass transport out of the various waterbodies. As can be seen, residence times are extended allowing pollutants to settle and interact in the Southern Basin, which is 124 days based on transport modeling.

Puget Sound residence times for pollutants are extended because of flow circulation conditions, described above, that carry toxic discharge contaminants further into the sound rather than out of it. This is particularly true for suspended solids that have the tendency to settle out when given sufficient residence time as is found in the side channels of the Puget Sound. This is a trend causing worsening water quality and sediment conditions in Puget Sound. This tendency is also inherent in the historic distribution of PCBs showing the fate of all persistent bioaccumulating toxins is to remain in the Sound and thereby find their way into organisms.

The greater the amount of time the mixed effluent spends in the sound, the more opportunities the pollutants have to interact with sound sediments, plants and animals. The problem is particularly acute for persistent toxic chemicals like heavy metals and organic compounds, which stay in the sound and do not breakdown, breakdown very slowly, or convert into other harmful chemicals. The extended residence times cause toxic pollutants to be persistently recycled through water, sediments and biota.

Upwelling Times

Effluent and settling particles from dischargers, do not flow immediately out of the system because only the upper layer has a net flow out of the system. In general, discharge outfalls are located on the floor of the sound. For example, the Westpoint Outfall, one of the largest sewage treatment discharges into the Puget Sound, is located at a depth of 244 feet. Because of the two-layer flow conditions that exist in Puget Sound, mixed effluent and settling particles in the bottom layer must upwell into the surface layer before they can leave the sound. The upwelling process is incorporated in the increased residence times of pollutants in the sound. [NOAA, 1990]

Upwelling times in Puget Sound are summarized in Table 5 based on waterbody volume and mass transport out the system. Upwelling times are: 10 days in the Southern Basin, 60 days in the Main Basin, 110 days in Whidbey Basin, and 120 days Hood Canal.

Upwelling times in Whidbey and Hood Canal are considerable and indicate the potential from toxic chemicals accumulation in these side channels of Puget Sound.

I.3.3. Puget Sound Hydrodynamics Effects on Outfall Mixing Zones

Effluent Tidal Return Conditions
For a range of permit types that Ecology has issued, a review of Fact Sheets reveals that mixing zone evaluations did not include an assessment of conditions causing background accumulation of pollutants in the water column. Specifically, the return of previously discharged effluent into the outfall-mixing zone, i.e., the tidal reflux or return rate, was not typically considered when assessing the effect of toxic chemicals in meeting criteria, particularly for chinook salmon. EPA and Ecology guidance both indicate that a tidal return rate of 0.5 should be considered the default value and effectively reduces stated dilution by 50 percent. This is because when previously discharged effluent is returned to the outfall mixing zone when the tide reverses, the background concentration of corresponding effluent constituents is significantly increased and reduces receiving water dilution. [EPA Estuaries, 1992; EPA TSD, 1991; Ecology Permit Manual, 2004d]

Ambient Velocity Conditions
Ambient velocities, and the unsteady flow characteristics inherent in tidal conditions, play a large role in determining the amount of available dilution in the Puget Sound. Ecology routinely assumes larger ambient velocity magnitudes than is warranted by outfall conditions, and overestimates mixing zone dilutions. [Ecology Permits, 2006a-e; NOAA, 1990; NOAA 1984a-c; Cannon; 1990; Albertson, 2001] Ecology also typically uses a uniform velocity profile with depth, which further over-estimates effluent dilution. The normal instream flow condition is significantly affected by channel bottom friction, which causes lower velocities, and lower dilution, in the bottom layer where outfalls are located. [Fischer, et al., 1979; White, 1986; Baumgartner, et al., 1993]

I.4 Effluent Chemical Types

I.4.1. Total Suspended Solids
Major industrial dischargers, additional industrial facilities, sewage treatment plants, and industrial and municipal stormwater dischargers all release measurable amounts of total suspended solids (TSS). Even though settling and other treatment methods remove a large proportion of the suspended solids, a certain amount does pass through the facilities and is allowed in the effluent under permit limitations. Effluent toxicants routinely adsorb onto suspended particles and are incorporated into the discharge under typical conditions. Many of the toxic chemicals evaluated in this report sequester into sediments, are persistent (do not break down easily), and bioaccumulate at levels harmful to mussels, sole, rockfish, salmon, chinook salmon (see Section II by Ewing subsections II.2.2 and II.2.3), seals, and killer whales. [Thomann and Mueller, 1986; Bowman and Sans, 1983; Miller, et al., 1985; Veith, et al. 1979; EPA Criteria, 1986; ATSDR, 2006; Ecology 303d list, 2004a]

Metals, PAHs, phthalates and PCHs have the strong tendency to adsorb onto suspended solids typically released in the effluent of NPDES permitted discharges. These toxic contaminants can be attached to suspended solids in proportions about 333,000 to 62,500,000 times greater than theoretically safe criteria for organisms for human consumption. These proportions were determined by dividing the permitted total

suspended solids concentration, by the EPA's National Toxic Rule criteria values for presumably safe levels of toxic contaminants. For example, Ecology-issued NPDES permits routinely allow total suspended solids discharges of in excess of 50,000 μg/l. For mercury, the EPA ambient water quality criterion for safe fish consumption is 0.15 μg/l resulting in a multiplier of 333,000 from a proportion of 50,000/ 0.15. For higher toxicity chemicals, such as hexachlorobenzene with a very low ambient concentration criterion at 0.0008 μg/l, a higher range multiplier of 62,500,000 results from the proportion 50,000/ 0.0008. [Ecology Permits, 2006a-e; EPA National Toxics Rule, 2002]

The calculations above assume that all the effluent TSS is in a toxic form, which is not usually the case. This suggests that the given multipliers are lower than the ones caluculated above. However, even if only 10% of the TSS is associated with toxic chemicals the multipliers only drop to 33,000 to 6,250,000 times greater than theoretically safe criteria for organisms for human consumption. In addition, effluent TSS concentrations greater than 50,000 μg/l are allowed by Ecology, tending to increase the multiplication factors presented above. Also, there are many other chemicals more toxic than hexachlorobenzene, and have an even lower ambient water quality criterion for fish for human consumption. This would tend again to increase multiplication factors when the TSS is divided by these lower criterion values. Lastly, not all the toxic contamination would result from one chemical and the additive effect of numerous toxic chemicals would also tend to increase the multiplication factors. Accordingly, the multipliers in the range of 33,000 to 6,250,000 are considered reflective of the potential adverse conditions related to toxic contamination associated with suspended solids.

I.4.2. Oil and Grease

Major industrial dischargers, additional industrial facilities, sewage treatment plants, industrial and municipal stormwater facilities all discharge measurable amounts of oil and grease. PAHS, phthalates and PCHs may also be contained in oil and grease discharges at levels about 4,000 to 6,700,000 times greater than theoretically safe criteria for organisms for human consumption. These proportions were determined by dividing the permitted oil and grease (O&G) concentration, by the EPA's National Toxic Rule criteria values for presumably safe levels of toxic contaminants. For example, Ecology-issued NPDES permits routinely allows O&G discharges in excess of 20,000 μg/l. For phthalate, bis(2-ethylhexyl) the EPA ambient water quality criterion for safe fish consumption is 5.0 μg/l resulting in a multiplier of 4,000 from a proportion of 20,000/ 5.0. For higher toxicity chemicals, such as benzo(a)anthracene with a very low ambient concentration criterion at 0.003 μg/l, a higher range multiplier of 6,700,000 results from the proportion 20,000/ 0.003. [Ecology Permits, 2006a-e; EPA National Toxics Rule, 2002]

The calculations above assume that all the effluent O&G is in a toxic form, which is not usually the case. This suggests that the given multipliers are lower than the ones calculated above. However, even if only 10% of the O&G is associated with toxic chemicals the multipliers only drop to 400 to 670,000 times greater than theoretically safe criteria for organisms for human consumption. In addition, effluent O&G concentrations greater than 20,000 μg/l are allowed by Ecology, tending to increase the multiplication

factors presented above. Also, there are many other chemicals more toxic than benzo(a)anthracene, and have an even lower ambient water quality criterion for fish for human consumption. This would tend again to increase multiplication factors when the O&G is divided by these lower criterion values. Lastly, not all the toxic contamination would result from one chemical and the additive effect of numerous toxic chemicals would also tend to increase the multiplication factors. Accordingly, the multipliers in the range of 400 to 670,000 are considered reflective of the potential adverse conditions related to toxic contamination associated with oil and grease.

I.4.3. Polynuclear Aromatic Hydrocarbons (PAHs)

Ecology authorizes significant discharges of polynuclear aromatic hydrocarbons throughout the Puget Sound area. PAHs are a class of organic compounds consisting of two or more bound aromatic benzene rings. PAHs are toxic to numerous organisms including fish, specifically, chinook salmon (see Section II.3.5 by Ewing). [EPA Criteria, 1986; EPA, 2002; Ecology 2006f-g] Some investigators also refer to PAH as polynuclear aromatic compounds (PAC), which are PAH compounds. [EPA P&P Mills, 2005]

Washington State Ecology sediment standards [Ecology, 2006g] are based on total organic carbon (TOC) percentages because PAHs, and chlorinated aromatic hydrocarbons, will readily adsorb onto carbonaceous substances. Bioavailable PAHs will find their way into the tissue of organisms through food pathways and through the water column (see Section II by Ewing). [WDFW Toxic Contaminants, 2001; WDFW, 1992-2000]

In addition to individual sediment standards for PAHs, low molecular weight polynuclear aromatic hydrocarbons (LPAHs) are totaled for comparison to sediment quality standards contained in WAC 173-204. High molecular weight polynuclear aromatic hydrocarbons (HPAHs) are also totaled for comparison to sediment quality standards contained in WAC 173-204. Table 12 shows that PAH contamination of sediments and organisms was found in 5 of the 13 WRIA comprising the most industrialized and urbanized Puget Sound areas. [Ecology 303(d) Assessment, 2004b]

I.4.4. Polychlorinated Hydrocarbons (PCHs)

Sediment and animal tissue contamination by polychlorinated hydrocarbons (PCHs) is widespread in the Puget Sound region with waterbody impairment associated with NPDES authorized toxic chemicals discharges including dichlorobenzene, trichlorobenzene, and hexachlorobenzene. Section II.3.5 on PCHs by Ewing discusses the effects of PCHs on organisms, particularly, chinook salmon. Table 12 shows that PCHs contamination of sediments is found in 10 of the 13 WRIA comprising the most industrialized and urbanized Puget Sound areas, for PCHs currently authorized for discharge. [Ecology 303(d) Assessment, 2004b; Ecology Permits, 2006a-e]

Historically, PCBs, Dioxins, certain Pesticides (e.g., DDT, Dieldrin) have widely contaminated Puget Sound. However, more recent and on-going discharge contamination is also shown in a review of 303(d) listings for year 2004. Historical contamination shows that PCB distribution in the Puget Sound is widespread. PCBs are concentrated

above sediment standards in urban and industrialized areas such as Bellingham Bay, Duwamish River, Elliott Bay, Dalco Passage, Skagit River, East Passage, Inner and Outer Commencement Bay, Poverty Bay, Squaxin Passages, Peale Passage, Pickering Passage, Carr Inlet, Eagle Harbor, Hale Passage, Case Inlet, Dana Passage. Puget Sound organisms with known PCB contamination are coho salmon, English sole, mussels, mountain whitefish, bridgelip sucker, copper rockfish, and seals (see Table 12).

I.4.5. Phenolic Compounds

Phenolic compounds such as isomers of methylphenol and pentachlorophenol are toxic and harmful to aquatic organism. [EPA Criteria, 1986; EPA, 2002a; Ecology Standards, 2006f-g] Industrial dischargers including major industrial dischargers in the oil refining and P&P mill industries are authorized to discharge large quantities of phenolic compounds into Puget Sound waters. Additional industrial dischargers, stormwater dischargers and municipal sewage treatment plants also discharge phenolic compounds (see Tables 7 through 11). Table 12 shows that phenolic compounds contaminate sediments in 10 of the 13 WRIA comprising the most industrialized and urbanized Puget Sound areas, for phenolic compounds currently authorized for discharge. [Ecology 303(d) Assessment, 2004b; Ecology Permits, 2006a-e]

I.4.6. Phthalates

Phthalate esters such bis(2-ethylhexyl)phthalate are toxic and harmful to aquatic organisms. [EPA Criteria, 1986; EPA, 2002a; Ecology Standards, 2006f-g] Industrial dischargers including major industrial dischargers in the oil refining and pulp and paper mill industries are authorized to discharge quantities of phthalates into Puget Sound waters. Additional industrial dischargers, stormwater dischargers and municipal STP are also known to discharge phthalates (see Tables 7 through 11). Table 12 shows that phthalates contaminate sediments and organisms in 8 of the 13 WRIA comprising the most industrialized and urbanized Puget Sound areas. [Ecology 303(d) Assessment, 2004b; Ecology Permits, 2006a-e]

I.4.7. Heavy Metals

Many Puget Sound facilities discharge heavy metals as shown in Tables 7 through 11. Toxic contamination by metals (see Section II.3.3 by Ewing) in the Puget Sound region is extensive. TMDLs for heavy metals are established or under development in 5 of 13 waterbodies in Puget Sound area waters (see Table 3). Other waterbodies have metals contamination but have no TMDL in place or under development. These waterbodies, presented in Table 12, include Elliott Bay, tributaries discharging to Bellingham Bay, Dyes Inlet, Sinclair Inlet and potentially others. [Ecology 303(d) list, 2004a; Ecology Assessment, 2004b]

Two deficiencies in Ecology's management of metal contamination are a lack of metals monitoring and an omission in the 2004 303(d) List and assessment of impairments due to metals in shellfish and fish tissue. Ecology includes only one case (mercury in crab in Dyes Inlet) in the 2004 303(d) List, acknowledging metals contamination of fish at harmful levels. However, Washington Fish and Wildlife reports metals contaminated fish in several locations. Sinclair Inlet and Elliott Bay rockfish (mercury); English sole in

Dyes Inlet, Port Orchard and Liberty Bay (lead); Sinclair Inlet, English sole in Dyes Inlet, Port Orchard and Liberty Bay (arsenic and copper). [WDFW Toxic Contaminants, 2001]

I.4.8. Ammonia

Ammonia dissolves in water and may directly exert a toxic effect on organisms in Puget Sound waters (see Section II.3.4. by Ewing). [also EPA Criteria, 1986] While many permits allow the discharge of ammonia, ineffective characterization of outfall mixing zone dilutions has resulted in inaccurate assessment of ammonia effects on fish throughout the Puget Sound, specifically chinook salmon. Toxic contamination by ammonia in the Puget Sound region is extensive with TMDLs being established or under development in 5 of 13 waterbodies in Puget Sound area waters (see Table 3).

I.4.9. Hydrogen Sulfide

Hydrogen sulfide dissolves in water and may directly exert a toxic effect on organisms, in Puget Sound waters (see Section II.3.4. by Ewing). [also EPA Criteria, 1986] Many of the industrial NPDES permits evaluated in this report have allowed permit limitations for hydrogen sulfide. Where anaerobic conditions occur near bottom sediments and in bottom layer waters, hydrogen sulfide concentrations may persist even after the effluent discharge enters sound area waters. This is because no oxygen exists in anaerobic conditions to allow conversion of toxic hydrogen sulfide (H_2S) to relatively harmless sulfate (SO_4). Additionally, where long outfalls are in operation hydrogen sulfide can be generated in the outfall pipeline because of anaerobic conditions. [Hvitved-Jacobsen, 2002] As in the case of ammonia, ineffective implementation of outfall mixing zone dilutions has resulted in inaccurate assessment of hydrogen sulfide effects throughout the Puget Sound.

I.4.10. Cyanide

Toxic concentrations of cyanide [EPA Criteria, 1986] are also authorized for discharge from at least some major industries in the Puget Sound Area as listed in Tables 7, 9, 11 and 12 (see Section II.3.4. by Ewing). These include oil refining and aluminum smelting operations. NPDES permits in these instances do not account for the actual toxic effect of cyanide because of ineffective characterization of outfall mixing zone dilutions resulting in inaccurate assessment of cyanide effects on fish.

I.4.11. DO Depleting Compounds – BOD, nutrients

In addition to toxic contamination, low dissolved oxygen problems affect Puget Sound aquatic biota. Sufficient dissolved oxygen is required for maintenance of aquatic life in Puget Sound waters (see Section II.3.4. by Ewing). [also EPA Criteria, 1986; Ecology Standards, 2006f] Dissolved oxygen depletion is likely where large amounts of oxygen depleting chemicals are discharged into Puget Sound waters with long residence times for contaminants. Discharges of oxygen demanding substances include biochemical oxygen demand (BOD), chemical oxygen demand (COD), ammonia, and indirectly through algal dynamics, the nutrients phosphorus and nitrogen. [WEF 1991; others]

A significant majority of the permits evaluated in this report included discharges of DO depleting substances (see Appendix B). Many areas of Puget Sound including Hood

Canal, Budd Inlet, Deschutes River, Carr Inlet, Commencement Bay, Green River, Duwamish River, Everett Harbor, Snohomish River, Ebey Slough, Clover Creek, and others have periods of depleted oxygen, demonstrating water quality impairment, because of introduced oxygen demanding substances from NPDES permitted facilities.

Other areas of concern for DO levels, i.e., Category 2 waterbodies on the 2004 303(d) List, are Nooksack River, Bellingham Bay, Samish River, Padilla and Fidalgo Bays, Guemes Channel, Skagit and Similk Bays, Stillaguamish River, Port Susan, Possession Sound, East Sound, Puyallup River, and others. [Ecology 303(d), 2004a; Ecology, 2004b; Ecology, 2006h] The effects of depleted dissolved oxygen are significant on salmon in rivers and estuaries of the Puget Sound region (see Section II.3.4. by Ewing). [Also Ecology WQ Standards, 2006f; Ecology 303d list, 2004a]

I.5 Wastewater Effluent Types

Table 6 summarizes the toxic compounds of concern when released into Puget Sound area waters. Tables 7 through 11 list toxic chemicals by source, i.e., discharger type, including major industrial, additional industrial, municipal STP, general stormwater and general industrial dischargers. Table 12 lists dischargers versus known toxic pollution in waterbodies of the Puget Sound region. [Ecology Permits, 2006a-e; Ecology 303(d) Assessment and List; 2004a-b] In addition to historical contamination from PCBs, present toxic chemicals contamination for PAHs, PCHs, phenolic compounds, phthalates, and metals discharges is authorized by Ecology's NPDES permit for dischargers in the Puget Sound area. The following discussion breaks down pollutant sources by discharger type.

I.5.1. Major Industrial Dischargers

Major industrial dischargers include petroleum refining, pulp and paper mills, aluminum smelters, power cogeneration, and chemicals manufacturing. Currently, Ecology authorizes 16 of these facilities to discharge into Puget Sound waters.

Petroleum Refining

There are a total of 6 major petroleum-refining facilities in the Puget Sound area (Table 12). [Ecology Permits, 2006a] Discharges from petroleum refining routinely contain the toxic compounds listed in Table 7. Many of these compounds are associated with waterbodies with extensive toxic pollution including PAHs, PCHs and phenolic compounds. These impaired waterbodies include the Strait of Georgia, Fidalgo Bay, and Commencement Bay. [Ecology 303(d) List, 2004a]

The 6 NPDES permits issued by Ecology for the petroleum refineries in the Puget Sound area authorize discharges of substantial amounts of oil that contain PAH which is not monitored or given permit effluent limits. [EPA, 1995; EPA, 1996; EPA, 2002; EPA 2005a; Ecology, 2006a] The NPDES permits fail to account for this routine toxic discharge from refinery outfalls despite listings of harmful concentrations in organisms and sediments in the 2004 303(d) List. [Ecology 303(d) List, 2004a]

Pulp and Paper Mill
There are a total of 6 major pulp and paper mill facilities in the Puget Sound area (Table 12). [Ecology Permits, 2006a] Discharges from pulp and paper mills routinely contain the toxic compounds listed in Table 8. Many of these compounds are associated with waterbodies having extensive toxic pollution including metals, PAHs, PCHs including dioxins, phthalates and phenolic compounds. These impaired waterbodies include Bellingham Bay, Everett Harbor, Commencement Bay and Puget Sound (south). [Ecology 303(d) List, 2004a]

The US Environmental Protection Agency indicates pulp and paper mills discharge polycyclic aromatic compounds. [EPA P&P Mills, 2005b] These compounds are referred to in the EPA document as PAC and are commonly known as polynuclear aromatic hydrocarbons (PAHs) compounds. The NPDES permits fail to account for toxic PAHs, phenols and phthalates that are routinely discharged from mill outfalls. This is despite these compounds showing up in harmful concentrations in organisms and sediments. [Ecology 303(d) List, 2004a]

Other Significant Dischargers
Major aluminum smelting (2 facilities), chemicals manufacturing (1 plant) and power cogeneration (1) facilities are additional important dischargers to Puget Sound waters. Four of these operations exist in the sound area and are associated with other sites with toxic chemicals contamination (Table 12). [Ecology, 2006a] These industries are known to discharge a wide range of toxic contaminants including metals, PAHs, phthalates, and PCH. These contaminants are in many instances associated with the high discharge concentrations of TSS and O&G authorized under Ecology's NPDES permit program. Collectively, a wide range of toxic contaminants, many associated with TSS and O&G, can be discharged under these permits as presented in Table 9.

I.5.2. Additional Industrial Dischargers
Ecology authorizes 56 individual industrial NPDES permits throughout the Puget Sound area (Appendix B). [Ecology, 2006a] Industrial dischargers are significant sources of toxic chemicals in Bellingham Bay, Fidalgo Bay, Snohomish River, Everett Harbor/Port Gardner, Lake Union/Lake Washington Ship Canal, Duwamish River, Elliott Bay, Puyallup River, Commencement Bay and Bud Inlet (see Table 12 and Appendix B). Permits include operations such as cement and asphalt manufacturing, chemical manufacturing, petroleum storage, shipyard, solid waste sites, transportation facilities, wood preserving and others. Collectively, a wide range of toxic contaminants, many associated with TSS and O&G, can be discharged under these permits as presented in Table 9.

I.5.3. General Industrial Permits
There are 98 general industrial wastewater permits authorizing potentially toxic discharges into the Puget Sound area waters. The types of general industrial permits considered in this report are boatyard (90 permits) and water treatment (8 permits).

General industrial dischargers may be sources of toxic chemicals in Drayton Harbor, Nooksack River, Bellingham Bay, Fidalgo Bay, Skagit River, Skagit Bay, Snohomish River, Everett Harbor/Port Gardner, Lake Union/Lake Washington Ship Canal, Duwamish River, Elliott Bay, Commencement Bay, Sinclair Inlet and other areas (see Table 12 and Appendix B).

Boatyard General Permit
Boatyard activity is new construction and repair of small vessels 65 feet or less in length. An Ecology general NPDES permit authorizes boatyard discharges into sewage treatment plant systems and may contain copper, zinc, lead and other toxic contaminants associated with oil, grease and total suspended solids. Stormwater flows are also allowed into nearby receiving waters with allowances for the discharge of oil and grease, TSS and copper. Both O&G and TSS may be associated with toxic contaminants such as metals, PAHs, PCHs, phthalates and other organics.

The stormwater discharge allowances in the boatyard general permits are especially uncontrolled by Ecology because no effluent limitations are set for toxic releases from these facilities. The boatyard general permit substitutes unenforceable "benchmark" values for enforceable limits. If "benchmark" values are exceeded, no prohibition of these discharge levels is required in the permit. Nor does the permit require the discharger to eliminate future exceedances of the "benchmark" values.

The "benchmark" values themselves exceed water quality standards for copper. For example, the water quality criterion for acute toxicity for dissolved copper is 4.61 micrograms per liter for freshwater (at hardness 25 mg/l as $CaCO_3$). Converting from dissolved copper, by using the conversion factor (CF) of 0.960 contained in WAC 173-201A-240(3), the total recoverable copper criterion is 4.80 µg/l. Thus, it can be seen for discharges to rivers that the "benchmark" value of 384 µg/l, expressed in the form of total recoverable copper, is 80 times greater than the 4.8 µg/l criterion. Additionally, while copper toxicity in freshwater is dependent on water hardness, no requirement is made in the general permit to monitor this essential component in determining water quality compliance for freshwater conditions. For marine waters, the acute criterion for total recoverable copper is 5.78 µg/l based on the dissolved criterion of 4.8 µg/l and the conversion factor (CF) of 0.83 contained in WAC 173-201A-240(3). Thus, the "benchmark" value of 229 µg/l, expressed in the form of total recoverable copper, is over 39 times greater than the marine acute criterion for total recoverable copper. Lastly, none of the benchmark values take into account accumulation of copper, or other metals, in sediments; or bioaccumulation of copper, or other metals, in organisms.

The "benchmark" values also allow oil, grease, and total suspended solids associated with toxic contaminants such as metals, PAHs and PCHs to be discharged into Puget Sound area waters. However, no monitoring of toxic contaminants other than copper is required in the permit for stormwater discharges from boatyard facilities. In addition, no monitoring of toxic contaminants other than copper, zinc and lead are required in the permit for process wastewater discharges from boatyard facilities into domestic sanitary sewer systems.

Drinking Water Treatment Plant General Permit
Drinking water treatment plants produce wastewater from filter backwash systems and contain chlorine, metals, and other contaminants removed from the filtering of surface waters. There are three water treatment plants on the Nooksack River.

I.5.4. Sewage Treatment Plant (STP) Permits

There are 86 sewage treatment plants authorized to discharge potentially toxic pollutants into Puget Sound area waters. Toxic chemicals can enter sewage treatment plant (STP) systems through domestic plumbing, the introduction of hazardous household chemicals, industrial (pretreatment) wastewater, stormwater inflows, and combined sewers. Table 10 identifies likely toxic pollutants in municipal wastewater. [Metcalf & Eddy, 2003; Ecology, 2006c]

About 88 industrial dischargers are permitted to release effluent into STP systems throughout the Puget Sound area (see Appendix B). These discharger operations include landfills, metal finishing, printing, shipyards, petroleum storage, seafood processing, wood treating, and others. Stormwater inflows, and effluents associated with combined sewers, are additional sources of toxic contaminants in STP effluents. Likely toxic chemicals in stormwater component flows are discussed in the next section. Ammonia is present in effluent and is a toxic component directly resulting from human waste and sewage treatment operations. Chlorine may also appear in toxic concentrations as an effluent disinfectant. Both O&G and TSS may be associated with toxic contaminants such as metals, PAHs, PCHs, phthalates and other organics.

I.5.5. Stormwater Related Discharges

Ecology's NPDES permit process authorizes 1593 general stormwater dischargers, as of January 2006, to release potentially toxic pollutants into Puget Sound area waters. These general permits authorize stormwater discharges from 788 industrial, 794 construction, and 11 municipal separate storm sewer system (MS4, Phase I) entities (see Appendix B). MS4 Phase I permittees have urbanized areas with greater than 100,000 people. The existing MS4 Phase I permittees include: Snohomish County with 3 unique permits and the City of Everett in the facility type/location description, the City of Seattle and King County with 4 unique permits with facility names all identified as Cedar/Green; and the City of Tacoma and Pierce County with 4 unique permits. [Ecology, 2006e; WSG, 2003]

Stormwater discharges from projected Phase II jurisdictional locations, i.e., urbanized areas with over 50,000 people and up to 100,000 people, are as yet unregulated through Ecology's NPDES stormwater program. Tentative Phase II facilities for the Puget Sound region are listed in Appendix B. These Phase II facilities are comprised of at least 4 counties (Kitsap, Skagit, Thurston, and Whatcom) as well as approximately 64 city jurisdictions. [WSG, 2003]

Toxic chemicals can enter stormwater in runoff from residential, industrial, commercial, and transportation areas (see Appendix B). These discharger operations include landfills, metal finishing, printing, shipyards, petroleum storage, seafood processing, wood

treating, and others. Both O&G and TSS may be associated with toxic contaminants such as metals, PAHs, PCHs, phthalates and other organics. Major industrial, additional industrial, STPs, and general industrial dischargers all have additional stormwater authorization for release of toxic chemicals. Table 11 identifies likely toxic pollutants authorized under general stormwater permits. [EPA, 1983]

The EPA states that "Today, nonpoint (NPS) pollution remains the Nation's largest source of water quality problems. It is the main reason that approximately 40 percent of the surveyed rivers, lakes and estuaries are not clean enough to meet basic fishing or swimming". [EPA, 2006] According to Ecology, "[s]tormwater is the leading contributor to water quality pollution in our urban waterways. As urban areas grow, it is also the state's fastest growing water quality problem." [Ecology 2004e] Ecology estimates one-third of all the impaired water bodies, identified for cleanup plans under the CWA, are polluted by stormwater runoff. [Ecology 2005g; Ecology 2004e] EPA's *Urban Runoff Pollution Prevention and Control Planning – Handbook* summarizes urban runoff pollutants including toxic pollutants, metals and organics, present in stormwater. [EPA, 1993]

Conditions have worsened since publication of EPA's 1993 Handbook. On it's webpage, Polluted Runoff in Washington State- Sources of Polluted Runoff, Ecology acknowledges that with "most easily-traceable pollution sources controlled through permits and enforcement, nonpoint pollutants account for most of the remaining water pollution in the United States. They are introduced into water through runoff." [Ecology, 2006j] Ecology cites the U.S. Environmental Protection Agency (EPA), which estimates more than 60 percent of water pollution problems come from rainfall run-off sources. [EPA, 2006]

Ecology's *Stormwater Management Manual for Western Washington* (2005d), particularly Volume I -- Minimum Technical Requirements and Site Planning, indicates harmful levels of metals, inorganics, organics and chlorinated organics are being discharged in stormwater into Puget Sound. [Ecology, 2005d] In Section II by Ewing, subsections II.3.3. through II.3.5., show that these toxic contaminants cause harm to chinook salmon. Ecology's SMWW Volume IV, for Source Control BMPs shows that substantial amounts of metals and organics are discharged. Accordingly, significant contamination in Puget Sound waters and sediments results because of Ecology authorized NPDES stormwater permits. These permits do not take into account salmon protection but rather focus on technology-based methods. [Ecology Permits 2006b,d,e; Ecology 2005d]

I.6. Toxic Discharges Summary

This report section finds that toxic contamination of water, sediments and organisms in the Puget Sound region is widespread and at concentration levels likely to be harmful to salmon and other organisms. It finds that Ecology NPDES authorized discharges are clearly major sources of toxic chemicals on an ongoing basis. This is in addition to the historic toxic contamination also apparent in the Puget Sound region. A summary of key findings for this report section is:

- Toxic contamination is widespread in the Puget Sound region based on a review of water quality, sediment and organism tissue data.

- Ecology's own TMDL and 303(d) List assessments for waterbodies show toxic contamination in the Puget Sound is extensive. These assessments are limited by data gaps and much more contamination is possible.

- Toxic contamination in Puget Sound matches the types of chemicals that Ecology NPDES permits authorize for industrial, municipal, and stormwater discharges.

- Ecology's NPDES Whole Effluent Toxicity testing on organisms fails to capture the synergistic effects of effluent toxic chemicals acting together, and does not characterize bioaccumulative effects of toxic contaminants.

- Ecology authorized NPDES discharges are major sources of toxic chemicals on an ongoing basis.

- Ecology routinely overestimates effluent dilution in their NPDES permit evaluations resulting in the release of harmful concentrations of toxic contaminants.

- Ecology's existing NPDES process fails to identify many sources, and the magnitudes, of toxic contaminants they authorize for release.

- Total suspended solids (TSS) and oil and grease (O&G) allowances in effectively all Ecology NPDES permits very probably contain unacknowledged and un-quantified toxic chemicals.

- Toxic contamination has been found in salmon, whitefish, sucker, mussels, sole, rockfish, seals, killer whales and other organisms in the Puget Sound region.

- Toxic chemicals, such as PAHs, PCHs and heavy metals, are persistent bioaccumulating toxins (PBTs) that are authorized for discharge by Ecology.

I.7. References

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II. Effects of Toxic Pollution on Puget Sound Chinook Salmon

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II.1. Introduction

This section pertains to the effect of toxic pollution on chinook salmon present in Puget Sound area waters. Pollution may negatively affect all aspects of the life histories of fish living in or passing through the Puget Sound. These effects may serve to reduce the populations to numbers approaching extinction (Landahl et al., 1997). At present, Puget Sound contains three species of federally listed salmonids, chinook salmon (Oncorhynchus tshawytscha), chum salmon (O. keta) and bull trout (Salvelinus confluentus). Chinook salmon in the Puget Sound area were listed as threatened in 1999. The chinook, or king, salmon is the largest of the Pacific salmon. Adults may exceed 100 pounds in weight. These salmon are adapted for long migrations to their natal streams and on occasion may swim more than a 1000 miles upstream to spawn. Because they require energy for the long migration, adults contain a high percentage of lipids and are one of the most prized fish for fishermen.

The desire of fishermen for the high quality flesh of chinook salmon started their long slide toward extinction. Over-fishing for chinook salmon began in the 1850s when salmon were caught in great numbers, canned, and shipped throughout the world as a cheap and abundant source of protein. As salmon populations began to decline, the advent of hydroelectric power added an additional burden to the fish populations. In an attempt to prevent further declines, hatcheries were established, but these were operated in such a way that they decreased rather than revived the population numbers. Poor management practices, decreased genetic variability, and increased disease all contributed to poor survival of hatchery offspring (Lichatowich and McIntyre, 1987; Lichatowich, 1999). Increasing populations of people put increased pressure on rivers for living space, for hydroelectric power, for flood control, and for the water itself. The result was fish populations with little water for habitat and severely reduced spawning areas.

Salmon have been in decline in the Northwest for over 100 years. In recent years, numbers have reached very low numbers and many populations are in danger of extinction (Nehlson et al. 1991). One of the most powerful tools for protecting these populations is the Endangered Species Act (ESA) enacted in 1973. Once a species is listed as threatened or endangered according to the ESA, it is protected and the federal government must ensure that future actions do not jeopardize the continued existence of the listed species or adversely modify their habitat.

Much of the salmonid decline at present can be attributed to loss of habitat (Nehlson et al. 1991). Loss of habitat can include a variety of factors such as loss of migration routes, loss of areas suitable for spawning, and loss of areas capable of sustaining juvenile

populations. Habitat loss also includes the deterioration of water quality through introduction of pollutants into our coastal waters, estuaries, rivers and streams. It is this latter case that will be addressed here.

II.2. Review of Toxic Effects on Salmon

The present review examines the effects of toxic pollutants on the biology of chinook salmon. A discussion of specific chemicals of concern is presented in the following section for heavy metals, other inorganic toxicants, organic compounds. The availability of studies in the published literature using chinook salmon as animal models is limited. The effects of pollutants on other salmonids can be used to fill in gaps in published literature to illustrate the wide range of problems that may occur with the listed chinook salmon. Other species of fish will be introduced occasionally to illustrate possible effects of pollutants that have not yet been studied in salmonids or effects that are more clearly illustrated in non-salmonid species. In the author's experience and the experience of hatcherymen throughout the Pacific Northwest, chinook salmon are a sensitive species that is difficult to rear. In comparison of pollutant effects between rainbow trout and chinook salmon, the chinook salmon generally respond at lower concentrations (Kime, 1998; Norris et al., 1991).

The similarity in biochemical mechanisms throughout the animal kingdom over a range of species makes it possible to extrapolate from one species to another. Often effects found in mammals will be subsequently found to occur in fish or salmonid species (see Colbourne and Clement (1992) as an example). For example, in the case of phthalates, little work has been done with fishes and the effects in mammals has been reviewed as a guide for possible areas of concern for salmonids. While these extrapolations should be viewed with caution, potential areas of concern should be addressed, especially with listed species.

II.2.1. Sublethal Impacts of Pollutants

Fish kills due to concentrations of pollutants at acute levels usually attract a great deal of attention and numerous agencies respond immediately to determine the cause of the mortality. With listed species, the populations are already low and the loss of every individual makes recovery that much more difficult. However, the rapid response by government agencies means that the problem can usually be quickly identified and a solution can be rapidly formulated. The real danger lies with low level concentrations which do not cause fish kills but still result in losses to the population through increased disease or predation. These sublethal effects can be substantial. Murty (1986) suggested that "In the long run, these sublethal concentrations may prove more deleterious than the lethal concentrations, because subtle and small effects on the fish may alter their behavior, feeding habits, position in the school, reproductive success, etc."

This review focuses on the effects of sublethal concentrations of common pollutants in the Puget Sound area on chinook salmon populations. These changes in physiology, behavior, reproduction, and health can have significant effects on the population structure and number of chinook salmon in the Puget Sound. The danger of these changes is that

they are not detectable by current techniques in fisheries biology. The result is a decline in population numbers from causes that cannot be clearly identified.

II.2.2. Pathways for Toxic Pollutants to Impact Salmonids

Chinook and other salmon use the Puget Sound as a waterway to and from the rivers and streams used for spawning. Chinook salmon adults feed extensively on the herrings and small fish that inhabit the Puget Sound, its bays and estuaries (Healey, 1991). In turn, sealions and killer whales feed on the congregated salmon. As the salmon are urged on by hormones, they leave the Puget Sound estuaries and travel up the rivers and streams to the spawning areas where they were born.

Juvenile chinook salmon remain in their natal stream for six months to several years, then begin the journey to the sea to grow and attain adulthood. On their way, they linger in estuaries for long periods of time, longer than any of the other salmonids (Thom, 1987), and frequent the shallow water area along the shoreline. Here they feed and adapt to seawater conditions. Young salmon may reside in the estuary for over a year before finally swimming for the open ocean.

Unfortunately, much of the pollution in Puget Sound has been introduced into the waters and sediment of the nearshore zone, including vital estuarine areas (see Section I by LaLiberte, subsections I.4.3. through I.4.11 and Table 12, for pollutants and locations). In the passage of both adult and juvenile salmon through Puget Sound, they experience direct exposure to pollutants in the water column or indirect exposure by consumption of food organisms, which have accumulated the pollutants (McCain et al., 1990). Lipophilic compounds from the food sources, such as polycyclic aromatic hydrocarbons and polychlorinated hydrocarbons, tend to bioaccumulate in the lipid-rich tissues of the salmon. These concentrated pollutants can have consequences on all aspects of the biology of the salmon and may affect the survival of the populations (Landahl et al., 1997; Arkoosh et al., 1998).

II.2.3. Bioaccumulation and Biomagnification

Bioaccumulation and biomagnification are complicated issues that will be discussed here only in a cursory way related to the possible accumulations of pollutants during the life history of the chinook salmon. Neff (2002) has an excellent discussion of the complexities of the accumulation and magnification of organics and metals.

As discussed in this subsection, it is apparent that any concentration level of persistent bioaccumlating toxins (PBTs) are very probably harmful to chinook salmon and other organisms. The PBTs discussed here include heavy metals, PAHs, phthalates and PCHs discharged from Ecology authorized NPDES permits as shown in Section I.6 under *Toxic Discharges and Bioaccumlation*.

Bioaccumulation refers to the uptake and accumulation of chemicals from all available external sources. It is the net result of uptake, distribution and excretion of a chemical present in the water, in sediments and in food. Bioconcentration is a special case of bioaccumulation where only the uptake from water is considered. The bioconcentration

factor (BCF) is the unitless ration of the concentration of a chemical in the organism divided by the concentration of a chemical in the surrounding water. BCF is often estimated by the partition coefficient (Kow) of a chemical between octanol and water. Octanol simulates the properties of the lipid interior of membranes and Kow is a function of the lipid solubility of the chemical.

BCFs are often used to show huge accumulations of PAHs and PCHs in organisms. These are usually derived from an empirical relationship between Kow of a particular chemical and its BCF that has been obtained from studies specifically studying the BCF in organisms. In most cases, the concentrations of PAHs and PCHs inside the organism are highly overestimated. For example, in the bluegill, benzo(a)pyrene has a calculated BCF of 63,100, while its measured BCF is 490 (Spacie et al., 1983). Similarly, di-2-ethylhexyl phthalate in sheepshead minnows has a calculated BCF of 24,547,000, while its measured BCF is 630 (Karara and Hayton, 1984).

Not only do calculated BCFs overestimate the concentrations of organic chemicals internally, they are also unrealistic in that they do not consider contributions of pollutants from sediments and from the food. Bioaccumulation factors (BAFs) more accurately portray the entire process of accumulation and excretion but they are more difficult to compare. Units of BAFs are in ug pollutant/mg dry weight of the organism. Comparisons require measurements from comparable fish in unpolluted areas.

Regardless of definitions, the lipid solubilities of PAHs and PCHs ensure that the fish concentrate these chemicals in their tissues at least hundreds of times greater concentrations than the concentration in the surrounding water. The concentrations in their tissues may or may not be higher than concentrations found in nearby sediments or in their food organisms, depending on individual methods of transformation and excretion of the chemicals. The high concentrations in tissues may be quite stable and may persist for years, especially in the case of the PCHs.

Metals show some bioaccumulation because they tend to bind sulfhydryl groups and phosphates within the tissues of organisms. In many cases, the levels rapidly decrease when the source of contamination is removed. Only when the metal is tranformed into an organic form, such as the formation of methylmercury, will it show appreciable bioaccumulation and a long residency in the tissues.

Biomagnification is another characteristic of persistent pollutants. This is defined as the increase in concentration of pollutants as they move to higher and higher trophic levels. Biomagnification has been demonstrated convincingly only for a few chemicals, such as methylmercury (Bargagli et al., 1998), PCBs (Oliver and Niimi, 1988; Evans et al., 1991), and some dioxins and furans (Opperhuizen and Sijm, 1990; Sijm et al., 1993). PAHs are readily metabolized and excreted by marine fish and invertebrates and do not biomagnify in food webs (Broman et al., 1990). When there is trophic step from aquatic prey to terrestrial predators, however, there is likely to be biomagnification. The air-breathers cannot release the hydrophobic chemicals by passive diffusion (Muir et al., 1998).

Chinook salmon are considered predators near the top of their food web (Healey, 1991). Adults feed on herring, anchovies, and small fishes. These prey organisms have already assimilated methylmercury and PCHs into their tissues from silt and organisms that they have fed on lower in the food web. The pollutants pass through the gut with the nutrients and become sequestered in fatty tissue in the case of PCHs or muscle in the case of methylmercury. Unfortunately, one of the extremely fatty tissues in returning adult chinook salmon are the ovaries and developing eggs. Concentrations often become high enough that they may pollute their relatively pristine spawning areas (Krummel et al., 2003).

II.2.4. Relationship of Tissue Concentrations to Specific Toxic Effects

Classical toxicology relates the concentrations of water soluble toxicants to specific effects in the species of interest. Even with this simplified system, the experimental complexity is considerable. Water soluble toxicants interact with the components of the water itself to form compounds or complexes that may alter their toxicity. The water quality also alters the physiology of the fish subjected to analysis, causing changes in the entry of the toxicant into the fish. Because the toxicant is water soluble, entry of the toxicant into the fish comes into equilibrium with the excretion from the fish. Little or no bioaccumulation of the toxicant occurs. The toxic properties of the toxicant, as measured by the specific effect, then become a function of the water concentration of the toxicant.

When the toxicant is relatively insoluble in water, i. e., soluble in lipids, bioaccumulation within the fish occurs and the difficulty of determining causal relationships between the tissue levels of the fish and the effect of interest becomes much more difficult.

The following problems need to be addressed to assess toxicants having little or no affinity for water (i.e., hydrophobic toxicants):

1) Delivery of the toxicant to the fish. Hydrophobic toxicants are poorly soluble in water and must be delivered to the fish either through very low water concentrations, through sediments, or indirectly through the food supply (Spacie and Hamelink, 1985).

2) Bioaccumulation occurs in different tissues at different rates. For a particular assay, it is difficult to determine which tissue is influencing the results.

3) Non-equilibrium conditions are present for long periods of time. It is difficult to determine the concentration of toxicant that is producing the results obtained.

4) Individual fish may receive different “dosages” either from different feeding habits, different resting areas in the tank, or differences in physiology. A correlative approach using individual fish is required for analysis.

5) Fish have the ability to biotransform PAHs and PCHs so that measured quantities may not reflect the concentrations that initiated the results obtained.

In spite of these difficulties for laboratory experiments, tissue concentrations have been used in the field to look at relationships to simple physiological functions. Johnson et al. (1998) sampled rock sole at various locations in Puget Sound and measured both PAH and PCB concentrations and measurements of fecundity. They then correlated pollutant concentrations in the fish with gonadosomatic index (ratio of gonad weight to body

weight), plasma estradiol concentrations, number of eggs, and weight of eggs. Egg weight was negatively correlated with PCB concentrations in the liver, but no other correlations were significant. Gravid females from contaminated sites were taken into the lab to be fertilized by reference males. Results showed lower spawning success for the sole from sites that were heavily contaminated with PAHs and PCBs. They concluded that sole with greater concentrations of pollutants showed reduced reproductive success.

A similar study was performed with English sole (Casillas et al., 1991) that found significant inverse correlations between the indices of fertility above and concentrations of PAHs and PCBs. Differences between rock and English soles in their uptake of pollutants and correlations with fertility indices was suggested to be due to differences in sediment preferences. Rock sole preferred coarse-grained or sandy sediments, whereas English sole preferred fine sediments.

These studies point out the difficulties of relating tissue concentrations of pollutants to physiological effects. Nevertheless, studies of hydrophobic contaminants such as PCBs and PAHs will have to rely on tissue concentrations for developing relationships with deleterious changes to fish populations. Concentrations in sediments or in the water are not necessarily related to the amounts of pollutants to which the fish tissues are exposed.

II.3. Problem Levels of Toxicants

This section examines the effects of selected pollutants on the biology of chinook salmon.

II.3.1. Toxic Chemical Parameters

Washington Department of Ecology bases waterbody status assessment on comparison with criteria for toxicants found in water (Ecology, 2006f) and sediments (Ecology, 2006g). LaLiberte presents a discussion of the results of Ecology's assessment in Section I.1. Where available for toxic contaminants, these numeric criteria are derived for concentrations that cause acute (rapid death) and chronic (sublethal) toxicity effects on organisms. In addition, Ecology uses ambient water quality concentrations based on the National Toxics Rule (NTR, 40 CFR 131.36) in assessing Puget Sound area waterbody status. The NTR identifies concentrations of waters impaired for organism consumption by humans (see 40 CFR 131.36). While the organism consumption concentrations for toxic chemicals in the NTR refer to human health, the chemical specific discussion below demonstrates that chinook salmon are more adversely affected than humans when exposed to the concentrations listed in the NTR. Accordingly, if a waterbody is impaired for organism consumption, then the implication is that chinook salmon are being adversely affected. In addition, because salmonids are harmed by many toxic concentrations lower than the NTR values, still more waterbodies should be 303(d) listed as impaired because of direct harm to chinook salmon and other sensitive organisms.

II.3.2. Locations of Concern

Locations of concern are those areas found to have a high degree of contamination from the pollutants described above.

Table 12 of Section I by LaLiberte, and subsections I.4.3 through I.4.11, summarize toxic contamination and related locations throughout the Puget Sound region. Major waterbodies in the Puget Sound region experiencing impairment because of toxic contamination include Bellingham Bay, Fidalgo Bay, Skagit River, Snohomish River, Everett Harbor/Port Gardner, main basin of Puget Sound, Lake Union/Lake Washington Ship Canal, Duwamish River, Elliott Bay, East Passage, Dalco Passage, Poverty Bay, Puyallup River, Inner and Outer Commencement Bay, Squaxin Passages, Peale Passage, Pickering Passage, Carr Inlet, Eagle Harbor, Hale Passage, Case Inlet, Dana Passage, and additional locations. In these waterbodies, bioaccumulation of toxic contaminants occurs at levels harmful to animals including, among other organisms, mountain whitefish, bridgelip sucker, mussels, English sole, rockfish, chinook salmon and other salmonids, seals, and killer whales.

II.3.3. Heavy Metals

Ions of heavy metals are found as common components of industrial wastewater discharges and are well known for their deleterious effects on aquatic organisms. Toxicity of the different metals varies in similar fashion with water conditions because of the similar properties of the metal ions. The metals described here, copper, chromium, cadmium, lead, and mercury, and zinc, all share low solubilities in their hydroxide form. Therefore, toxicity of the metals is inversely related to the pH of the water. In acid conditions with low pH, toxicity is high, while in alkaline water with high pH, the metals precipitate as hydroxides and the toxicity is diminished. Similarly, the hardness of the water, a function of its carbonate content, and the presence of phosphates leads to precipitates of carbonate and phosphate salts and results in diminished toxicity. Turbidity resulting from the presence of clays and humic acids decreases the toxicity of the metals because the metals are bound by the ion exchange properties of the suspended material (Sprague, 1985).

Metals have a number of similar toxic effects on fish because of their similar properties. Most metals tend to accumulate in the gill tissue, where the metals form precipitates with the mucus. This leads to decreased ventilation, coughing responses, decreased oxygen and carbon dioxide exchange, and a depletion of energy reserves. The depletion of energy reserves causes decreased swimming ability and a slower response to predators. Internally, heavy metals bind to phosphates and sulfides, causing major disruption of physiological functions (Leland and Kuwabara, 1985; Kime, 1998)

Metals tend to accumulate within the body of the fish by binding to phosphate and sulfide groups of various proteins. When the sulfhydryl groups of enzymes are bound, the enzyme activity is inhibited and results in a general decline in fish health. At high enough concentrations, osmoregulatory and hormonal systems cease to function.

As a protective mechanism against the actions of heavy metals, fish respond by producing a sulfhydryl rich protein called metallothionein. Metals bind to the sulfhydryl groups and are eventually excreted with the protein (Leland and Kuwabara, 1985; Kime, 1998).

Most metals interfere with olfaction in salmonids (Klaprat et al. 1992). Salmon use olfaction as the major sensory input describing the environment around them. Olfaction has been shown to play important roles in predator avoidance (Scholz et al., 2000; Brown and Smith, 1997; Hiroven et al., 2000), recognition of kin (Quinn and Busack, 1985; Olsen, 1992), homing of adults to natal streams (Wisby and Hasler, 1954; Hasler and Scholz, 1983; Stabell, 1992), and spawning rituals of adults (Sorensen, 1992; Olsen and Liley, 1993; Moore and Waring, 1996). Interference in chemoreception by metals will be discussed more fully for the individual metals.

Endocrine disruption is often reported as a response to metal exposure (Kime 1998). Endocrine disruption can occur at several levels and the presence of heavy metals and their ability to disrupt enzyme function can interrupt any of these. Endocrine function is initiated in the brain in response to external stimuli. Neural responses activate the pituitary which either produces the active hormone or a stimulatory factory which travels through the blood to activate the active hormone. The active hormone then circulates through the blood stream to its site of action where it binds to membrane receptors to set up a signal pathway that leads to activation of specific genes within the genome.

Most work with endocrine disruption in fish by heavy metals has been done with fish other than salmonids. While there is no reason to believe that the endocrine systems of these fish are different from salmonids in a major way, these studies have not been included here and will be discussed only briefly in the sections on the specific metals.

Heavy metals interfere with the workings of the immune system in salmonids (Anderson et al. 1996) but the mechanism of interference is not clear (Kime, 1998). The metals may affect the immune system directly or the response could result from a stress reaction which elevates cortisol which subsequently results in immunosuppression (Schreck, 1996). Suppression of the immune system increases infection of salmonids to bacteria, fungi, viruses, and parasites. Such infections decrease the vitality of the fish and increase the chances of mortalities due to osmotic imbalance, inability to feed, or predation.

Copper

The effects of copper on salmonids have been examined by numerous authors because of the abundance of many instances of high copper concentrations in the rivers and streams. Reviews by Sorensen (1991), Alabaster and Lloyd (1982), and numerous other authors have been published in books on toxicology. Although organisms for a variety of enzymatic and physiological functions require copper, excess amounts of copper become toxic. The sources of copper in Puget Sound are discussed in Section I.4.7.

Effects of copper are difficult to clarify in the natural environment because of the wide variety of reactions that it undergoes with common stream components. Copper forms insoluble precipitates at low concentrations in the presence of a number of anions. Therefore, toxicity depends strongly on pH and hardness of the water used for experiments (Alabaster and Lloyd, 1982; Sorensen 1991). Toxicity also depends upon temperature and dissolved oxygen in the water (Alabaster and Lloyd, 1982; Lloyd, 1961). Organic compounds such as humic acids and suspended solids can lower the toxicity of

copper. These compounds are thought to act as ion-exchangers and preferentially bind aqueous copper (Brown et al., 1974).

Copper ions cause precipitates to form in the mucus of the gill and cause respiratory distress, indicated by coughing, spastic head movements, and lethargy. A number of papers have indicated that copper affects the ion regulatory systems in salmonids (Sorensen 1991; Heath, 1995). Reid and McDonald (1988) found that plasma levels of Na+ are reduced in rainbow trout after exposure to copper. Copper was found to inhibit the activity of the osmoregulatory enzyme, (Na+K)-ATPase (Lauren and McDonald 1987). Lorz and McPherson (1976) found that exposures of coho salmon to copper concentrations from 10 to 80 ug Cu/L caused decreased (Na+K)-ATPase activity and survival in seawater.

Exposure of coho salmon to copper inhibits the seaward migration of the smolts (Lorz and McPherson, 1976). The lowest dose measured (5 ug Cu/L) inhibited migration even though it had no effect on (Na+K)-ATPase activity or seawater tolerance. Inhibition of migration for migrant salmonids such as coho and chinook salmon subjects the juveniles to increased densities, limited food supplies, and probably increased mortality.

Recent papers have explored the effects of copper on the olfactory system of salmonids (Baldwin et al. 2003; Hansen et al., 1999a, 1999b). Baldwin et al. (2003) used electrical potential readings from the olfactory epithelium as a measure of the olfactory responsiveness of natural odorants in chinook salmon exposed to copper. Copper inhibited the responsiveness of the epithelium to odorants within 10 minutes of exposure. Inhibitory responses occurred in a dose-dependent manner in a range of copper concentrations from 1.0 to 20.0 ug/L. Inhibition was not dependent on hardness of the water. The authors concluded that short term exposures to very low levels of copper may interfere with olfactory-mediated behaviors that promoted survival and spawning migrations.

Hansen et al. (1999) examined the avoidance of chinook salmon and rainbow trout to water polluted with copper or cobalt. Chinook salmon were found to be the most sensitive, avoiding water containing as low as 0.7 ug Cu/L. Rainbow trout avoided water containing as low as 1.6 ug Cu/L. When fish were acclimated to water containing 2 ug Cu/L, rainbow trout avoided water with concentrations of 4 ug Cu/L and preferred clean water, but chinook salmon did not avoid any concentration of copper and did not have a preference for clean water. The authors concluded that the chinook salmon exposed to low levels of copper had their olfactory senses impaired to the point where they could not avoid water of lethal concentrations. This impairment also probably had deleterious effects on predator avoidance, homing, and spawning activities.

Hansen et al. (1999) followed their avoidance studies with confocal laser-scanning microscopic observations of olfactory epithelia in chinook salmon and rainbow trout. They found that the number of olfactory receptors was severely reduced in chinook salmon exposed to 50 ug Cu/L or greater for 1 hour, while olfactory receptors in rainbow trout were reduced after exposure to 200 ug Cu/L or greater for 1 hour. If exposure time

was increased to 4 hours, receptors in both species were reduced by concentrations of 25 ug Cu/L. Olfactory bulb electroencephalogram responses to an odorant were virtually eliminated in chinook salmon exposed to more than 50 ug Cu/L for 1 hour, or rainbow trout exposed to more than 200 ug Cu/L for 1 hour. The results show the increased sensitivity of chinook salmon over rainbow trout and suggest that short exposures to sublethal concentrations of copper can cause major damage to the olfactory system.

Copper causes immunosuppression in most species of fish and this can be particularly damaging in salmonids. Baker et al. (1983) showed that exposure of chinook salmon and rainbow trout to sublethal concentrations of copper caused an increased susceptibility to infection by Vibrio anguillarum. Similarly, Hetrick et al. (1979) showed that exposure to copper increased susceptibility of rainbow trout to infectious hematopoietic necrosis virus and Knittel (1981) found that steelhead exposed to copper were more susceptible to Yersinia ruckeri. Anderson et al (1989) showed that exposure of isolated rainbow trout spleen cells in vitro to copper caused inhibition of the antibody-producing cells.

Cadmium

Cadmium is widely used in industry and is produced from lead-mine workings and from smelting and electroplating industries (Kime, 1998). Sources of cadmium for the Puget Sound waters are discussed in Section I.4.7. Toxicity of the metal to aquatic organisms depends upon a number of water quality factors, including temperature, dissolved oxygen, pH, hardness, salinity, and suspended solids (Alabaster and Lloyd, 1982).

Cadmium has no biological function in organisms. As a non-degradable, cumulative pollutant, cadmium can disrupt the multiple trophic levels of aquatic organisms and the effects can persist for centuries (Sorensen, 1991). Salmonids were found to be among the most sensitive aquatic organisms to the presence of cadmium. Some other invertebrates were equally sensitive but most of the organisms tested were much more resistant to the effects of cadmium (Alabaster and Lloyd, 1982)

Originally, it was thought that the lethal effects of cadmium were due to respiratory impairment. In early studies, Carpenter (1927) suggested that the orange-brown precipitate of mucus and cadmium at the gill surface caused death by oxygen deficiency. Bilinski and Jonas (1973) reported extensive degeneration of gill structures in rainbow trout exposed to 1120 ug Cd per liter for 24 hours. They observed detachment of the epithelial layer, hypertrophy and hyperplasia of the interlamellar epithelium, and a decrease in lactate oxidation in gill filaments of surviving fish

Behavior of the fish at sublethal concentrations suggested that neuronal damage might also be occurring. Cearley and Coleman (1974) described erratic, uncoordinated swimming movements, muscular spasms and convulsions, loss of equilibrium, and periods of paralysis and lethargy. Similar convulsive swimming movements were reported by Eaton (1974) and Pascoe and Mattey (1977). These convulsive movements were suggested to have survival value in removing mucus containing high levels of cadmium. Varanasi and Markey (1978) showed that in coho salmon, high levels of

mucus were sloughed off during exposure to cadmium, which accelerated the removal of cadmium from the body.

Cadmium exposure causes only mild changes in osmoregulation (Heath 1995) but regulation of divalent cations is quite sensitive to the presence of cadmium. Plasma calcium dropped 50% during a week-long exposure of rainbow trout to 300 ug/L cadmium (Roch and Maly, 1979). Decreases in calcium in the blood is apparently due to inhibition of calcium influx alone (Reid and MacDonald, 1988; Baldisserotto et al., 2004). Sauer and Watabe (1988) suggest that the cadmium displaces calcium from protein carriers in the gill epithelium. Changes in calcium efflux in the gill and kidney are not affected greatly by cadmium exposure (Gill et al., 1989). Alterations in plasma calcium concentrations may explain the spasms and hyperexcitability seen in some fish that have been exposed to cadmium (Larsson et al., 1981).

Olfactory function is compromised by exposure to cadmium (Klaprat et al. 1992). Forty day exposures of pike juveniles to 0.03 uM (3.4 ug/L) cadmium caused deterioration of the olfactory nerve (Dedual, 1987). Wild brown trout suffered complete loss of their olfactory sensory cells after two days exposure to high levels of cadmium (Moran et al. 1987). Water containing cadmium at 1.7 uM (190 ug/L) was not avoided by the golden shiner, suggesting that the olfactory capacity was impaired.

Effects of cadmium on embryonic development occur at levels where growth and mortality of adults are not affected. Eaton et al. (1978) found toxic effects of cadmium exposure on embryos of lake trout, brown trout, and brook trout at concentrations between 4.4 and 12.3 ug/L cadmium, 3.8 and 11.7 ug/L cadmium, and 1.1 and 3.8 ug/L cadmium, respectively. Brown et al. (1994) found exposure of rainbow trout to cadmium concentrations up to 5.5 ug/L had no effect on adult mortality or growth. However, eggs exposed to 1.8 and 3.4 ug/L cadmium did not develop to the fry stage. Oogenesis was delayed in brown trout by concentrations of 9.3 and 29.1 ug/L cadmium.

Exposure to cadmium is known to suppress the immune system of salmonids in some cases and to stimulate immune responses in others. O'Neill (1981) found that brown trout exposed to cadmium had reduced circulatory antibody responses compared to controls. Thuvander (1989) showed that low doses of cadmium (0.7 and 3.6 ug/L) in the water reduced the mitogenic responses in fish immunized to Vibrio anguillarum. On the other hand, MacFarlane et al. (1986) found that exposure of striped bass to cadmium provided a higher degree of protection from Flexibacter columnaris than controls without cadmium exposure.

Chromium

Chromium is the seventh most abundant element in the crust of the earth (Katz and Salem, 1994). Chromium makes its way into the aqueous environment from both natural and anthropogenic sources. Sources for chromium in Puget Sound waters are given in Section I.4.7. Chromium is both an essential trace metal using in most higher organisms and a toxic contaminant at higher concentrations. Its use in organisms centers around the insulin receptors and their binding of insulin for glucose regulation and utilization.

Chromium is found in several valences: divalent, trivalent, tetravalent, pentavalent, and hexavalent forms. Trivalent forms, such as chromic chloride, and hexavalent forms, such as potassium chromate or potassium dichromate, are the most common forms. Of the two, the hexavalent form is the most toxic. This may relate to its anionic nature, which allows it to pass easily through membranes, such as that of the gill (Katz and Salem, 1994).

Exposure of chinook salmon and rainbow trout to 20 ug/L chromium in a long rearing period inhibited growth (Olson and Foster, 1956). Growth of both rainbow trout and brook trout over an 8-month period was diminished at all concentrations of chromium used (100-1500 ug/L) (Benoit, 1976). When the test was continued to 22 months, however, brook trout growth was similar at all concentrations over 340 ug/L.

Osmoregulatory functions seem to be inhibited by the presence of chromium. Survival of coho salmon transferred from freshwater to 20% saline was reduced after exposure to 230 ug/L chromium for 4 weeks (Sugatt, 1980). Hexavalent chromium has been shown to inhibit the ion transport enzyme, (Na+K)-ATPase, but not the Mg-ATPase of intestine, gill, liver, and kidney of rainbow trout (Kuhnert et al., 1976). A component of gill mucus decreased significantly after six months exposure to 200 ug/L chromium. This was considered part of a general decrease in gill function, which included mucus excretion, osmoregulation, and respiration (Arillo et al., 1982).

Endocrine disruption in response to chromium exposure has not been studied extensively in salmonids. Billard and Roubaud (1985) found that fertilization of rainbow trout eggs was suppressed after exposure to a number of metals, including chromium. Sperm were much more sensitive to chromium and other metals than ova.

Suppression of the immune system of fishes can occur after exposure to chromium in the water (Kime, 1998). Whether this results from inhibition of mechanisms by the chromium itself or triggering the cortisol response in the fish is not known. Cortisol is well known for its immunosuppression qualities (Schreck, 1996). O'Neil (1981a) found that the serum antibody response was diminished in rainbow trout exposed to chromium and other metals.

Hexavalent chromium has been shown to be carcinogenic in mammals and humans (O'Flaherty, 1995). It is thought that the hexavalent chromium crosses the membrane barriers of the lung and undergoes a subsequent reduction to trivalent chromium with production of reactive intermediates. Trivalent chromium is capable of reacting with DNA and of causing DNA-protein crosslinking. It is not known whether similar mechanisms occur in fish.

Although fish seem relatively insensitive to chromium in the water, invertebrates and phytoplankton seem extremely sensitive (Committee, 1974). LC50 for the water flea Daphnia was determined to be 32 ug/L, while 50% growth reduction of two diatoms in hard and soft water was 200 and 400 ug/L. These results suggest that even though fish

may survive low concentrations of chromium in their waters, their food base may be reduced.

Chromium does not seem to bioconcentrate to any significant degree (Neff, 2002).

Lead

The presence of lead in waters of Puget Sound and its sources are presented in Section I.4.7 and Section I.5. The effects of lead on salmonids has been reviewed by several authors (Aronson, 1971; Sorensen, 1991). Lead poisoning in fish results in neuronal, muscular, and hematological changes similar to those found in mammals. These lead to muscle spasm, paralysis, hyperactivity, and loss of equilibrium (Davies, 1976). In wild fish, these symptoms would render the fish susceptible to predators. In rainbow trout, both dorsal and lateral flexure of the tail region occurs in response to lead, causing a condition called lordoscoliosis (Davies, 1976). This could be due a result of accumulation of lead in the brain (Sorensen 1991).

Inhibition of d-amino levulinic acid dehydratase seems to be a characteristic of salmonids exposed to lead in the environment (Hodson, 1976; Hodson et al. 1977). Exposure to copper, cadmium, mercury or zinc did not cause inhibition of the enzyme (Jackim 1973). Johansson-Sjobeck and Larsson (1979) showed that the enzyme was strongly depressed in erythrocytes, spleen, and renal tissues of rainbow trout exposed to sublethal concentrations of lead for 30 days. This inhibition was present even after a recovery period of seven weeks in lead-free water. d-Amino levulinic acid dehydratase is a key enzyme in the synthesis of porphyrin rings (Dresel and Falk, 1956). Its inhibition by lead prevents formation of heme for hemoglobin synthesis and results in the anemia seen in salmonids exposed to lead. Porphyrin rings are also used in the synthesis of cytochromes so one would expect lead poisoning to result in reduced energy and decreased swimming ability. Cytochrome P450 synthesis, which also requires porphyrin rings, would be inhibited so the fish would be expected to be more sensitive to the effects of polychlorinated hydrocarbons and PAHs (see below).

Exposure to lead can lead to skeletal deformities in salmonids. Holcombe et al. (1976) reared three generations of brook trout exposed to concentrations of lead ranging from 0.9 to 474 ug/L. Second generation alevins showed spinal abnormalities (scoliosis) in 58%, 21%, 5%, 9%, 6% and 1% of fish whose parents were exposed to 474, 235, 119, 58, 34, and 0.9 ug lead/L, respectively. Growth of these fish was inhibited. Scoliosis developed later in 33% of the alevins exposed to 474 ug/L. All members of this group died after 46 weeks of exposure. Third generation alevins showed spinal abnormalities in 21%, 2%, and 2% of fish whose parents were exposed to 119, 58, and 34 ug lead/L, respectively. Again, growth was inhibited. Hyperactivity, erratic swimming, muscular spasms, and loss of equilibrium were noted at the higher concentrations. Their inference was that lead was affecting both nervous and muscular tissues.

Immune systems of fish are susceptible to suppression by lead exposure (Dunier, 1994). Brown trout injected intraperitoneally with lead nitrate showed a decrease in antibody titer against the MS2 bacteriophage (O'Neill, 1981b).

Lead does not bioaccumulate in fish to a significant extent. This is probably due to its ionic nature and its inability to induce the synthesis of metallothioneins, the sulfur-rich proteins which act as protective heavy metal sinks (Leland and Kuwabara, 1985).

Mercury

Mercury in the aquatic environment is derived from natural and anthropogenic sources. Sources for mercury in the waters of Puget Sound are discussed in Section I.4.7 and Section I.5. Tables 7 through 12 demonstrate that anthropogenic sources of mercury include oil refining, pulp and paper mills, other industrial dischargers, municipal STP, and urban stormwater runoff from industrial, construction and municipal facilities. The insolubility of mercury compounds results in the deposition of precipitates in the sediments. Here, they are transformed by bacteria into methylmercury. Methymercury is able to pass through the membrane tissues readily, whereas mercuric ions precipitate the sulfhydryl groups of mucus and are trapped at the outside of the organism (Leland and Kuwabara, 1985; Sorenson, 1991).

The concentrations of methylmercury in tissues pass up through the trophic levels, becoming more concentrated at each level. At the level of top predators, such as swordfish, shark, and tuna, mercury concentrations have become concentrated enough to provide a health risk. In the Northwest, salmon are one of the top predators. However, mercury contamination is highest near the sources of pollution and adult salmon encounter these area only briefly on their spawning migrations. Consequently they have lower levels of mercury than other fishes in the area (Bothner and Piper, 1973; Henderson and Shanks, 1973) and are not considered a health risk to humans.

Mercury has a high affinity for sulfhydryl groups and many of its toxic effects are concerned with this reaction. Mercury has been shown to stimulate the production of mucus at the gill surface (Olson and Fromm, 1973; Varanasi et al., 1975; Lock et al., 1981) and bind tightly to it. This binding inhibits respiration and ion exchange properties of the gill (Part and Lock, 1983; Klinck et al., 2005). Much of the mercury content of the fish resulting from exposure can be sloughed off with the mucus during the first day (Varanasi et al., 1975).

Once inside the fish, mercury binds tenaciously to sulfhydryl groups, destroying the permeability characteristics of the membranes (Lock et al., 1981). The ion-transport enzyme, (Na+K)-ATPase, that is used for osmoregulation, nerve function, and kidney excretion is inhibited by mercury (Bouquegneau, 1977), although studies on the effects of mercury on osmoregulation have shown only minor effects (Heath, 1995). A number of changes to gill, liver, kidney, pancreas, and erythrocytes have been reported (Sorenesen, 1991).

Neurological damage is probably a result of exposure to mercury, based on the behavioral changes that occur. Rainbow trout fingerlings showed loss of equilibrium, a dark coloration, erratic swimming, and inactivity prior to death (MacLeod and Pessah, 1973)

Exposure of rainbow trout to low levels of mercury (100 ug/L) supressed the olfactory responses after a period of two hours (Hara et al. 1976). Supression increased with increased concentrations and times.

Mercury is extremely embryotoxic and teratogenic to salmonids and other fishes (Sorensen, 1991). A three-generation study of brook trout exposed to mercury (McKim et al., 1976) showed numerous reproductive abnormalities. Yearling trout exposed to 2.93 ug/L mercury for 39 weeks produced trunk deformities , muscle spasms, and 88% mortality in their offspring.

Mercury causes irreversible damage to sperm of fish at very low concentrations (Wester, 1991; Kime, 1998). Whether the damage is done by morphological changes, changes in sperm motility or damage to DNA is not known. Fertilization of steelhead has been shown to be decreased by exposure to mercury (McIntyre, 1973).

In females, exposure to mercury causes interruptions in the normal development of ova and in the hormones necessary for successful completion of ovulation (Kime, 1998). Little work seems to have been done with salmonid species, however. In the killifish, Fundulus heteroclitus, mercury decreased egg fertilization by blocking the micropyle and preventing entry of sperm (Khan and Weis, 1993). Electron microscopy showed that this occurred by swelling the walls of the micropyle.

Exposure to mercury causes immunosuppression (Anderson, 1996), leading to increased disease incident and mortality. Voccia et al. (1994) studied the in vitro impairment of immune cells from rainbow trout from exposure to methylmercury and mercuric chloride. Methylmercury appears to be ten times as potent as mercuric chloride. Exposure of the blue gourami to 9 ug/L methylmercury for 4 to 5 weeks caused a decreased immune response to viral and bacterial antigens (Roales and Perlmutter, 1977)

Four mercuric fungicides, phenylmercuric acetate, methyl mercury dicyandiamide, diphenylmercury, and N-methylmercuric-1,2,3,6-tetrahydro-3,6-methano-3,4,5,6,7,7-hexachlorophthalimide (MEMMI), were incubated with the marine diatom, Nitzschia delicatissima (Harriss et al., 1970). At concentrations of 0.1 ppb, MEMMI and methylmercury dicyandiamide caused significant inhibition of photosynthesis. At a concentration of 1 ppb, all four inhibited growth and photosynthesis in freshwater plankton. Diphenylmercury showed the least inhibition of photosynthesis. The authors concluded that at least some of the phytoplankton in marine and freshwater environments are very sensitive to mercuric compounds and that these may cause a profound effect on higher trophic levels.

Mercury can be bioaccumulated both directly from the water or from diet (Leland and Kuwabara, 1985). Rainbow trout are about seven times more efficient at extracting mercury from diet than from the water. Concentration of mercury in the tissues is dependent upon experimental conditions but Wobeser (1975) suggests bioconcentration factors of 36 and 480 for mercury and methylmercury, respectively. Methylmercury

concentration apparently does not depend on its greater lipophilic character, because it tends to concentrate in muscle rather than more lipid filled organs (Neff, 2002).

Zinc

Zinc is a required metal for metabolic reactions and is second in quantity only to iron in the vertebrate body. Zinc is used as a cofactor for a number of enzymes, including carbonic anhydrase, superoxide dismutase, and lactate dehydrogenase (Sorensen, 1991). However, at high concentrations, zinc can be toxic to fish and cause mortality, growth inhibition, respiratory and cardiac damage, and inhibition of spawning,

As is the case with other metal ions, zinc toxicity in fish is dependent upon water quality. Toxicity increases with increased temperature, increased pH, decreased hardness, and decreased dissolved oxygen. In salmonids, the sensitivity to zinc concentrations also depends on the developmental stage. Chapman (1978) exposed four life stages of chinook salmon and steelhead to zinc in continuous-flow toxicity tests. He found that alevins of both species were more tolerant of zinc than other stages. Parr of chinook salmon were more sensitive to zinc than steelhead, while swim-up and smolt stages were equal for chinook salmon and steelhead. Farmer et al. (1979) found that smolt stages of Atlantic salmon were more sensitive to zinc poisoning than parr stages.

Sprague (1968) demonstrated that rainbow trout will avoid water containing zinc at the low concentration of 5.6 ug/L. Saunders and Sprague (1967) reported that adult Atlantic salmon on their spawning migration avoided areas contaminated with copper and zinc at sublethal concentrations. From both field and laboratory work, they concluded that concentrations above 38 ug/L copper and 480 ug/L zinc would essentially block migration.

High levels of zinc in the water (3.7-6.8 mg/L) caused an increased feeding time in zebrafish (Cairns and Loos, 1967). Whether this was due to inhibition of olfactory receptors by the zinc is not known.

Exposure of coho salmon to zinc concentrations up to 6 mg/L for 144 hours had no effect on seawater tolerance or gill (Na+K)-ATPase specific activity (Lorz and McPherson, 1976). Under these conditions, the concentration of zinc at which 50% of the coho salmon were killed within 96 hours (LC50) was 50 times greater than that of copper, indicating that zinc was much less toxic than copper.

Watson and Beamish (1980) exposed rainbow trout to 2 mg/L zinc and found small increases in Mg++ -ATPase, Ca++ -ATPase, Na+ + K+ -ATPase and Na+ -NH4+ -ATPase specific activities. Neither osmolality or electrolyte concentrations in the serum were different from controls. However, Spry and Wood (1985) found increases in sodium flux and decreases in calcium flux across the gills of rainbow trout exposed to zinc. Overall, zinc seems to cause only moderate changes in monovalent ions but may have an effect on divalent ion exchange (Heath, 1995)

Billard and Roubaud (1985) found that the toxicity of zinc was greater for sperm than for ova of rainbow trout. Exposure of the zebrafish to 5 mg/L zinc for 9 days during which ova were maturing caused a delay in spawning (Speranza et al., 1977). It was suggested that zinc might act by delaying the final maturation of oocytes and the release of pheromones by the female. Zinc also inhibited reproduction in the viviparous guppy (Pierson, 1981). Concentrations of 0.61 mg/L zinc caused fewer births and delayed the time until birth of the first brood.

Immunosuppression of the primary humoral response to an intraperitoneal injection of MS2 bacteriophage was found in rainbow trout and carp exposed to zinc, nickel, copper, and chromium (O'Neill, 1981c).

II.3.4. Other Inorganic Toxicants

A number of other inorganic compounds that are commonly released in commercial discharges include ammonia, cyanide, hydrogen sulfide, and chemicals that deplete dissolved oxygen concentrations (see Sections I.4.8 through I.4.11).

Several studies have documented negative changes in behavior that occur at sublethal concentrations of un-ionized ammonia, beginning at 0.05 mg/L (Woltering et al. 1978). Changes in gill permeability occurred at concentrations of un-ionized ammonia as low as 0.09 mg/L (Lloyd and Orr 1969). Because salt and water regulation in estuarine fish occurs at the gill surface, changes in the gill permeability can reduce the ability of fish to survive. These sublethal concentrations of ammonia can cause malformation of trout embryos and histopathological changes (i.e., tissue changes characteristic of disease) in gills, kidneys, and livers of fish (Flis, 1968; Smith and Piper 1972; Thurston et al. 1978; Soderberg, 1985; EPA, 1986; Soderberg 1995). Salmonids that are exposed to these concentrations of ammonia reduce their feeding and thereby reduce their growth and survival (Soderberg 1995). Many of the permits allow the release of ammonia into Puget Sound. Toxic contamination is described in Section I.4.8.

Water quality standards for ammonia concentrations have been designed to protect against sublethal effects. The EPA standards for water quality specify un-ionized ammonia continuous concentrations based on water temperature and pH (EPA, 1986).

Cyanide produced as a toxic waste can cause severe respiratory stress in salmon. Cyanide binds strongly to the heme molecule in hemoglobin and prevents the oxygen carrying function of hemoglobin. Cyanide also binds to cytochrome oxidase, the terminal enzyme in energy formation. Cyanide is released from some of the refineries in Puget Sound (see Section I.4.10).

Hydrogen sulfide is a very toxic gas that is found where organic material has decayed under anaerobic conditions. EPA has identified hydrogen sulfide as a compound whose chronic concentration for both freshwater and marine organisms should not exceed 0.002 mg/L. Salmon hatchery standards specify that there should be no detectable levels of hydrogen sulfide.

Hydrogen sulfide interferes with cytochrome oxidase, and, in this way, its toxic effects are similar to those of cyanide. At very low concentrations, it causes gill damage, respiratory arrest, poor feeding, and susceptibility to disease in fish. Many of the industries in Puget Sound are allowed to discharge hydrogen sulfide (see Section I.4.9).

Organic materials released to the environment undergo oxidative metabolism by bacteria. This oxidative capacity is measured crudely as a process known as biological oxygen demand (BOD). If enough organic material is released into the environment, the oxygen concentrations in the water can decrease to levels that cause respiratory distress, lack of feeding and growth, and death in salmon (Davis, 1975; Kramer, 1987). A number of areas in Puget Sound that have been subjected to oxygen depleting substances are described in Section I. 4. 11.

II.3.5. Organic Compounds

Organic compounds considered here include the polycyclic aromatic hydrocarbons (PAHs), the phthalates, and the polychlorinated hydrocarbons (PCHs) consisting of dioxins (polychlorinated dibenzodioxins and dibenzofurans) and polychlorinated biphenyls (PCBs). Origins of these compounds are considered in Sections I.4.3, I.4.4, I.4.5, I.4.6, and I.5.

A characteristic of PAHs and PCHs is their hydrophobic quality. Solubilities of these compounds in water are quite low and decrease with the number of aromatic rings in the compound. Solubility of a common five-membered ring, benzo(a)pyrene, for example, is only 3.8 ug/L. Concentrations of these organics in water to which fish are exposed is therefore quite low. They tend to bind to organic materials in the sediment, where they remain unchanged for years, perhaps centuries. They remain in equilibrium with concentrations in water. Their danger to aquatic organisms is that they are readily absorbed and concentrated in lipids. Their concentrations are subject to biomagnification as they move through trophic levels. Consequently, top predators such as whales, seals and salmon tend to have high concentrations in their tissues.

An indication of the presence of organic compounds in the environment of fish is the presence of cytochrome P450 1A (CYP1A) within the fish tissues, especially the liver. Organic materials such as PAHs or dioxins bind to an aryl hydrocarbon receptor in the cytoplasm of cells of liver and other tissues. The aryl hydrocarbon (Ah) receptor complex is composed of a tetrachlorodibenzodioxin (TCDD) receptor protein and the heat shock protein Hsp90. Upon binding, the Hsp90 is released and the complex binds the translocation protein, arnt. This new complex is escorted to the cell nucleus, translocates into the nucleus, and binds to xenobiotic response elements on the DNA. This induces the transcription of CYP1A genes. The messenger RNA is then translated, the apoprotein binds to heme molecules, and the completed CYP1A protein is inserted into the membranes of the endoplasmic reticulum. The enzyme then acts by oxidizing the aromatic material to increase the solubility. A second step (using different enzymes) is to conjugate the oxidized material with glutathione or glucuronide to increase the solubility and permit excretion of the foreign material (Goksoyr and Husoy, 1998).

Toxicity for many organic materials is the result of binding to the aryl hydrocarbon receptor within the cells of the fish. This observation is based on the strong correlation between the strength of the binding of the organic material to the Ah-receptor and the degree of toxicity expressed (Theobald and Peterson, 1994). In some cases, it is known that the oxidized aryl hydrocarbon is more toxic than the original compound. In most cases, the mechanisms for toxicity are not known.

One hypothesis for the mechanism of toxicity is that the organic compounds bioaccumulate to fill the lipid bilayer of membranes (Neff, 1985). The organic compounds then inactivate membrane proteins and cause disruption of physiological functions. Because the eggs of most aquatic organisms contain storage lipids for use by the developing embryos, the organics tend to concentrate in the eggs, at the stages which are most sensitive to disruption of the developmental process. The result is interference with DNA activity, teratogenesis, and cancer development.

Another of the membrane-dependent functions which is sensitive to interferences by organic pollutants is hormonal activity. Consequently, this group of compounds is known for its ability to cause endocrine disruption. Pesticides have been extensively studied for their ability to cause endocrine disruption (Colborn and Clement, 1992; Rolland et al., 1997; Kime, 1998). One of the common hormones disrupted by organic materials is the metabolic hormone, thyroxine. Extensive proliferation of thyroid tissue has been shown in chinook and coho salmon in the Great Lakes due to some unknown goiterogenic agent (Leatherland, 1992). In some cases, the thyroid tissue has exceeded 1000-fold enlargement from that of the same stock on the Pacific coast (Moccia et al., 1981). Thyroid enlargement was found in 100% of the fish examined.

The similarities between thyroxine and TCDD led McKinney et al. (1985) to postulate that the Ah receptor and the thyroid-hormone receptor in the cytoplasm of cells were the same. Binding of aryl hydrocarbons to the thyroid hormone receptor would block thyroid hormones from binding and thus prevent any thyroid mediated genetic expression. A number of the toxic actions of the hydrocarbons discussed here could therefore be directly linked to effects of hyper- or hypothyroidism.

In salmon, the sex of individuals can be determined relatively late in development. Applications of testosterone during the egg and fry stages of salmonids can convert the young fish completely to males. Applications of estradiol, the female sex hormone, can cause production of all female salmon (Hunter and Donaldson, 1983). In chinook salmon, Pifferer et al. (1994) showed that brief treatments with an aromatase inhibitor could convert potentially female salmon fry into functional males. The transsexual males had testes indistinguishable from normal males and were used to fertilize eggs from normal females. The offspring were completely female. They suggest that the aromatase, an enzyme that converts testosterone to estradiol, acts as a regulatory switch during sexual differentiation. Concentrations of androgens and estrogens circulating in the blood provide stimuli that control the levels of aromatase in tissues (Callard and Callard, 1987). In salmonids, where sex differentiation is not fixed at fertilization, the

potential for major impacts on populations from estrogen mimics or aromatase inhibitors like the organic compounds discussed here may be quite large.

Polycyclic Aromatic Hydrocarbons (PAHs)
Polycyclic aromatic hydrocarbons (PAHS) are ubiquitous in industrial watersheds because of their presence in some of the most commonly used industrial chemicals and in urbanized areas due to vehicular emissions. One of the most common of these is oil. PAHs comprise the smaller molecular weight components of oil. Oil spills are a major source of PAH contamination in both freshwater and marine environments (Neff, 1985). PAH liberation into the waters of Puget Sound is described in Sections I.4.2, I.4.3, and I.5.

The effect of PAHs on aquatic organisms is not completely understood, although the literature on the effects of oil spills on aquatic organisms is voluminous. Part of this problem is that PAHs are a very diverse group and they are very insoluble in water. These characteristics do not lend themselves to classic toxicology studies in which a single compound is added to the water supplied to the aquatic organism in question. Many PAHs are carcinogenic to mammals, however, and the carcinogenic properties of PAHs have been well studied with aquatic organisms.

Puget Sound is rich with PAHs which have probably contributed to the development of carcinomas in bottom fish (Malins et al., 1984; Malins et al., 1985; Pierce et al. 1978). Positive correlations were found between the number of neoplasms found in English sole and the concentrations of selected PAHs, including benzo(a)pyrene and benz(a)anthracene, in the sediments (Malins, 1984). Another study of English sole found that concentrations of derivatives of nitrogen heterocyclic compounds were higher in fish with hepatic neoplasms than healthy fish (Roubal and Malins, 1985). A mechanism for development of these neoplasms was found by Varanasi et al. (1989) who showed that benzo(a)pyrene can form adducts with the DNA of English sole. Further work in vitro showed that cultures of salmon liver from coho salmon are capable of forming metabolites of benzo(a)pyrene that will interact with DNA (Varanasi and Gmur, 1980).

PAHs seems to be involved in reproductive disruption in salmonids (Matthiesson and Sumpter, 1998). Afonso et al. (1997) showed that two of the PAHs, (-naphthoflavone and 20-methylcholanthrene, reduced 17(-estradiol production in ovarian follicles of coho salmon. No effect on testosterone production was observed. It was suggested that the PAHs were inhibiting the aromatase in ovarian follicles. Such inhibition would lead to masculinization of females. Males with two X chromosomes instead of the normal XY complement will produce all female offspring when bred with normal females. Disruption of sex ratios can have severe impacts on populations.

Unfortunately, few studies have looked directly at the effects of PAHs on the complexities of salmonid reproduction. Most have involved exposure of salmon and trout to mixtures of industrial pollutants whose mechanisms of action are impossible to extricate (Kime, 1998; Matthiessen and Sumpter, 1998).

PAHs induce a wide array of damage to the olfactory tissues of fish (Klaprat et al. 1992). Exposure to whole crude oil at 0.14 mg/L for 7 days caused hyperplasia of olfactory cells and wide areas of degeneration in the Atlantic silverside (Gardner, 1975). An insoluble oil fraction at 0.58 mg/L caused similar lesion in this fish. Larval sand sole (Psettichthys melanostictus) exposed to 800 ug/L of the water soluble fraction of crude oil developed abnormal chemosensory ciliary and microridges on epithelial cells were lost (Hawkes, 1980).

Salmonids will not necessarily avoid petroleum contaminated water, even at lethal concentrations (Hara et al. 1992). Maynard and Weber (1981) found that presmolt salmon would not avoid potentially toxic concentrations of petroleum hydrocarbons, although they would avoid lower concentrations of the components of the mixture. This suggests that damage to the olfactory cells may be occuring at higher concentrations, rending the fish unable to smell the toxic hydrocarbons.

Feeding of juvenile salmon can be interrupted by exposure to PAHs. Purdy (1989) exposed coho salmon to a mixture of seven hydrocarbons at two concentrations. At the lowest level, 0.08%, feeding was reduced. At the highest level, 0.15%, feeding was completely inhibited and fish would not feed for three days after exposure.

Salmonid smolts are sensitive to some of the components of crude oil as they enter the sea on their seaward migration. Outmigrant smolts of chum salmon (Oncorhynchus gorbuscha), pink salmon (O. nerka), and Dolly Varden trout (Salvelinus malma) were adapted to 15 thousandth percent (o/oo) seawater for three days, then 30 o/oo seawater for three days before subjected to water containing crude oil and benzene (Moles et al., 1979). Smolts were twice as sensitive to the mixture in 30 o/oo seawater as they were in freshwater. Stickle et al. (1982) subjected coho salmon smolts to various concentrations of naphthalene and toluene in a flow-through system. LC50 at 48 hours for napthalene and toluene in 30 o/oo seawater was 63% and 54% of the LC50 at 48 hours for fish in freshwater. Changes in osmolality and plasma ion concentrations occurred only at lethal concentrations. The authors suggest that the toxic effects of these compounds are not the result of inhibition of osmoregulatory mechanisms but loss of osmoregulation occurs because of other toxic actions. Englehardt et al. (1981) showed gill damage to rainbow trout after exposure to petroleum hydrocarbons. These damages resulted in changes in plasma ion concentrations.

Immunologists suspect that PAHs supress the immune system of fish but direct proof has been difficult to obtain (Anderson, 1996; Arkoosh et al., 1998). Reports by Collier et al. (1999) have suggested that chinook salmon in the Puget Sound are exposed to PAHs in their food supply and that this is associated with decreased disease resistance. Using a plaque forming assay, Arkoosh et al. (1994) found the chinook salmon from Duwamish Waterway near Seattle were unable to invoke a B-cell response from anterior kidney leukocytes in response to a T-cell-dependent antigen. Fish from a non-polluted waterway or a nearby hatchery were capable of showing the response. Salmon from the polluted waterway could show a B-cell response to a T-cell-independent antigen, but the response was smaller than that from fish from the non-polluted waterrway or hatchery. Injection

of 7,12-dimethylbenz(a)anthracene into chinook salmon caused suppression of B-cell responses to both T-cell-dependent and T-cell-independent antigens (Arkoosh et al., 1994).

Anderson et al (1984) found that exposure of rainbow trout to phenol before exposure to Yersinia ruckeri bacterins reduced the number of splenic antibody-producing cells. Payne and Fancey (1989) found that exposure of the flounder (Pseudopleuronectes americanus) to PAHs reduced the number of circulating melanomacrophages.

Phthalates

Introduction of phthalate esters into the waters of Puget Sound is discussed in Sections I.4.6 and I.5. Few studies are available on the effects of phthalate esters on fishes of any kind (Kime, 1998). Only one could be found using salmonids. An abstract by Tollefsen et al. (2001) described experiments with estrogenic effects of phthalates on Atlantic salmon. The authors examined in vivo and in vitro estrogenic activity of n-butyl benzyl phthalate (BBP), di-(n-butyl)-phthalate (DBP) and di-(2-ethylhexyl)-phthalate (DEHP) using estrogen receptor-mediated production of vitellogenin and eggshell zona radiata proteins as biomarkers. They found that both BBP and DBP acted as estrogenic agonists under in vitro exposure conditions, whereas only BBP was estrogenic under flow through conditions. DEHP was not found to be estrogenic either in vivo or in vitro. Both BBP and DBP were weakly estrogenic in vivo, but were found to interact with plasma sex steroid-binding proteins. The authors suggest that the phthalates have multiple modes of estrogenic action in salmon.

Di-n-butylphthalate was tested on the cyprinodontiform fish, Rivulus marmoratus, at concentrations of 1 mg/L and 2 mg/L (Davis, 1988). Fecundity and viability of embryos was decreased at 2 mg/L but not at 1 mg/L. Skeletal abnormalities in offspring increased from 4% in controls to 10% and 19% in fish exposed to 1 mg/L and 2 mg/L, respectively. In a nine-week post-exposure period, skeletal abnormalities decreased to less than 5% in all groups.

Effects of diethylphthalate (DEP) on the freshwater fish, Cirrhina mrigala, were studied by Ghorpade et al. (2002). Fish were treated with 25, 50, 100, and 200 mg/L DEP for 72 hours. All the fish in 100 and 200 mg/L were killed within 24 hours and 50% of those in 50 mg/L were killed in 72 hours. Only 10% of those treated with 25 mg/L were killed in 72 hours. Survivors of the treatment with 25 mg/L were treated for an additional three days. After that time, they were sacrificed and assayed for metabolic enzyme activities. There was a significant increase in liver and muscle acid phosphatase, alkaline phosphatase, alanine aminotransferase and succinic dehydrogenase in DEP-treated fish compared with positive and negative controls. Acetylcholinesterase in brain was significantly decreased. Results showed that the levels of enzymes could be profoundly altered by sublethal levels of DEP.

Studies on mammals (National Toxicology Program, 1982) provide areas of concern that should be addressed in determining the effects of phthalates in the aquatic environment. Phthalate esters in mammals have been found to be carcinogenic and teratogenic. A

number of developmental abnormalities were found in neonatal mice, including exencephaly, club foot, bent or absent tail, and vertebral abnormalities (Tomita et al. 1982).

One interesting aspect of phthalate esters is that they are inhibitors of the enzyme, HMG-CoA reductase, which controls the initial steps of cholesterol synthesis. In this respect, they resemble the statins, a popular human drug that inhibits the same enzyme (Cohen, 2005). Cholesterol is required in cell membranes to maintain their fluidity and properties so that too great an inhibition of cholesterol may result in muscular or neurological problems (Mathews and Van Holde, 1990). Because of the popularity of statins, human wastewater probably contains large amounts of statins (Barnes et al., 2002; Walker, 2005), which may act in an additive fashion with the phthalates to suppress HMG-CoA reductase in fish. Reduction of cholesterol synthesis in fish may affect osmoregulation, chemoreception, and reproductive function..

Polychlorinated Hydrocarbons (PCHs)

Polychlorinated hydrocarbons (PCHs) are a group of aromatic hydrocarbons, which contain at least one chlorine molecule in their structure. These compounds are known as polychorinated biphenyls (PCBs) if they have a pair of ring structures to which various numbers of chlorine atoms are attached; polychlorinated dibenzo-dioxins (PCDDs) if there are a pair of oxygen atoms between the two chlorinated benzyl groups that form a six-membered ring; polychorinated dibenzo-furans (PCDFs) if there is a single oxygen atom between the two chlorinated benzyl groups that forms a five-membered (furan) ring. A discussion of the PCHs and their origins in the waters and sediments of Puget Sound is found in Sections I.4.4 and I.5.

PCBs exist in 209 congener forms, of which 20 of the planar congeners are the most toxic. All of these are fat soluble and residues are found most often in fat and liver tissues. Because of the lipid concentrations found in salmonid eggs, this developmental stage tends to concentrate the PCBs and shows the greatest sensitivity. Of all the fish tested, chinook salmon show the greatest sensitivity to effects of PCBs (Eisler and Belisle 1996).

Dioxins exist in 75 congener forms, of which 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) is the most common and most active congener. This molecule assumes a planar shape and is able to bind efficiently to the aryl hydrocarbon (Ah) receptor in cells. Biological activity is strongly correlated with binding of planar dioxins, furans, and PCBs to the Ah receptor. Substitutions which bend the molecule from a planar structure do not have a strong affinity for the Ah receptor and have little biological activity. Consequently, the various congeners vary widely in potency.

The most toxic congener of PCHs is 2,3,7,8 TCDD, and researchers have assigned “toxic equivalency factors” (TEFs), relative to 2,3,7,8 TCDD, to all the PCHs for which toxicity has been demonstrated (Van den Berg et al., 1998). TEFs are assumed to be additive in nature and have been established for humans and mammals, birds, and fish. TEFs are based on experimental studies where the endpoint was the binding affinity to the aryl

hydrocarbon receptor or the induction of cytochrome P4501A1 (Van den Berg et al., 1998). By using TEFs in conjunction with chemical residue data, "toxic equivalent" (TEQ) concentrations can be calculated for tissue, sediments and water. TEQs, in turn, can then facilitate remedial action as they represent the biological effect exerted by the sum of the PCH contaminants in the environment (Van den Berg et al., 1998).

PCHs are highly lipophilic and concentrate in tissues rich in lipids. In females, the most lipid-rich tissue is the developing egg. PCBs and other organochlorine compounds were shown to be tranferred from the flesh of female chinook salmon and lake trout to the developing eggs (Miller, 1993).). Because of the lipophilic nature of these compounds, the concentrations in the water or sediments that result in contamination of eggs can be vanishingly small.

Dioxins and organochlorine compounds have been shown to cause reproductive impairment of salmonids in the Great Lakes (Ankley et al. 1991; Giesy et al., 1986; Mac and Edsall, 1991; Mac et al., 1985). Early stages are much more sensitive to PCDDs, PCDFs, and PCBs than adults (Spitsbergen et al., 1991; Walker et al., 1991). Egg concentrations of TCDD as low as 0.04 ng/g eggs significantly increased early life mortalities (Spitsbergen et al., 1991). Development of eggs of lake and rainbow trout containing high levels of PCHs resulted from half-hatched mortalities and fry with subcutaneous yolk sac edema, symptoms similar to blue-sac disease (Roberts and Shepard, 1986). As with other PCH effects, the symptoms were mediated through the Ah receptors and induction of cytochrome P450 1A1 (Walker and Peterson, 1991)

Newly hatched rainbow trout that were treated with the PCB, Arochlor 1260, showed decreased proportion of females in the population and severe abnormalities in the gonads (Matta et al., 1998). Although three concentrations of Arochlor 1260 were tested, levels in the fish from all three concentrations reached 2.1-2.5 ug/g after a three hour exposure. The authors were unable to relate the observed effects to inhibition of the aromatase enzyme, alteration of sex steroids, or endocrine mimicking by the Arochlor 1260.

Reports by Collier et al. (1999) have suggested that chinook salmon in the Puget Sound are exposed to PCHs in their food supply and that this exposure is correlated with decreased disease resistance. Using a plaque forming assay, Arkoosh et al. (1994) found the chinook salmon from Duwamish Waterway near Seattle were unable to invoke a B-cell response from anterior kidney leukocytes in response to a T-cell-dependent antigen. Fish from a non-polluted waterway or a nearby hatchery were capable of showing the response. Salmon from the polluted waterway could show a B-cell response to a T-cell-independent antigen, but the response was smaller than that from fish from the non-polluted waterway or hatchery. Injection of Arochlor 1254 into chinook salmon caused suppression of B-cell responses to both T-cell-dependent and T-cell-independent antigens (Arkoosh et al., 1994).

Mayer and Mayer (1985) showed that the susceptibility to disease of rainbow trout increased when they were exposed to Arochlor 1254 and 1260. Similarly, Spitzbergen et al. (1988) found that exposure of rainbow trout to TCDD or Arochlor 1254 resulted in a

decreased resistance to the virus IHNV. In another study, Spitsbergen et al. (1986) found that the mitogenic response of rainbow trout was partially suppressed by exposure to TCDD.

II.4. Summary of Toxic Effects on Chinook Salmon

From analysis of the residues in the water, in the sediments, and in the tissues of chinook salmon from the Puget Sound, there is ample evidence of pollutant concentrations that may initiate many of the deleterious effects on salmon populations described here. While many of the studies cited here were conducted on single chemicals, or, at most, a mixture of a few chemicals, Puget Sound chinook salmon are actually exposed to water, sediments, and food that are contaminated by a large number of inorganic and organic pollutants. The exact nature of the combined toxic effects may be additive or multiplicative. Because the necessary research to determine the nature of the interaction of pollutants is lacking and because the salmon populations are in sharp decline, it must be assumed at this point that the complex mixture of pollutants faced by the salmon during their passage through Puget Sound is extremely detrimental to their populations.

From laboratory experiments, we know that the sublethal concentrations of the individual pollutants impair physiological functions at every stage in the life history of the salmon:

1) They interfere with the biochemical machinery of the cells.

2) They show various neurotoxic effects that interfere with normal behavior.

3) They inhibit the olfactory system in such a way to interfere with homing, predator avoidance, and spawning.

4) They interfere with the immune system, leading to increased mortality from diseases.

5) They increase the incidence of carcinogenesis through oxidized metabolites, DNA adducts and interference with DNA repair mechanisms.

6) They interfere with developmental processes, leading to reduced fertility, increased mortality of the young, and teratogenesis.

7) They act as endocrine disruptors, causing interference with the intricate balance of hormones needed for reproduction, osmoregulation, and homeostasis.

8) PBTs released at any concentration level are very probably harmful to chinook salmon, and other organisms, because of their persistent and bioaccumulating characteristics.

The Endangered Species Act requires that these widespread pollutants be regulated to ensure the continued survival of the salmon populations of Puget Sound.

II.5. Common and Scientific Names for Fish Described Above

Chinook Salmon	Oncorhynchus tshawytscha
Coho Salmon	Oncorhynchus kisutch
Chum Salmon	Oncorhynchus keta
Pink Salmon	Oncorhynchus gorbuscha
Rainbow Trout	Oncorhynchus mykiss (Formerly Salmo gairdneri)
Atlantic Salmon	Salmo salar
Brown Trout	Salmo trutta
Brook Trout	Salvelinus fontinalis
Bull Trout	Salvelinus confluentus
Lake Trout	Salvelinus namaycush
Dolly Varden Trout	Salvelinus malma
Bluegill	Lepomis macrochirus
Sheepshead Minnow	Cyprinodon variegatus
Common carp	Cyprinus carpio
Pike	Esox lucius
Golden Shiner	Notemigonus crysoleucas
English sole	Parophrys vetulus
Rock sole	Pleuronectes bilineatus
Sand sole	Psettichthys melanostictus
Flounder	Pseudopleuronectes americanus
Atlantic silverside	Menidia menidia

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Effect On Puget Sound Chinook Salmon Of NPDES Authorized Toxic Discharges As Permitted by Washington Department of Ecology

APPENDICES

A through E

April 2006

Appendices

Appendix A.

Curriculum Vitae

Appendix A.1

For Dave LaLiberte, MSCE, Environmental Engineer

David M. LaLiberte, P.E.
Principal Engineer

Summary:

My qualifications comprise over eighteen years of experience in surface water quality analysis and evaluation, environmental quality control, pollution abatement, effluent treatment alternatives, discharge requirements for NPDES permits, and environmental design. I have managed and performed on many environmental project teams assisting state and federal agencies, as well as municipal and industrial facilities in Oregon, Idaho, Alaska, elsewhere in the Pacific NW, and throughout the USA.

Education: M.S., Civil Engineering, Portland State University, 1990
B.S., Civil Engineering, Portland State University, 1988

Firm Membership: Water Environment Federation (WEF)

Registration: Professional Engineer (Civil and Environmental)

LEA, Inc. Experience:

Citizens for Responsibility v. Izaak Walton League, Circuit Court of the State of Oregon for Lane County, Expert Analysis for Plaintiff evaluating the effects of lead contamination from shooting range into South Fork Spencer Creek (2004-2005). Sediment sampling was conducted for metals including lead, arsenic, copper and polynuclear aromatic hydrocarbons (PAH). This information was evaluated for pollutant distribution and transport from the contaminated site and relative to upstream and downstream properties. Expert testimony was given at trial in 2004. Expert analysis and testimony was also provided in the subsequent equitable relief phase. Participation in the settlement conference was also provided.

Oregon Department of Environmental Quality - WQ Technical Assistance: Industrial Discharge Effluent Evaluation, Outfall Mixing Zone Analysis with Design Assessment (2002-03). Provided water quality evaluation and environmental engineering assistance to the Oregon DEQ. Work included receiving WQ analysis, outfall design review and mixing zone analysis. NPDES requirements were based on EPA *Quality Criteria for Water*, EPA *Technical Support Document for Water-based Toxics Control* (TSD) and State Administrative Rules. The mixing zone models CORMIX and PLUMES were evaluated relative to the cases at hand. Potential discharge chlorine residual and temperature requirements were evaluated. The effect of potential temperature Total Maximum Daily Loads (TMDLs) in the Columbia River was also evaluated.

Water Environment Services, Clackamas County, Oregon - Water Quality Evaluations and NPDES Permit Requirements for the four (4) WES publicly owned treatment works (POTW) discharges (2000-2004, 1999). These included evaluation of discharge effects on the Willamette River (2 outfalls), Sandy River and a tributary of the Clackamas River. Field water quality sampling including detailed outfall mixing zone investigations. Water quality

assessment was conducted relative to effluent temperature, disinfection and ammonia requirements to protect fish and aquatic organisms. Effluent mixing zone simulation and analysis was performed. Treatment alternatives analysis and costing were undertaken to ensure existing and future discharge conditions were protective of river WQ. River outfall piping alignment and diffuser design was provided including construction management of river installation.

Westport Sewer Service District, Clatsop County, Oregon - MZ Evaluation with Alternative Disinfection (2003-2004). This project assessed water quality and mixing zone effects of disinfected treated wastewater discharged to Westport Slough, a segment of the Columbia River. Chlorine residual reduction or elimination was a key evaluation concern to satisfy Oregon DEQ requirements. Comparisons of alternative disinfection treatment scenarios and costs were performed that would allow the discharger to continue to meet WQ requirements. Ultraviolet disinfection, chlorination-dechlorination, and outfall diffuser feasibility were all investigated with comparison costs. In particular, the existing chlorination system was evaluated relative to how easily it could be retrofitted to function with dechlorination. The alternatives analysis aided the discharger in making a determination as to course of action.

Canby Utility Board - Industrial Discharge from Water Treatment Plant Study and Predesign (1999-2000) addressing Molalla River water quality issues with Oregon DEQ including treatment alternatives: filter backwash sedimentation basin, disinfected effluent de-chlorination, river infiltration gallery design, intake piping system, and sediment and riparian effects mitigation.

Water Environment Services of Clackamas County Hoodland WWTP Outfall Project Descriptions and Costs (2000); FEMA engineering, budgeting and negotiations is intended to reimburse Clackamas County for flood damage to their wastewater treatment plant outfall on the Sandy River. Numerous regulatory issues affected costs including an ACE 404 permit for instream construction work, NMFS ESA Section 7 Consultation, and NEPA documentation including and environmental and biological assessments.

City of Bremerton, CSO Projects --A comprehensive review of the City of Bremerton, Washington collection system model was performed (2000). Hydraulic modeling was used to update information for the main sewer lines, combined sewer overflows and discharge conditions. Selected CSO reduction alternatives were evaluated and implemented. The purpose of the CSO reduction alternatives was accomplished and potential early action projects were identified. These projects yielded substantial CSO reductions while being quickly implemented at reasonable cost. Revised CSO baselines were produced conforming to Washington Department of Ecology requirments for Bremerton’s 17 CSO outfalls. Expert witness testimony supporting the findings of the CSO baselines was provided in a hearing at the Federal Court in Seattle.

Previous Experience (Montgomery Watson Americas)

In addition, I have performed as project manager and/or project engineer on the following undertakings:

City of Portland, Bureau of Environmental Services included Water Quality Evaluations and Diffuser Designs (2000-2001, 1997,1994) for wet and dry weather flows with chlorine residual discharges, and wet weather stormwater runoff for suspended solids and metals with potentially affected agencies including US Corps of Engineers, Oregon Division of State Lands, NOAA Fisheries, Oregon Dept. of Fish and Wildlife and US Fish and Wildlife.

- Project Engineer for Water Environment Services of Clackamas County Kellogg Creek WWTP Odor Control Project. Participated as team engineer to design malodorous air collection system for headworks, primary clarifiers, secondary clarifiers, and dissolved air floatation thickening (DAFT) building. Malodorous air was passed through a biofilter for treatment.

- Project Engineer for Crescent City, California WWTP outfall mixing zone analysis. A major consideration of this project was developing alternative outfall pipeline alignments and an effective discharge location to optimize mixing.

- Project Manager/Engineer for the Kensington Mine in Alaska. PLUMES mixing zone modeling was used to evaluate the conditions affecting this industrial outfall.

- Project Manager/Engineer for the Hoodland WWTP Outfall project, which includes outfall diffuser design and construction (1998) in a sensitive Sandy River corridor.

- City of Bremerton Corrosion and Fluoridation Facility detention facility design. An on-site detention facility was designed pursuant to Washington Department of Ecology's requirements as specified in the *Puget Sound Stormwater Management Manual*.

- Project Task Manager—Jefferson County (Birmingham, Alabama) stream water quality analysis was performed relating to recommended NPDES permit limits for dry and wet weather conditions. Collection system analysis and treatment plant design constraints are also considerations in this potentially very large project.

- Project Engineer using Pizer's HYDRA, data compatible with the City's XP-SWMM format, to evaluate gravity flow conditions in the proposed dual outfall system consisting of two connected parallel outfall systems over one mile each and including wet weather (CSO) hydraulic structures such as flow control structures, mix boxes and outfall diffusers.

- Project Engineer evaluating stormwater hydrologic, hydraulic and quality conditions in Clackamas County for the CCSD#1. The graphically enhanced model, XP-SWMM, was used to develop the hydrology and hydraulics for the Kellogg and Mt. Scott Creeks basins in CCSD#1.

- Project Manager/Engineer evaluating stormwater hydrologic, hydraulic and quality conditions in Balch Creek Basin for the City of Portland, Bureau of Environmental Services, Oregon. The Army Corps of Engineers (COE) hydrographic model, (HEC-1) and hydraulic model (HEC-2) were applied to establish design criteria for flood magnitude, stormwater detention, water quality facility hydraulics and fish passage culvert hydraulics.

City of Madison, Wisconsin - stream water quality modeling analysis of POTW discharge relative to NPDES permitting requirements (1995-1996). A key objective of this study was restoration of base flows to the Sugar River Basin using high quality POTW effluent. An EPA QUAL2E model was developed for Badger Mill Creek and the Sugar River. Physical, chemical and biological simulation included temperature, algae, dissolved oxygen (DO), biochemical oxygen demand (BOD), total suspended solids (TSS) and ammonia. Particular attention was focused on the inter-relationships between temperature, climatological conditions, stream shading and channel conditions, DO, BOD and algal activity. Temperature and discharge point design alternatives were investigated using the model. It was demonstrated that, with minimal WWTP facility upgrading and cost, the City could beneficially discharge high quality effluent to surface streams. This assurance was primarily accomplished through detailed modeling analysis and model approach consensus building with regulators (WDNR). Some keys to the success of this project were in identifying important NPDES permitting issues, evaluating them with the model, recommending permit effluent limits and negotiating with regulators.

Washington Beef, Incorporated in Toppenish, Washington – Development of an NPDES permit under the direction of the EPA (1993-94). The project objective was development of receiving water based permit effluent limits for this food-products industry discharger using dissolved air floatation (DAF) treatment. Important project elements were: interfacing with regulatory (EPA Region 10 and Washington Ecology) and public agencies; evaluation of the effect of effluent parameters on receiving water using modeling analysis (EPA QUAL2E and EPA CORMIX); and providing long-term treatment system design recommendations. Fishery issues were of key concern for this project. Receiving water modeling was used to analyze the discharge effects of on stream dissolved oxygen and temperature on the aquatic environment. The inter-relationship between temperature, climatological conditions, stream shading and channel conditions, DO and algal activity were thoroughly investigated. Temperature and discharge design alternatives were evaluated using the water quality model.

Previous Experience (Brown and Caldwell)

Oregon Department of Environmental Quality and Oregon Department of State Land Conservation and Development - Non-point Source Pollution Control Guidebook for Local Government (1994) evaluation of non-point runoff pollution and control measures including detention facilities, sedimentation basins, water quality ponds and marshes; City of Portland, Bureau of Environmental Services (1989-90) - evaluated effects of combined sewer overflows and stormwater discharges on the Columbia Slough of the Columbia River. Hydrologic and water quality modeling support was provided including field sampling.

- Project Engineer for NPDES waste discharge permit review and support related to permit effluent limits for the City of Vancouver, Washington. Two tracer dye studies were performed at their two municipal WTP outfalls. The key project objective was to determine actual outfall dilution and provide a physical, receiving water basis for setting permit effluent limits. The mixing zone evaluations showed that actual dilution was greater than estimated by the regulatory agency (Washington Department of Ecology) and higher permit effluent limits were recommended.

  Project Task Manager and Engineer for a comprehensive hydraulic and water quality compliance evaluation and recommendations. The City of Portland's Columbia Boulevard

WTP, the largest municipal discharger in Oregon (300 MGD), required assistance in meeting their water quality compliance needs. A highly detailed Columbia River tidal flow evaluation was performed in the outfall vicinity to serve as the basis for the mixing zone simulation and diffuser design. EPA CORMIX, and the EPA supported PLUME model family (including UDKHDEN), were used in the modeling analysis. A thorough investigation of water quality compliance options led to regulatory (ODEQ) approval of the multi-port diffuser design, the lowest cost compliance option.

- Project Engineer for Kehei, Hawaii Water Reuse Facility (1992). Participated as team engineer to design upgrades to the facility's aeration basin including aeration blower design and aeration basin air piping with small bubble diffusion.

- Project Engineer for the Columbia Slough flow augmentation project for the City of Portland Bureau of Environmental Services, Oregon. Dynamic water quality modeling (COE CE-QUAL-W2), water quality sampling, and hydrodynamic sampling were performed for this dynamic "freshwater" estuary. This project was driven by the City's need to evaluate the impact of water quality limited conditions on the Columbia Slough and was coupled to the City's EPA SWMM model. The objective was to propose best management practices (BMP) and evaluate design alternatives. The effect of temperature on the aquatic environment was examined in detail. The sophisticated two-dimensional (vertical and longitudinal) dynamic model evaluated temperature regimes and their effect on in-stream water quality. In-stream temperature design alternatives were investigated via simulation of climatological conditions, stream shading and channel conditions, algal processes and kinetics, and instream DO.

- Project Engineer conducting stormwater hydrologic and hydraulic simulation to evaluate flood effects for the City of Beaverton, Oregon. HEC-1 hydrographic modeling was conducted to generate peak flow values from surface runoff for existing and future conditions. HEC-1 model results for 2, 5, 10, 25, 50 and 100-year storm events were supplied to the HEC-2 model for detailed hydraulic analysis. The HEC-2 modeling was required as part of a cost assessment that included potential flood damage of key storm events.

- Project Manager and Engineer for a mixing zone evaluation and diffuser design for the City of Albany, Oregon. An outfall pipeline and 40 MGD capacity multi-port diffuser was designed for this municipal discharger using EPA CORMIX. Simulation was performed to optimize the diffuser design. The DEQ approved design will meet water quality compliance needs for chlorine and ammonia.

- Project Engineer mixing zone modeling and design for the City of Gresham, Oregon. Alternative disinfection and multiport diffuser design were evaluated. Modeling (EPA CORMIX) was utilized to optimize multiport diffuser design for this WWTP outfall. Simulation offered the flexibility to test numerous design conditions.

- Project Manager and Engineer for a mixing zone evaluation and diffuser design for the Unified Sewerage Agency, Washington County, Oregon. Analysis of four municipal treatment facility outfalls was conducted according to DEQ NPDES requirements. Model

simulation was performed to determine revised wet weather chlorine residual effluent limits. The models were calibrated to dye study results. Wet weather stream surveys were also performed at two sites, Hillsboro and Forest Grove. Alternative disinfection was evaluated and diffuser design recommendations were also made.

- Project Manager and Engineer for outfall mixing zone simulation and water quality compliance evaluation for the Oak Lodge Sanitary District, Oregon. As part of NPDES permit requirements, model simulation was performed to characterize the municipal discharge-mixing zone. Available dilution values and recommended permit effluent limits for chlorine, ammonia and metals were derived from the study.

- Project Manager for a mixing zone evaluation and diffuser recommendations for Electronic Controls Devices, Incorporated. A mixing zone field evaluation of this circuit board manufacturer's discharge was performed. Very low amounts of organics and metals from the facility discharge needed to be discharged to a small stream in a responsible manner. This study illustrated that the discharge was well within compliance requirements.

Previous Experience (Portland State University Research Assistant)
City of Portland, Bureau of Environmental Services (1989-90) - evaluated effects of combined sewer overflows and stormwater discharges on the Columbia Slough of the Columbia River. Hydrologic and water quality modeling support was provided including field sampling.

- Project Engineer evaluating combined sewer overflows (CSO) and stormwater discharges on the Columbia Slough. Hydrologic and water quality modeling, using the City's EPA SWMM model data, of urban runoff from sub-basins discharging to the Columbia Slough was supplied as input to the Army Corps of Engineers in-stream surface water model, CE-QUAL-W2. This study was performed for the City of Portland, Bureau of Environmental Services in Oregon.

- Project Engineer for the South Slough National Estuarine Reserve Hydrodynamic and Water Quality Study, State of Oregon, Division of State Lands, Charleston, Oregon. Dynamic water quality modeling, water quality sampling, and hydrodynamic sampling were performed for this southern section of the Coos Bay estuary. Tracer (rhodamine) dye study results were used to calibrate the Army Corps of Engineers CE-QUAL-W2 water quality model.

- Project Engineer for design of stream flow measurement structures on two tributaries of the South Slough National Estuarine Reserve (State of Oregon, Division of State Lands) in Charleston, Oregon. Analysis and design of stream flow measurement structures was required as part of a study assessing the hydrology and hydraulics of this pristine estuary.

- Project Engineer for a hydrologic, hydraulic and water quality assessment of Smith and Bybee Lakes in Portland, Oregon. Lake sampling and modeling was performed. The objective of the study was to evaluate the potential for water quality impairment due to the close proximity of St. John's municipal landfill and Columbia (North) Slough inflow. A hydraulic model of possible flow control structures was incorporated into the Army Corps of Engineers CE-QUAL-W2 hydrodynamic and water quality model. Recommended

actions were advanced for improving lake water quality based on simulation scenarios. This study was conducted as part of a larger study for the Port of Portland, Metropolitan Service District, and City of Portland, Bureau of Environmental Services, Portland, Oregon.

- Project Engineer for evaluation of fish screen approach velocities and hydraulic design analysis for the Eugene Water and Electric Board, Leaburg, Oregon. The effects of downstream baffles on velocities through fish screens at the Leaburg Power Canal Facility were evaluated for fish passage.

- Project Manager and Engineer assessing the water quality impact of urban runoff from the Leadbetter storm outfall discharge to Bybee Lake. This study was conducted for the Port of Portland, Portland, Oregon.

- Project Engineer assisting in initial field work and model development for assessing impact of landfill leachate on surrounding surface waters. Conducted for the Metropolitan Service District (METRO) as part of the St. Johns Landfill closure.

Publications and Presentations

Stream Temperature Trading, Presented at the Pacific Northwest Pollution Control Annual Conference, 2001, Bend, Oregon.

Winter Temperature Gradients in Circular Clarifiers (January 1999), *Water Environment Research*, **70**, 1274.

Wet Weather River Diffuser Port Velocities: The Energetic Debate, Presented at the Pacific Northwest Pollution Control Annual Conference 1998, Portland, Oregon.

Near Field Mixing and Regulatory Compliance Implications Presented at Portland State University, February, 1998.

Whither the Wet Weather Flow, Presented at the Pacific Northwest Pollution Control Annual Conference 1997, Seattle, Washington.

Appendix A.2

For Dick Ewing, Ph. D., Biologist

RESUME

Name: Richard Dennis Ewing

Address: 2340 S. E. Ryan St.
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Business Phone: 541-752-8259

FAX: 541-758-7005

E-Mail: dickewing8@yahoo.com

Education:

B. A. in biology, Reed College, Portland, Oregon, 1962

Ph. D. in cell and molecular biology, University of Miami, Coral Gables, Florida, 1968.

Professional Career:

1967-1970 Postdoctoral research fellow at Oak Ridge National Laboratory, Oak Ridge, Tennessee. Research on nucleotide and lipid metabolism.

1970, summer. Postdoctoral fellow in fertilization and gamete physiology program under Dr. Charles Metz, Marine Biological Laboratory, Wood's Hole, Mass.

1970-1971. Postdoctoral fellow in the chemistry department under Dr. Max Tishler, Wesleyan University, Middletown, Conn.

1971-1972. Research associate, zoology department, Oregon State University, Corvallis, Oregon, under Dr. Frank Conte. Research on mechanisms of osmoregulation in crustaceans.

1972-1973. Temporary assistant professor in zoology department, Oregon State University. Taught general physiology, cell physiology, and cell physiology laboratory.

1973-1975. Research associate, zoology department, Oregon State University, Corvallis, Oregon, under Dr. Frank Conte. Principal investigator of NSF grant on the biogenesis of (Na+K)-ATPase in crustaceans.

1975-1991. Associate professor (courtesy) in zoology department, Oregon State University.

1975-1992. Fishery research physiologist, Oregon Department of Fish and Wildlife, Corvallis, Oregon. Research on parr-smolt transformation and migration in salmonids and improved methods of hatchery rearing for salmonids.

1984-1988. Courtesy faculty position with biology department, Linfield College, McMinnville, Oregon.

1985-1992. Owner, Biotech Biochemical Analyses. Biochemical analyses on fish tissues.

1987-1992. Owner, Biotech Aquaculture Services. Consulting on fisheries issues.

1989-2002. Associate professor (courtesy) in fish and wildlife department, Oregon State University.

1992-present. President of small corporation, Biotech Research and Consulting, Inc., resulting from consolidation of two sole proprietorship companies.

Other Professional Achievements

Member of AAAS, AFS, American Physiological Society, World Aquaculture Society.

Award for Excellence in Fisheries, American Fisheries Society, 1987.

Editor, Northwest Fish Hatchery Newsletter, 1985-1995.

Co-editor, Hatchery Nutrition Newsletter, started in 1992.

Associate Editor, Progressive Fish Culturist, 1990-1993.

Member of the technical subcommittee on oxygen standards in Oregon rivers for the Oregon Department of Environmental Quality, 1993.

Finalist, AFS Best Paper Award for Progressive Fish Culturist, 1994.

Member of Multnomah County Health Division Task Force on West Nile Virus. Responsible for developing a plan for responding to possible virus outbreak. 2004

Present 1-4 papers per year at professional meetings, including Northwest Fish Culture Conference, Oregon American Fisheries Society meeting, Annual Smolt Workshops, International Smolt Conferences, etc.

Authored or co-authored over 50 reports to funding agencies.

Authored or co-authored about 60 papers in refereed journals.

Relevant Experience

Responsible for an experimental fish laboratory at Oregon Department of Fish and Wildlife, Corvallis. 1975-1992. Duties included sterilization of eggs, rearing of fry, maintenance of juveniles for up to five years under conditions that permitted use of the fish in smolting experiments.

Occasional testing of toxicity in salmonid fry and juveniles for the Engineering Department of Oregon Department of Fish and Wildlife. 1975-1992.

Chemical safety officer for Research Laboratory, Corvallis, of the Oregon Department of Fish and Wildlife, 1975-1992. Duties included writing a chemical safety manual for the laboratory.

Project leader for the Hatchery Practices Group of Oregon Department of Fish and Wildlife. Our group of six people was responsible for examining and solving hatchery problems of a scientific nature within ODFW fish hatcheries, writing up this information in reports, and conveying useful information to the hatchery personnel.

Collection and analysis of water quality data from experimental use of oxygen supplementation and Michigan raceways at Willamette Hatchery, Oakridge, OR. 1988-2000. Results formed one of the most comprehensive collections of water quality data for a salmonid hatchery.

Review of the sublethal effects of pesticides on salmonids for the Northwest Coalition for Alternatives to Pesticides. 1998-1999.

Analysis of herbicides in runoff from spray operations in the Alsea River basin, Alsea Citizens Committee, 1998-2000. Report submitted in 2000 and posted on the web at www.audubon.org.

Collection and analysis of pesticide runoff after forest spraying for Boise, Inc. 2003.

Analysis of pesticide runoff after forest spraying for the Confederated Tribes of Siletz Indians, 1999-2004.

Expert witness for Montgomery Watson Americas concerning litigation by Alaska Department of Fish and Game over construction and operation of Fort Richardson Fish Hatchery. 2003.

Expert witness for Patti Goldman, Earth Justice, Seattle concerning litigation between pesticide groups and US Environmental Protection Agency, 2002.

Expert witness for National Environmental Law Center concerning litigation between OSPIRG and Pacific Seafoods Company, 2005

Recent Projects for Biotech Research and Consulting, Inc.

Analysis of cortisol and gill ATPase activities in chinook salmon for the U. S. Geological Survey Columbia River Research Laboratory, 2005-2006.

Feed proximate analysis for the Fisheries Research Station, Utah Department of Natural Resources, 2005

Analysis of smolt indices in net pen reared chinook and coho salmon for the Clatsop Economic Development Council, 2005

Determination of astaxanthin concentrations in feed samples for Oregon Department of Fish and Wildlife, 2005

Analysis of smolt indices in net pen reared chinook and coho salmon for the Washington Department of Fish and Wildlife, 2005.

Collection and analysis of plasma samples for cortisol concentration in relation to water temperatures for Confederated Tribes of Siletz Indians. 2004

Analysis of physiological samples for Washington Cooperative Fisheries Research Unit which was examining the effects of selected pesticides on the seawater tolerance of salmonids. 2004

Compilation of a database on chinook salmon for the Center for Aquaculture and Biosciences International, London. 2004.

Analysis of calcium and strontium concentrations in streams of Eastern Oregon for Oregon Department of Fish and Wildlife. 2004.

Consultant with Normandeau, Inc., on an Army Corps of Engineers grant looking at aspects of fisheries biology on the Columbia River, 2001-2004.

Analysis of hormones in lamprey in the Columbia basin, U. S. Geological Service, 2001-2003.

Analysis of physiological parameters in adaptation of sturgeon to saltwater, U of California, Davis, 2001-2003.

Analysis of enzyme activities and metabolites in chinook salmon undergoing migration through the Columbia River, University of Idaho, 1997-2003.

Analysis of water quality after carcass placement in the Lostine River, Oregon Department of Fish and Wildlife, 2001-2002.

Calculations of amount of oxygen required and development of an experimental plan for increasing production through oxygen supplementation at Gnat Creek Hatchery, Clatsop Economic Development Commission, 2002

Review of Salmon Safe policy for Portland Department of Parks and Recreation, 2002.

PUBLICATIONS

1. Ewing, R. D. and J. S. Clegg. 1965. An apparent absence of lactate dehydrogenase (LDH) isozymes during the development of Artemia salina. Am. Zool. 5:442.

2. Ewing, R. D. and J. S. Clegg. 1969. Lactate dehydrogenase activity and anaerobic metabolism during embryonic development of Artemia salina. Comp. Biochem. Physiol. 31:297-307.

3. Ewing, R. D. and F. J. Finamore. 1970. Phospholipid metabolism during development of the brine shrimp Artemia salina. I. Incorporation of cytidine 5'-phosphate into cytidine diphosphate choline by a microsomal enzyme system. Biochim. Biophys. Acta 218:463-473.

4. Ewing, R. D. and F. J. Finamore. 1970. Phospholipid metabolism during development of the brine shrimp Artemia salina. II. Synthesis of phosphatidyl choline by a microsomal enzyme system from nauplii. Biochim. Biophys. Acta. 218:474-481.

5. Ewing, R. D., and J. S. Clegg. 1972. Evidence for a single macromolecular form of lactate dehydrogenase in Artemia salina. Arch. Biochem. Biophys. 150:566-572.

6. Ewing, R. D., G. L. Peterson, and F. P. Conte. 1972. Larval salt gland of Artemia salina nauplii. Effect of inhibitors on survival at various salinities. J. Comp. Physiol. 80:247-254.

7. Ewing. R. D. 1973. Cholinephosphotransferase activity during early development of the sea urchin Arbacia punctulata. Dev. Biol. 31:234-241.

8. Conte, F. P., G. L. Peterson, and R. D. Ewing. 1973. Larval salt gland of Artemia salina nauplii. Regulation of protein synthesis by environmental salinity. J. Comp. Physiol. 82:277-289.

9. Ewing, R. D., G. L. Peterson, and F. P. Conte. 1974. Larval salt gland of Artemia salina nauplii. Localization and characterization of the sodium- and potassium-activated adenosinetriphosphatase. J. Comp. Physiol. 88:217-234.

10. Peterson, G. L., R. D. Ewing, and F. P. Conte. 1975. De novo synthesis of larval brine shrimp (Na+K)-activated ATPase. Fed. Proc. 34:772.

11. Ewing, R. D. and S. L. Johnson. 1976. A simplified procedure for analysis of (Na+K)-activated ATPase. Oregon Department of Fish and Wildlife, Information Report Series No 76-3, 10 pp.

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Appendix B.

Ecology NPDES Permitted Facilities In the Puget Sound Region

Table of Permits. Number & Types of NPDES Permits Authorized by Ecology
To Discharge Toxic Pollutants into the Puget Sound Region Identified in this Study

Facility Permits			
Major Individual Industrial			16
Additional Individual Industrial			56
Individual Sewage Treatment Plant			86
General Industrial			98
General Stormwater			1593
North & East PS - This is in Ecology's NW Region			
South & West PS - This is in Ecology's SW Region			
SW PS excluding Juan de Fuca			
Additional Individual Industrial			
North & East PS		34	
South & West PS		22	
Total Additional Individual Industrial			56
Individual Municipal Sewage Treatment Plant			
Total Individual STP			86
Individual Industrial Dischargers to STP (Pretreated)			
North & East PS		79	
South & West PS		10	89
General Industrial			
North & East PS		85	
	78	General-Boatyard	
	7	General-Drinking Water Treatment	
South & West PS		13	
	12	General-Boat Yard	
	1	General-Drinking Water Treatment	
Total General-Boat Yard		90	
Total General-Drinking Water Treatment		8	
Total General Industrial			98
General Stormwater			
All General Stormwater Permits		1593	
	788	Industrial including landfills	
	794	Construction including landfills	
	11	Municipal	
Stormwater Permits Associated with Landfills		14	
	12	Landfill Discharge using General Industrial Stormwater Permit	
	2	Landfill Discharge using General Construction Stormwater Permit	

Appendix C.

Summary Waterbody Assessment Criteria

Table I - Marine Sediment Quality Criteria

WAC 173-204-320

Marine Sediment Quality Standards

CHEMICAL PARAMETER	MG/KG DRY WEIGHT PPM DRY
ARSENIC	57.00
CADMIUM	5.10
CHROMIUM	260.00
COPPER	390.00
LEAD	450.00
MERCURY	0.41
SILVER	6.10
ZINC	410.00

CHEMICAL PARAMETER	MG/KG ORGANIC CARBON (PPM CARBON)
LPAH	370.00
NAPHTHALENE	99.00
ACENAPHTHYLENE	66.00
ACENAPHTHENE	16.00
FLUORENE	23.00
PHENANTHRENE	100.00
ANTHRACENE	220.00
2-METHYLNAPHTHALENE	38.00
HPAH	960.00
FLUORANTHENE	160.00
PYRENE	1000.00
BENZ(A)ANTHRACENE	110.00
CHRYSENE	110.00
TOTAL BENZOFLUORANTHENES	230.00
BENZO(A)PYRENE	99.00
INDENO (1,2,3,-C,D) PYRENE	34.00
DIBENZO (A,H) ANTHRACENE	12.00
BENZO(G,H,I)PERYLENE	31.00
1,2-DICHLOROBENZENE	2.30
1,4-DICHLOROBENZENE	3.10
1,2,4-TRICHLOROBENZENE	0.81
HEXACHLOROBENZENE	0.38
DIMETHYL PHTHALATE	53.00
DIETHYL PHTHALATE	61.00
DI-N-BUTYL PHTHALATE	220.00
BUTYL BENZYL PHTHALATE	4.90
BIS (2-ETHYLHEXYL) PHTHALATE	47.00
DI-N-OCTYL PHTHALATE	58.00
DIBENZOFURAN	15.00
HEXACHLOROBUTADIENE	3.90
N-NITROSODIPHENYLAMINE	11.00
TOTAL PCBs	12.00

CHEMICAL PARAMETER	UG/KG DRY WEIGHT (PARTS PER BILLION (PPB) DRY)
PHENOL	420
2-METHYLPHENOL	63
4-METHYLPHENOL	670
2,4-DIMETHYL PHENOL	29
PENTACHLOROPHENOL	360
BENZYL ALCOHOL	57
BENZOIC ACID	650

from WAC 173-204-412

TABLE 1 - Puget Sound Reference Total Organic Carbon Values

Silt-Clay* %	TOC** %
0-20	0.50
20-50	1.70
50-80	3.20
80-100	2.60

*Silt-Clay Particles (percent Dry Weight)

**Total Organic Carbon (percent Dry Weight)

South Nanamkin Creek	Class III
Spring Creek	Class III
Stapaloop Creek	Class III
Stepstone Creek	Class III
Stranger Creek	Class II
Strawberry Creek	Class III
Swimptkin Creek	Class III
Three Forks Creek	Class I
Three Mile Creek	Class III
Thirteen Mile Creek	Class II
Thirty Mile Creek	Class II
Trail Creek	Class III
Twentyfive Mile Creek	Class III
Twentyone Mile Creek	Class III
Twentythree Mile Creek	Class III
Wannacot Creek	Class III
Wells Creek	Class I
Whitelaw Creek	Class III
Wilmont Creek	Class II

(2) Lakes:

Apex Lake	LC
Big Goose Lake	LC
Bourgeau Lake	LC
Buffalo Lake	LC
Cody Lake	LC
Crawfish Lakes	LC
Camille Lake	LC
Elbow Lake	LC
Fish Lake	LC
Gold Lake	LC
Great Western Lake	LC
Johnson Lake	LC
LaFleur Lake	LC
Little Goose Lake	LC
Little Owhi Lake	LC
McGinnis Lake	LC
Nicholas Lake	LC
Omak Lake	SRW
Owhi Lake	SRW
Penley Lake	SRW
Rebecca Lake	LC
Round Lake	LC
Simpson Lake	LC
Soap Lake	LC
Sugar Lake	LC
Summit Lake	LC
Twin Lakes	SRW

[54 FR 28625, July 6, 1989]

§ 131.36 Toxics criteria for those states not complying with Clean Water Act section 303(c)(2)(B).

(a) *Scope.* This section is not a general promulgation of the section 304(a) criteria for priority toxic pollutants but is restricted to specific pollutants in specific States.

(b)(1) EPA's Section 304(a) criteria for Priority Toxic Pollutants.

A			B Freshwater		C Saltwater		D Human Health (10^{-6} risk for carcinogens) For consumption of:	
(#) Compound		CAS Number	Criterion Maximum Conc.[d] (µg/L)	Criterion Continuous Conc.[d] (µg/L)	Criterion Maximum Conc.[d] (µg/L)	Criterion Continuous Conc.[d] (µg/L)	Water & Organisms (µg/L)	Organisms Only (µg/L)
			B1	B2	C1	C2	D1	D2
1	Antimony	7440360	.....	.....	.....	.....	14 a	4300 a
2	Arsenic	7440382	360 m	190 m	69 m	36 m	0.018 abc	0.14 abc
3	Beryllium	7440417	.....	.....	.....	.....	n	n
4	Cadmium	7440439	3.7 e	1.0 e	42 m	9.3 m	n	n
5a	Chromium (III)	16065831	550 e	180 e	.....	.....	n	n
b	Chromium (VI)	18540299	15 m	10 m	1100 m	50 m	n	n
6	Copper	7440508	17 e	11 e	2.4 m	2.4 m	.....	.....
7	Lead	7439921	65 e	2.5 e	210 m	8.1 m	n	n
8	Mercury	7439976	2.1 m	0.012 ip	1.8 m	0.025 ip	0.14	0.15
9	Nickel	7440020	1400 e	160 e	74 m	8.2 m	610 a	4600 a
10	Selenium	7782492	20 p	5 p	290 m	71 m	n	n
11	Silver	7440224	3.4 e	.....	1.9 m	.....	.....	.....
12	Thallium	7440280	.....	.....	.....	.....	1.7 a	6.3 a
13	Zinc	7440666	110 e	100 e	90 m	81 m		
14	Cyanide	57125	22	5.2	1	1	700 a	220000 aj
15	Asbestos	1332214	.....	.....	.....	.....	7,000,000 fibers/L k	.....
16	2,3,7,8-TCDD (Dioxin)	1746016	.....	.....	.....	.....	0.000000013 c	0.000000014 c
17	Acrolein	107028	.....	.....	.....	.....	320	780
18	Acrylonitrile	107131	.....	.....	.....	.....	0.059 ac	0.66 ac
19	Benzene	71432	.....	.....	.....	.....	1.2 ac	71 ac
20	Bromoform	75252	.....	.....	.....	.....	4.3 ac	360 ac
21	Carbon Tetrachloride	56235	.....	.....	.....	.....	0.25 ac	4.4 ac
22	Chlorobenzene	108907	.....	.....	.....	.....	680 a	21000 aj
23	Chlorodibromomethane	124481	.....	.....	.....	.....	0.41 ac	34 ac
24	Chloroethane	75003	.....	.....	.....	.....	.....	.....
25	2-Chloroethylvinyl Ether	110758	.....	.....	.....	.....	.....	.....
26	Chloroform	67663	.....	.....	.....	.....	5.7 ac	470 ac
27	Dichlorobromomethane	75274	.....	.....	.....	.....	0.27 ac	22 ac
28	1,1-Dichloroethane	75343	.....	.....	.....	.....	.....	.....
29	1,2-Dichloroethane	107062	.....	.....	.....	.....	0.38 ac	99 ac
30	1,1-Dichloroethylene	75354	.....	.....	.....	.....	0.057 ac	3.2 ac
31	1,2-Dichloropropane	78875	.....	.....	.....	.....	.....	.....
32	1,3-Dichloropropylene	542756	.....	.....	.....	.....	10 a	1700 a

A		B Freshwater		C Saltwater		D Human Health (10^{-6} risk for carcinogens) For consumption of:	
(#) Compound	CAS Number	Criterion Maximum Conc.[d] (µg/L)	Criterion Continuous Conc.[d] (µg/L)	Criterion Maximum Conc.[d] (µg/L)	Criterion Continuous Conc.[d] (µg/L)	Water & Organisms (µg/L)	Organisms Only (µg/L)
		B1	B2	C1	C2	D1	D2
33 Ethylbenzene	100414					3100 a	29000 a
34 Methyl Bromide	74839					48 a	4000 a
35 Methyl Chloride	74873					n	n
36 Methylene Chloride	75092					4.7 ac	1600 ac
37 1,1,2,2-Tetrachloroethane	79345					0.17 ac	11 ac
38 Tetrachloroethylene	127184					0.8 c	8.85 c
39 Toluene	108883					6800 a	200000 a
40 1,2-Trans-Dichloro-ethylene	156605						
41 1,1,1-Trichloroethane	71556					n	n
42 1,1,2-Trichloroethane	79005					0.60 ac	42 ac
43 Trichloroethylene	79016					2.7 c	81 c
44 Vinyl Chloride	75014					2 c	525 c
45 2-Chlorophenol	95578						
46 2,4-Dichlorophenol	120832					93 a	790 aj
47 2,4-Dimethylphenol	105679						
48 2-Methyl-4,6-Dinitrophenol	534521					13.4	765
49 2,4-Dinitrophenol	51285					70 a	14000 a
50 2-Nitrophenol	88755						
51 4-Nitrophenol	100027						
52 3-Methyl-4-Chlorophenol	59507						
53 Pentachlorophenol	87865	20 f	13 f	13	7.9	0.28 ac	8.2 acj
54 Phenol	108952					21000 a	4600000 aj
55 2,4,6-Trichlorophenol	88062					2.1 ac	6.5 ac
56 Acenaphthene	83329						
57 Acenaphthylene	208968						
58 Anthracene	120127					9600 a	110000 a
59 Benzidine	92875					0.00012 ac	0.00054 ac
60 Benzo(a)Anthracene	56553					0.0028 c	0.031 c
61 Benzo(a)Pyrene	50328					0.0028 c	0.031 c
62 Benzo(b)Fluoranthene	205992					0.0028 c	0.031 c

63 Benzo(ghi)Perylene	191242						
64 Benzo(k)Fluoranthene	207089					0.0028 c	0.031 c
65 Bis(2-Chloro-ethoxy)Methane	111911						
66 Bis(2-Chloroethyl)Ether	111444					0.031 ac	1.4 ac
67 Bis(2-Chloroiso-propyl)Ether	108601					1400 a	170000 a
68 Bis(2-Ethyl-hexyl)Phthalate	117817					1.8 ac	5.9 ac
69 4-Bromophenyl Phenyl Ether	101553						
70 Butylbenzyl Phthalate	85687						
71 2-Chloronaphthalene	91587						
72 4-Chlorophenyl Phenyl Ether	7005723						
73 Chrysene	218019					0.0028 c	0.031 c
74 Dibenzo(ah)Anthracene	53703					0.0028 c	0.031 c
75 1,2-Dichlorobenzene	95501					2700 a	17000 a
76 1,3-Dichlorobenzene	541731					400	2600
77 1,4-Dichlorobenzene	106467					400	2600
78 3,3′-Dichlorobenzidine	91941					0.04 ac	0.077 ac
79 Diethyl Phthalate	84662					23000 a	120000 a
80 Dimethyl Phthalate	131113					313000	2900000
81 Di-n-Butyl Phthalate	84742					2700 a	12000 a
82 2,4-Dinitrotoluene	121142					0.11 c	9.1 c
83 2,6-Dinitrotoluene	606202						
84 Di-n-Octyl Phthalate	117840						
85 1,2-Diphenylhydrazine	122667					0.040 ac	0.54 ac
86 Fluoranthene	206440					300 a	370 a
87 Fluorene	86737					1300 a	14000 a
88 Hexachlorobenzene	118741					0.00075 ac	0.00077 ac
89 Hexachlorobutadiene	87683					0.44 ac	50 ac
90 Hexachlorocyclopenta-diene	77474					240 a	17000 aj
91 Hexachloroethane	67721					1.9 ac	8.9 ac
92 Indeno(1,2,3-cd)Pyrene	193395					0.0028 c	0.031 c
93 Isophorone	78591					8.4 ac	600 ac
94 Naphthalene	91203						
95 Nitrobenzene	98953					17 a	1900 aj
96 N-Nitrosodimethylamine	62759					0.00069 ac	8.1 ac
97 N-Nitrosodi-n-Propyl-amine	621647						
98 N-Nitrosodiphenylamine	86306					5.0 ac	16 ac
99 Phenanthrene	85018						

A			B Freshwater		C Saltwater		D Human Health (10^{-6} risk for carcinogens) For consumption of:	
(#) Compound		CAS Number	Criterion Maximum Conc.[d] (µg/L)	Criterion Continuous Conc.[d] (µg/L)	Criterion Maximum Conc.[d] (µg/L)	Criterion Continuous Conc.[d] (µg/L)	Water & Organisms (µg/L)	Organisms Only (µg/L)
			B1	B2	C1	C2	D1	D2
100	Pyrene	129000	.....	.....	.....	.....	960 a	11000 a
101	1,2,4-Trichlorobenzene	120821	.....	.....	.....	.....	.....	.....
102	Aldrin	309002	3 g	.....	1.3 g	.....	0.00013 ac	0.00014 ac
103	alpha-BHC	319846	.....	.....	.....	.....	0.0039 ac	0.013 ac
104	beta-BHC	319857	.....	.....	.....	.....	0.014 ac	0.046 ac
105	gamma-BHC	58899	2 g	0.08 g	0.16 g	.....	0.019 c	0.063 c
106	delta-BHC	319868	.....	.....	.....	.....	.....	.....
107	Chlordane	57749	2.4 g	0.0043 g	0.09 g	0.004 g	0.00057 ac	0.00059 ac
108	4,4′-DDT	50293	1.1 g	0.001 g	0.13 g	0.001 g	0.00059 ac	0.00059 ac
109	4,4′-DDE	72559	.....	.....	.....	.....	0.00059 ac	0.00059 ac
110	4,4′-DDD	72548	.....	.....	.....	.....	0.00083 ac	0.00084 ac
111	Dieldrin	60571	2.5 g	0.0019 g	0.71 g	0.0019 g	0.00014 ac	0.00014 ac
112	alpha-Endosulfan	959988	0.22 g	0.056 g	0.034 g	0.0087 g	0.93 a	2.0 a
113	beta-Endosulfan	33213659	0.22 g	0.056 g	0.034 g	0.0087 g	0.93 a	2.0 a
114	Endosulfan Sulfate	1031078	.....	.....	.....	.....	0.93 a	2.0 a
115	Endrin	72208	0.18 g	0.0023 g	0.037 g	0.0023 g	0.76 a	0.81 aj
116	Endrin Aldehyde	7421934	.....	.....	.....	.....	0.76 a	0.81 aj
117	Heptachlor	76448	0.52 g	0.0038 g	0.053 g	0.0036 g	0.00021 ac	0.00021 ac
118	Heptachlor Epoxide	1024573	0.52 g	0.0038 g	0.053 g	0.0036 g	0.00010 ac	0.00011 ac
119	PCB–1242	53469219	.....	0.014 g	.....	0.03 g	.....	.....
120	PCB–1254	11097691	.....	0.014 g	.....	0.03 g	.....	.....
121	PCB–1221	11104282	.....	0.014 g	.....	0.03 g	.....	.....
122	PCB–1232	11141165	.....	0.014 g	.....	0.03 g	.....	.....
123	PCB–1248	12672296	.....	0.014 g	.....	0.03 g	.....	.....
124	PCB–1260	11096825	.....	0.014 g	.....	0.03 g	.....	.....
125a	PCB–1016	12674112	.....	0.014 g	.....	0.03 g	.....	.....
125b	Polychlorinated biphenyls (PCBs)	.....	.....	.....	.....	.....	0.00017 q	0.00017 q
126	Toxaphene	8001352	0.73	0.0002	0.21	0.0002	0.00073 ac	0.00075 ac
	Total Number of Criteria (h) =	.....	24	29	23	27	85	84

FOOTNOTES

a. Criteria revised to reflect current agency q_1* or RfD, as contained in the Integrated Risk Information System (IRIS). The fish tissue bioconcentration factor (BCF) from the 1980 criteria documents was retained in all cases.

b. The criteria refers to the inorganic form only.

c. Criteria in the matrix based on carcinogenicity (10^{-6} risk). For a risk level of 10^{-5}, move the decimal point in the matrix value one place to the right.

d. Criteria Maximum Concentration (CMC) = the highest concentration of a pollutant to which aquatic life can be exposed for a short period of time (1-hour average) without deleterious effects. Criteria Continuous Concentration (CCC) = the highest concentration of a pollutant to which aquatic life can be exposed for an extended period of time (4 days) without deleterious effects. µg/L = micrograms per liter.

e. Freshwater aquatic life criteria for these metals are expressed as a function of total hardness (mg/L as $CaCO_3$), the pollutant's water effect ratio (WER) as defined in §131.36(c) and multiplied by an appropriate dissolved conversion factor as defined in §131.36(b)(2). For comparative purposes, the values displayed in this matrix are shown as dissolved metal and correspond to a total hardness of 100 mg/L and a water effect ratio of 1.0.

f. Freshwater aquatic life criteria for pentachlorophenol are expressed as a function of pH, and are calculated as follows. Values displayed above in the matrix correspond to a pH of 7.8.

$$CMC = \exp(1.005(pH) - 4.830)$$
$$CCC = \exp(1.005(pH) - 5.290)$$

g. Aquatic life criteria for these compounds were issued in 1980 utilizing the 1980 Guidelines for criteria development. The acute values shown are final acute values (FAV) which by the 1980 Guidelines are instantaneous values as contrasted with a CMC which is a one-hour average.

h. These totals simply sum the criteria in each column. For aquatic life, there are 31 priority toxic pollutants with some type of freshwater or saltwater, acute or chronic criteria. For human health, there are 85 priority toxic pollutants with either ''water + fish'' or ''fish only'' criteria. Note that these totals count chromium as one pollutant even though EPA has developed criteria based on two valence states. In the matrix, EPA has assigned numbers 5a and 5b to the criteria for chromium to reflect the fact that the list of 126 priority toxic pollutants includes only a single listing for chromium.

i. If the CCC for total mercury exceeds 0.012 µg/l more than once in a 3-year period in the ambient water, the edible portion of aquatic species of concern must be analyzed to determine whether the concentration of methyl mercury exceeds the FDA action level (1.0 mg/kg). If the FDA action level is exceeded, the State must notify the appropriate EPA Regional Administrator, initiate a revision of its mercury criterion in its water quality standards so as to protect designated uses, and take other appropriate action such as issuance of a fish consumption advisory for the affected area.

j. No criteria for protection of human health from consumption of aquatic organisms (excluding water) was presented in the 1980 criteria document or in the 1986 Quality Criteria for Water. Nevertheless, sufficient information was presented in the 1980 document to allow a calculation of a criterion, even though the results of such a calculation were not shown in the document.

k. The criterion for asbestos is the MCL (56 FR 3526, January 30, 1991).

l. [Reserved: This letter not used as a footnote.]

m. Criteria for these metals are expressed as a function of the water effect ratio, WER, as defined in 40 CFR 131.36(c).

$$CMC = \text{column B1 or C1 value} \times WER$$
$$CCC = \text{column B2 or C2 value} \times WER$$

n. EPA is not promulgating human health criteria for this contaminant. However, permit authorities should address this contaminant in NPDES permit actions using the State's existing narrative criteria for toxics.

o. [Reserved: This letter not used as a footnote.]

p. Criterion expressed as total recoverable.

q. This criterion applies to total PCBs (*e.g.*, the sum of all congener or isomer or homolog or Aroclor analyses).

GENERAL NOTES

1. This chart lists all of EPA's priority toxic pollutants whether or not criteria recommendations are available. Blank spaces indicate the absence of criteria recommendations. Because of variations in chemical nomenclature systems, this listing of toxic pollutants does not duplicate the listing in Appendix A of 40 CFR Part 423. EPA has added the Chemical Abstracts Service (CAS) registry numbers, which provide a unique identification for each chemical.

2. The following chemicals have organoleptic based criteria recommendations that are not included on this chart (for reasons which are discussed in the preamble): copper, zinc, chlorobenzene, 2-chlorophenol, 2,4-dichlorophenol, acenaphthene, 2,4-dimethylphenol, 3-methyl-4-chlorophenol, hexachlorocyclopentadiene, pentachlorophenol, phenol.

3. For purposes of this rulemaking, freshwater criteria and saltwater criteria apply as specified in 40 CFR 131.36(c).

NOTE TO PARAGRAPH (B)(1): On April 14, 1995, the Environmental Protection Agency issued

a stay of certain criteria in paragraph (b)(1) of this section as follows: the criteria in columns B and C for arsenic, cadmium, chromium (VI), copper, lead, nickel, silver, and zinc; the criteria in B1 and C1 for mercury; the criteria in column B for chromium (III); and the criteria in column C for selenium. The stay remains in effect until further notice.

(2) Factors for Calculating Hardness-Dependent, Freshwater Metals Criteria

CMC=WER exp { m_A[ln(hardness)]+b_A} x Acute Conversion Factor

CCC=WER exp { m_C[ln(hardness)]+b_C} x Chronic Conversion Factor

Final CMC and CCC values should be rounded to two significant figures.

Metal	m_A	b_A	m_C	b_C	Freshwater conversion factors	
					Acute	Chronic
Cadmium	1.128	–3.828	0.7852	–3.490	[a] 0.944	[a] 0.909
Chromium (III)	0.8190	3.688	0.8190	1.561	0.316	0.860
Copper	0.9422	–1.464	0.8545	–1.465	0.960	0.960
Lead	1.273	-1.460	1.273	–4.705	[a] 0.791	[a] 0.791
Nickel	0.8460	3.3612	0.8460	1.1645	0.998	0.997
Silver	1.72	–6.52	[b] N/A	[b] N/A	0.85	[b] N/A
Zinc	0.8473	0.8604	0.8473	0.7614	0.978	0.986

Note to table: The term ''exp'' represents the base e exponential function.

Footnotes to table:

[a] The freshwater conversion factors (CF) for cadmium and lead are hardness-dependent and can be calculated for any hardness [see limitations in § 131.36(c)(4)] using the following equations:

Cadmium
Acute: CF=1.136672—[(ln hardness)(0.041838)]
Chronic: CF=1.101672—[(ln hardness)(0.041838)]
Lead (Acute and Chronic): CF = 1.46203—[(ln hardness)(0.145712)]

[b] No chronic criteria are available for silver.

(c) *Applicability*. (1) The criteria in paragraph (b) of this section apply to the States' designated uses cited in paragraph (d) of this section and supersede any criteria adopted by the State, except when State regulations contain criteria which are more stringent for a particular use in which case the State's criteria will continue to apply.

(2) The criteria established in this section are subject to the State's general rules of applicability in the same way and to the same extent as are the other numeric toxics criteria when applied to the same use classifications including mixing zones, and low flow values below which numeric standards can be exceeded in flowing fresh waters.

(i) For all waters with mixing zone regulations or implementation procedures, the criteria apply at the appropriate locations within or at the boundary of the mixing zones; otherwise the criteria apply throughout the waterbody including at the end of any discharge pipe, canal or other discharge point.

(ii) A State shall not use a low flow value below which numeric standards can be exceeded that is less stringent than the following for waters suitable for the establishment of low flow return frequencies (i.e., streams and rivers):

AQUATIC LIFE	
Acute criteria (CMC)	1 Q 10 or 1 B 3
Chronic criteria (CCC)	7 Q 10 or 4 B 3
HUMAN HEALTH	
Non-carcinogens	30 Q 5
Carcinogens	Harmonic mean flow

Where:

CMC—criteria maximum concentration—the water quality criteria to protect against acute effects in aquatic life and is the highest instream concentration of a priority toxic pollutant consisting of a one-hour average not to be exceeded more than once every three years on the average;

CCC—criteria continuous concentration—the water quality criteria to protect against chronic effects in aquatic life is the highest instream concentration of a priority toxic pollutant consisting of a 4-day average not to be exceeded more than once every three years on the average;

1 Q 10 is the lowest one day flow with an average recurrence frequency of once in 10 years determined hydrologically;

1 B 3 is biologically based and indicates an allowable exceedence of once every 3 years. It is determined by EPA's computerized method (DFLOW model);

7 Q 10 is the lowest average 7 consecutive day low flow with an average recurrence frequency of once in 10 years determined hydrologically;

4 B 3 is biologically based and indicates an allowable exceedence for 4 consecutive days once every 3 years. It is determined by EPA's computerized method (DFLOW model);

30 Q 5 is the lowest average 30 consecutive day low flow with an average recurrence frequency of once in 5 years determined hydrologically; and the harmonic mean flow is a long term mean flow value calculated by dividing the number of daily flows analyzed by the sum of the reciprocals of those daily flows.

(iii) If a State does not have such a low flow value for numeric standards compliance, then none shall apply and the criteria included in paragraph (d) of this section herein apply at all flows.

(3) The aquatic life criteria in the matrix in paragraph (b) of this section apply as follows:

(i) For waters in which the salinity is equal to or less than 1 part per thousand 95% or more of the time, the applicable criteria are the freshwater criteria in Column B;

(ii) For waters in which the salinity is equal to or greater than 10 parts per thousand 95% or more of the time, the applicable criteria are the saltwater criteria in Column C; and

(iii) For waters in which the salinity is between 1 and 10 parts per thousand as defined in paragraphs (c)(3) (i) and (ii) of this section, the applicable criteria are the more stringent of the freshwater or saltwater criteria. However, the Regional Administrator may approve the use of the alternative freshwater or saltwater criteria if scientifically defensible information and data demonstrate that on a site-specific basis the biology of the waterbody is dominated by freshwater aquatic life and that freshwater criteria are more appropriate; or conversely, the biology of the waterbody is dominated by saltwater aquatic life and that saltwater criteria are more appropriate.

(4) *Application of metals criteria.* (i) For purposes of calculating freshwater aquatic life criteria for metals from the equations in paragraph (b)(2) of this section, the minimum hardness allowed for use in those equations shall not be less than 25 mg/l, as calcium carbonate, even if the actual ambient hardness is less than 25 mg/l as calcium carbonate. The maximum hardness value for use in those equations shall not exceed 400 mg/l as calcium carbonate, even if the actual ambient hardness is greater than 400 mg/l as calcium carbonate. The same provisions apply for calculating the metals criteria for the comparisons provided for in paragraph (c)(3)(iii) of this section.

(ii) The hardness values used shall be consistent with the design discharge conditions established in paragraph (c)(2) of this section for flows and mixing zones.

(iii) Except where otherwise noted, the criteria for metals (compounds #2, #4–# 11, and #13, in paragraph (b) of this section) are expressed as dissolved metal. For purposes of calculating aquatic life criteria for metals from the equations in footnote m. in the criteria matrix in paragraph (b)(1) of this section and the equations in paragraphs (b)(2) of this section, the water-effect ratio is computed as a specific pollutant's acute or chronic toxicity values measured in water from the site covered by the standard, divided by the respective acute or chronic toxicity value in laboratory dilution water.

(d) *Criteria for Specific Jurisdictions*—(1) *Rhode Island, EPA Region 1.* (i) All waters assigned to the following use classifications in the Water Quality Regulations for Water Pollution Control adopted under Chapters 46–12, 42–17.1, and 42–35 of the General Laws of Rhode Island are subject to the criteria in paragraph (d)(1)(ii) of this section, without exception:

6.21 Freshwater	6.22 Saltwater:
Class A	Class SA
Class B	Class SB
Class C	Class SC

(ii) The following criteria from the matrix in paragraph (b)(1) of this section apply to the use classifications identified in paragraph (d)(1)(i) of this section:

Use classification	Applicable criteria
Class A Class B waters where water supply use is designated	These classifications are assigned the criteria in Column D1—#2, 68

Use classification	Applicable criteria
Class B waters where water supply use is not designated. Class C; Class SA; Class SB; Class SC	Each of these classifications is assigned the criteria in: Column D2—#2, 68

(iii) The human health criteria shall be applied at the 10^{-5} risk level, consistent with the State policy. To determine appropriate value for carcinogens, see footnote c in the criteria matrix in paragraph (b)(1) of this section.

(2) *Vermont, EPA Region 1.* (i) All waters assigned to the following use classifications in the Vermont Water Quality Standards adopted under the authority of the Vermont Water Pollution Control Act (10 V.S.A., Chapter 47) are subject to the criteria in paragraph (d)(2)(ii) of this section, without exception:

Class A
Class B
Class C

(ii) The following criteria from the matrix in paragraph (b)(1) of this section apply to the use classifications identified in paragraph (d)(2)(i) of this section:

Use classification	Applicable criteria
Class A	This classification is assigned criteria in:
Class B waters where water supply use is designated	Column B2—#105
Class B waters where water supply use is not designated Class C.	These classifications are assigned all the criteria in: Column B2—#105 Column D2—#2

(iii) The human health criteria shall be applied at the State-proposed 10^{-6} risk level.

(3) *New Jersey, EPA Region 2.* (i) All waters assigned to the following use classifications in the New Jersey Administrative Code (N.J.A.C.) 7:9–4.1 et seq., Surface Water Quality Standards, are subject to the criteria in paragraph (d)(3)(ii) of this section, without exception.

N.J.A.C. 7:9–4.12(b): Class PL
N.J.A.C. 7:9–4.12(c): Class FW2
N.J.A.C. 7:9–4.12(d): Class SE1
N.J.A.C. 7:9–4.12(e): Class SE2
N.J.A.C. 7:9–4.12(f): Class SE3
N.J.A.C. 7:9–4.12(g): Class SC
N.J.A.C. 7:9–4.13(a): Delaware River Zones 1C, 1D, and 1E
N.J.A.C. 7:9–4.13(b): Delaware River Zone 2
N.J.A.C. 7:9–4.13(c): Delaware River Zone 3
N.J.A.C. 7:9–4.13(d): Delaware River Zone 4
N.J.A.C. 7:9–4.13(e): Delaware River Zone 5
N.J.A.C. 7:9–4.13(f): Delaware River Zone 6

(ii) The following criteria from the matrix in paragraph (b)(1) of this section apply to the use classifications identified in paragraph (d)(3)(i) of this section:

Use classification	Applicable criteria
PL (Freshwater Pinelands), FW2	These classifications are assigned the criteria in: Column B1—all except #102, 105, 107, 108, 111, 112, 113, 115, 117, and 118. Column B2—all except #105, 107, 108, 111, 112, 113, 115, 117, 118, 119, 120, 121, 122, 123, 124, and 125a. Column D1—all at a 10^{-6} risk level except #23, 30, 37, 38, 42, 68, 89, 91, 93, 104, 105; #23, 30, 37, 38, 42, 68, 89, 91, 93, 104, 105, at a 10^{-5} risk level. Column D2—all at a 10^{-6} risk level except #23, 30, 37, 38, 42, 68, 89, 91, 93, 104, 105; #23, 30, 37, 38, 42, 68, 89, 91, 93, 104, 105, at a 10^{-5} risk level.
PL (Saline Water Pinelands), SE1, SE2, SE3, SC	These classifications are each assigned the criteria in: Column C1—all except #102, 105, 107, 108, 111, 112, 113, 115, 117, and 118. Column C2—all except #105, 107, 108, 111, 112, 113, 115, 117, 118, 119, 120, 121, 122, 123, 124, and 125a. Column D2—all at a 10^{-6} risk level except #23, 30, 37, 38, 42, 68, 89, 91, 93, 104, 105; #23, 30, 37, 38, 42, 68, 89, 91, 93, 104, 105, at a 10^{-5} risk level.
Delaware River zones 1C, 1D, 1E, 2, 3, 4, 5 and Delaware Bay zone 6	These classifications are each assigned the criteria in: Column B1—all. Column B2—all.

Use classification	Applicable criteria
	Column D1—all at a 10^{-6} risk level except #23, 30, 37, 38, 42, 68, 89, 91, 93, 104, 105; #23, 30, 37, 38, 42, 68, 89, 91, 93, 104, 105, at a 10^{-5} risk level. Column D2—all at a 10^{-6} risk level except #23, 30, 37, 38, 42, 68, 89, 91, 93, 104, 105; #23, 30, 37, 38, 42, 68, 89, 91, 93, 104, 105, at a 10^{-5} risk level.
Delaware River zones 3, 4, and 5, and Delaware Bay zone 6	These classifications are each assigned the criteria in: Column C1—all. Column C2—all. Column D2—all at a 10^{-6} risk level except #23, 30, 37, 38, 42, 68, 89, 91, 93, 104, 105; #23, 30, 37, 38, 42, 68, 89, 91, 93, 104, 105, at a 10^{-5} risk level.

(iii) The human health criteria shall be applied at the State-proposed 10^{-6} risk level for EPA rated Class A, B_1, and B_2 carcinogens; EPA rated Class C carcinogens shall be applied at 10^{-5} risk level. To determine appropriate value for carcinogens, see footnote c. in the matrix in paragraph (b)(1) of this section.

(4) *Puerto Rico, EPA Region 2.* (i) All waters assigned to the following use classifications in the Puerto Rico Water Quality Standards (promulgated by Resolution Number R–83–5–2) are subject to the criteria in paragraph (d)(4)(ii) of this section, without exception.

Article 2.2.2—Class SB
Article 2.2.3—Class SC
Article 2.2.4—Class SD

(ii) The following criteria from the matrix in paragraph (b)(1) of this section apply to the use classifications identified in paragraph (d)(4)(i) of this section:

Use classification	Applicable criteria
Class SD	This Classification is assigned criteria in: Column B1—all, except: 10, 102, 105, 107, 108, 111, 112, 113, 115, 117, and 126. Column B2—all, except: 105, 107, 108, 112, 113, 115, and 117. Column D1—all, except: 6, 14, 105, 112, 113, and 115. Column D2—all, except: 14, 105, 112, 113, and 115.
Class SB, Class SC	These Classifications are assigned criteria in: Column C1—all, except: 4, 5b, 7, 8, 10, 11, 13, 102, 105, 107, 108, 111, 112, 113, 115, 117, and 126. Column C2—all, except: 4, 5b, 10, 13, 108, 112, 113, 115, and 117. Column D2—all, except: 14, 105, 112, 113, and 115.

(iii) The human health criteria shall be applied at the State-proposed 10^{-5} risk level. To determine appropriate value for carcinogens, see footnote c, in the criteria matrix in paragraph (b)(1) of this section.

(5) *District of Columbia, EPA Region 3.*

(i) All waters assigned to the following use classifications in chapter 11 Title 21 DCMR, Water Quality Standards of the District of Columbia are subject to the criteria in paragraph (d)(5)(ii) of this section, without exception:

1101.2 Class C waters

(ii) The following criteria from the matrix in paragraph (b)(1) of this section apply to the use classification identified in paragraph (d)(5)(i) of this section:

Use classification	Applicable criteria
Class C	This classification is assigned the additional criteria in: Column B2—#10, 118, 126 Column D1—#15, 16, 44, 67, 68, 79, 80, 81, 88, 114, 116, 118.

(iii) The human health criteria shall be applied at the State-adopted 10^{-6} risk level.

(6) *Florida, EPA Region 4.*

(i) All waters assigned to the following use classifications in Chapter 17–301 of the Florida Administrative Code (i.e., identified in Section 17–302.600) are subject to the criteria in paragraph (d)(6)(ii) of this section, without exception:

Class I
Class II
Class III

(ii) The following criteria from the matrix paragraph (b)(1) of this section apply to the use classifications identified in paragraph (d)(6)(i) of this section:

Use classification	Applicable criteria
Class I	This classification is assigned the criteria in: Column D1—#16
Class II Class III (marine)	This classification is assigned the criteria in: Column D2—#16
Class III (freshwater)	This classification is assigned the criteria in: Column D2—#16

(iii) The human health criteria shall be applied at the State-adopted 10^{-6} risk level.

(7) *Michigan, EPA Region 5.*

(i) All waters assigned to the following use classifications in the Michigan Department of Natural Resources Commission General Rules, R 323.1100 designated uses, as defined at R 323.1043. Definitions; A to N, (i.e., identified in Section (g) ''Designated use'') are subject to the criteria in paragraph (d)(7)(ii) of this section, without exception:

Agriculture
Navigation
Industrial Water Supply
Public Water Supply at the Point of Water Intake
Warmwater Fish
Other Indigenous Aquatic Life and Wildlife
Partial Body Contact Recreation

(ii) The following criteria from the matrix in paragraph (b)(1) of this section apply to the use classifications identified in paragraph (d)(7)(i) of this section:

Use classification	Applicable criteria
Public Water supply	This classification is assigned the criteria in: Column B1—all, Column B2—all, Column D1—all.
All other designations	These classifications are assigned the criteria in: Column B1—all, Column B2—all, and Column D2—all.

(iii) The human health criteria shall be applied at the State-adopted 10^{-5} risk level. To determine appropriate value for carcinogens, see footnote c in the criteria matrix in paragraph (b)(1) of this section.

(8) *Arkansas, EPA Region 6.*

(i) All waters assigned to the following use classification in section 4C (Waterbody uses) identified in Arkansas Department of Pollution Control and Ecology's Regulation No. 2 as amended and entitled, ''Regulation Establishing Water Quality Standards for Surface Waters of the State of Arkansas'' are subject to the criteria in paragraph (d)(8)(ii) of this section, without exception:

Extraordinary Resource Waters
Ecologically Sensitive Waterbody
Natural and Scenic Waterways
Fisheries:
  (1) Trout
  (2) Lakes and Reservoirs
  (3) Streams
    (a) Ozark Highlands Ecoregion
    (b) Boston Mountains Ecoregion
    (c) Arkansas River Valley Ecoregion
    (d) Ouachita Mountains Ecoregion
    (e) Typical Gulf Coastal Ecoregion
    (f) Spring Water-influenced Gulf Coastal Ecoregion
    (g) Least-altered Delta Ecoregion
    (h) Channel-altered Delta Ecoregion
Domestic Water Supply

(ii) The following criteria from the matrix in paragraph (b)(1) of this section apply to the use classification identified in paragraph (d)(8)(i) of this section:

Use classification	Applicable criteria
Extraordinary Resource Waters Ecologically Sensitive Waterbody Natural and Scenic Waterways Fisheries: (1) Trout (2) Lakes and Reservoirs (3) Streams (a) Ozark Highlands Ecoregion (b) Boston Mountains Ecoregion (c) Arkansas River Valley Ecoregion (d) Ouachita Mountains Ecoregion (e) Typical Gulf Coastal Ecoregion (f) Spring Water-influenced Gulf Coastal Ecoregion (g) Least-altered Delta Ecoregion (h) Channel-altered Delta Ecoregion	These uses are each assigned the criteria in— Column B1—#4, 5a, 5b, 6, 7, 8, 9, 10, 11, 13, 14 Column B2—#4, 5a, 5b, 6, 7, 8, 9, 10, 13, 14

(9) *Kansas, EPA Region 7.*

(i) All waters assigned to the following use classification in the Kansas Department of Health and Environment regulations, K.A.R. 28–16–28b through K.A.R. 28–16–28f, are subject to the criteria in paragraph (d)(9)(ii) of this section, without exception.

Section (2)(A)—Special Aquatic Life Use Waters
Section (2)(B)—Expected Aquatic Life Use Waters
Section (2)(C)—Restricted Aquatic Life Use Waters
Section (3)—Domestic Water Supply.
Section (4)—Food Procurement Use.

(ii) The following criteria from the matrix in paragraph (b)(1) of this section apply to the use classifications identified in paragraph (d)(9)(i) of this section:

Use classification	Applicable criteria
Sections (2)(A), (2)(B), (2)(C), (4).	These classifications are each assigned criteria as follows: Column B1, #2, 4 Column B2, #4 Column D2, #2, 12, 21, 29, 39, 46, 68, 79, 81, 86, 93, 104, 114, 118
Section (3)	This classification is assigned all criteria in: Column D1, all except #1, 9, 12, 14, 15, 17, 22, 33, 36, 39, 44, 75, 77, 79, 90, 112, 113, and 115.

(iii) The human health criteria shall be applied at the State-adopted 10^{-6} risk level.

(10) *California, EPA Region 9.*

(i) All waters assigned any aquatic life or human health use classifications in the Water Quality Control Plans for the various Basins of the State (''Basin Plans''), as amended, adopted by the California State Water Resources Control Board (''SWRCB''), except for ocean waters covered by the Water Quality Control Plan for Ocean Waters of California (''Ocean Plan'') adopted by the SWRCB with resolution Number 90–27 on March 22, 1990, are subject to the criteria in paragraph (d)(10)(ii) of this section, without exception. These criteria amend the portions of the existing State standards contained in the Basin Plans. More particularly these criteria amend water quality criteria contained in the Basin Plan Chapters specifying water quality objectives (the State equivalent of federal water quality criteria) for the toxic pollutants identified in paragraph (d)(10)(ii) of this section. Although the State has adopted several use designations for each of these waters, for purposes of this action, the specific standards to be applied in paragraph (d)(10)(ii) of this section are based on the presence in all waters of some aquatic life designation and the presence or absence of the MUN use designation (Municipal and domestic supply). (See Basin Plans for more detailed use definitions.)

(ii) The following criteria from the matrix in paragraph (b)(1) of this section apply to the water and use classifications defined in paragraph (d)(10)(i) of this section and identified below:

Water and use classification	Applicable criteria
Waters of the State defined as bays or estuaries except the Sacramento-San Joaquin Delta and San Francisco Bay	These waters are assigned the criteria in: Column B1—pollutants 5a and 14 Column B2—pollutants 5a and 14 Column C1—pollutant 14 Column C2—pollutant 14 Column D2—pollutants 1, 12, 17, 18, 21, 22, 29, 30, 32, 33, 37, 38, 42–44, 46, 48, 49, 54, 59, 66, 67, 68, 78–82, 85, 89, 90, 91, 93, 95, 96, 98
Waters of the Sacramento—San Joaquin Delta and waters of the State defined as inland (i.e., all surface waters of the State not bays or estuaries or ocean) that include a MUN use designation	These waters are assigned the criteria in: Column B1—pollutants 5a and 14 Column B2—pollutants 5a and 14 Column D1—pollutants 1, 12, 15, 17, 18, 21, 22, 29, 30, 32, 33, 37, 38, 42–48, 49, 59, 66, 67, 68, 78–82, 85, 89, 90, 91, 93, 95, 96, 98
Waters of the State defined as inland without an MUN use designation	These waters are assigned the criteria in: Column B1—pollutants 5a and 14 Column B2—pollutants 5a and 14 Column D2—pollutants 1, 12, 17, 18, 21, 22, 29, 30, 32, 33, 37, 38, 42–44, 46, 48, 49, 54, 59, 66, 67, 68, 78–82, 85, 89, 90, 91, 93, 95, 96, 98
Waters of the San Joaquin River from the mouth of the Merced River to Vernalis	In addition to the criteria assigned to these waters elsewhere in this rule, these waters are assigned the criteria in: Column B2—pollutant 10
Waters of Salt Slough, Mud Slough (north) and the San Joaquin River, Sack Dam to the mouth of the Merced River	In addition to the criteria assigned to these waters elsewhere in this rule, these waters are assigned the criteria in: Column B1—pollutant 10 Column B2—pollutant 10
Waters of San Francisco Bay upstream to and including Suisun Bay and the Sacramento-San Joaquin Delta	These waters are assigned the criteria in: Column B1—pollutants 5a, 10* and 14 Column B2—pollutants 5a, 10* and 14 Column C1—pollutant 14 Column C2—pollutant 14 Column D2—pollutants 1, 12, 17, 18, 21, 22, 29, 30, 32, 33, 37, 38, 42–44, 46, 48, 49, 54, 59, 66, 67, 68, 78–82, 85, 89, 90, 91, 93, 95, 96, 98

Water and use classification	Applicable criteria
All inland waters of the United States or enclosed bays and estuaries that are waters of the United States that include an MUN use designation and that the State has either excluded or partially excluded from coverage under its Water Quality Control Plan for Inland Surface Waters of California, Tables 1 and 2, or its Water Quality Control Plan for Enclosed Bays and Estuaries of California, Tables 1 and 2, or has deferred applicability of those tables. (Category (a), (b), and (c) waters described on page 6 of Water Quality Control Plan for Inland Surface Waters of California or page 6 of its Water Quality Control Plan for Enclosed Bays and Estuaries of California.)	These waters are assigned the criteria for pollutants for which the State does not apply Table 1 or 2 standards. These criteria are: Column B1—all pollutants Column B2—all pollutants Column D1—all pollutants except #2
All inland waters of the United States that do not include an MUN use designation and that the State has either excluded or partially excluded from coverage under its Water Quality Control Plan for Inland Surface Waters of California, Tables 1 and 2, or has deferred applicability of these tables. (Category (a), (b), and (c) waters described on page 6 of Water Quality Control Plan for Inland Surface Waters of California.)	These waters are assigned the criteria for pollutants for which the State does not apply Table 1 or 2 standards. These criteria are: Column B1—all pollutants Column B2—all pollutants Column D2—all pollutants except #2
All enclosed bays and estuaries that are waters of the United States that do not include an MUN designation and that the State has either excluded or partially excluded from coverage under its Water Quality Control Plan for Inland Surface Waters of California, Tables 1 and 2, or its Water Quality Control Plan for Enclosed Bays and Estuaries of California, Tables 1 and 2, or has deferred applicability of those tables. (Category (a), (b), and (c) waters described on page 6 of Water Quality Control Plan for Inland Surface Waters of California or page 6 of its Water Quality Control Plan for Enclosed Bays and Estuaries of California.)	These waters are assigned the criteria for pollutants for which the State does not apply Table 1 or 2 standards. These criteria are: Column B1—all pollutants Column B2—all pollutants Column C1—all pollutants Column C2—all pollutants Column D2—all pollutants except #2

*The fresh water selenium criteria are included for the San Francisco Bay estuary because high levels of bioaccumulation of selenium in the estuary indicate that the salt water criteria are underprotective for San Francisco Bay.

(iii) The human health criteria shall be applied at the State-adopted 10^{-6} risk level.

(11) *Nevada, EPA Region 9.* (i) All waters assigned the use classifications in Chapter 445 of the Nevada Administrative Code (NAC), Nevada Water Pollution Control Regulations, which are referred to in paragraph (d)(11)(ii) of this section, are subject to the criteria in paragraph (d)(11)(ii) of this section, without exception. These criteria amend the existing State standards contained in the Nevada Water Pollution Control Regulations. More particularly, these criteria amend or supplement the table of numeric standards in NAC 445.1339 for the toxic pollutants identified in paragraph (d)(11)(ii) of this section.

(ii) The following criteria from matrix in paragraph (b)(1) of this section apply to the waters defined in paragraph (d)(11)(i) of this section and identified below:

Water and use classification	Applicable criteria
Waters that the State has included in NAC 445.1339 where Municipal or domestic supply is a designated use	These waters are assigned the criteria in: Column B1—pollutant #118 Column B2—pollutant #118 Column D1—pollutants #15, 16, 18, 19, 20, 21, 23, 26, 27, 29, 30, 34, 37, 38, 42, 43, 55, 58–62, 64, 66, 73, 74, 78, 82, 85, 87–89, 91, 92, 96, 98, 100, 103, 104, 105, 114, 116, 117, 118
Waters that the State has included in NAC 445.1339 where Municipal or domestic supply is not a designated use	These waters are assigned the criteria in: Column B1—pollutant #118 Column B2—pollutant #118 Column D2—all pollutants except #2.

(iii) The human health criteria shall be applied at the 10^{-5} risk level, consistent with State policy. To determine appropriate value for carcinogens, see footnote c in the criteria matrix in paragraph (b)(1) of this section.

(12) *Alaska, EPA Region 10.*

(i) All waters assigned to the following use classifications in the Alaska Administrative Code (AAC), Chapter 18 (i.e., identified in 18 AAC 70.020) are subject to the criteria in paragraph (d)(12)(ii) of this section, without exception:

70.020.(1) (A) Fresh Water
70.020.(1) (A) Water Supply
(i) Drinking, culinary, and food processing,
(iii) Aquaculture;
70.020.(1) (B) Water Recreation
(i) Contact recreation,
(ii) Secondary recreation;
70.020.(1) (C) Growth and propagation of fish, shellfish, other aquatic life, and wildlife
70.020.(2) (A) Marine Water
70.020.(2) (A) Water Supply
(i) Aquaculture,
70.020.(2) (B) Water Recreation
(i) contact recreation,
(ii) secondary recreation;
70.020.(2) (C) Growth and propagation of fish, shellfish, other aquatic life, and wildlife;
70.020.(2) (D) Harvesting for consumption of raw mollusks or other raw aquatic life.

(ii) The following criteria from the matrix in paragraph (b)(1) of this section apply to the use classifications identified in paragraph (d)(12)(i) of this section:

Use classification	Applicable criteria
(1)(A) i	Column B1—#9, 10, 13, 53, and 126 Column B2—#10 Column D1 #'s 16, 18–21, 23, 26, 27, 29, 30, 32, 37, 38, 42–44, 53, 55, 59–62, 64, 66, 68, 73, 74, 78, 82, 85, 88, 89, 91–93, 96, 98, 102–105, 107–111, 117–126
(1)(A) iii	Column B1—#9, 10, 13, 53, and 126 Column B2—#10 Column D2 #'s 14, 16, 18–21, 22, 23, 26, 27, 29, 30, 32, 37, 38, 42–44, 46, 53, 54, 55, 59–62, 64, 66, 68, 73, 74, 78, 82, 85, 88–93, 95, 96, 98, 102–105, 107–111, 115–126
(1)(B)i, (1)(B) ii, (1)(C)	Column B1—#9, 10, 13, 53, and 126 Column B2—#10 Column D2 #'s 14, 16, 18–21, 22, 23, 26, 27, 29, 30, 32, 37, 38, 42–44, 46, 53, 54, 55, 59–62, 64, 66, 68, 73, 74, 78, 82, 85, 88–93, 95, 96, 98, 102–105, 107–111, 115–126
(2)(A) i, (2)(B)i, and (2)(B)ii, (2)(C), (2)(D)	Column C1—#9, 10, 13, and 53 Column C2—#10 Column D2 #'s 14, 16, 18–21, 22, 23, 26, 27, 29, 30, 32, 37, 38, 42–44, 46, 53, 54, 55, 59–62, 64, 66, 68, 73, 74, 78, 82, 85, 88–93, 95, 96, 98, 102–105, 107–111, 115–126

(iii) The human health criteria shall be applied at the State-proposed risk level of 10^{-5}. To determine appropriate value for carcinogens, see footnote c in the criteria matrix in paragraph (b)(1) of this section.

(13) [Reserved]

(14) *Washington, EPA Region 10.*

(i) All waters assigned to the following use classifications in the Washington Administrative Code (WAC), Chapter 173–201 (i.e., identified in WAC 173–201–045) are subject to the criteria in paragraph (d)(14)(ii) of this section, without exception:

173–201–045
Fish and Shellfish
Fish
Water Supply (domestic)
Recreation

(ii) The following criteria from the matrix in paragraph (b)(1) of this section apply to the use classifications identified in paragraph (d)(14)(i) of this section:

Use classification	Applicable criteria
Fish and Shellfish; Fish	These classifications are assigned the criteria in: Column C2—6, 14 Column D2—all
Water Supply (domestic)	These classifications are assigned the criteria in: Column D1—all
Recreation	This classification is assigned the criteria in: Column D2—Marine waters and freshwaters not protected for domestic water supply

(iii) The human health criteria shall be applied at the State proposed risk level of 10^{-6}.

[57 FR 60910, Dec. 22, 1992; 58 FR 31177, June 1, 1993, as amended at 58 FR 34499, June 25, 1993; 58 FR 36142, July 6, 1993; 60 FR 22229, 22235, May 4, 1995; 60 FR 44120, Aug. 24, 1995; 61 FR 60617, Nov. 29, 1996; 62 FR 52927, Oct. 9, 1997; 62 FR 53214, Oct. 10, 1997; 63 FR 10144, Mar. 2, 1998; 64 FR 61193, Nov. 9, 1999; 65 FR 19661, Apr. 12, 2000]

§ 131.37 California.

(a) *Additional criteria.* The following criteria are applicable to waters specified in the Water Quality Control Plan for Salinity for the San Francisco Bay/Sacramento-San Joaquin Delta Estuary, adopted by the California State Water Resources Control Board in State Board Resolution No. 91–34 on May 1, 1991:

(1) *Estuarine habitat criteria.* (i) *General rule.* (A) Salinity (measured at the surface) shall not exceed 2640 micromhos/centimeter specific conductance at 25 °C (measured as a 14-day moving average) at the Confluence of the Sacramento and San Joaquin Rivers throughout the period each year from February 1 through June 30, and shall not exceed 2640 micromhos/centimeter specific conductance at 25 °C (measured as a 14-day moving average) at the specific locations noted in Table 1 near Roe Island and Chipps Island for the number of days each month in the February 1 to June 30 period computed by reference to the following formula:

Number of days required in Month X = Total number of days in Month X * $(1 - 1/(1+e^{K})$

where

K = A + (B*natural logarithm of the previous month's 8-River Index);
A and B are determined by reference to Table 1 for the Roe Island and Chipps Island locations;
x is the calendar month in the February 1 to June 30 period;
and e is the base of the natural (or Napierian) logarithm.

Where the number of days computed in this equation in paragraph (a)(1)(i)(A) of this section shall be rounded to the nearest whole number of days. When the previous month's 8-River Index is less than 500,000 acre-feet, the number of days required for the current month shall be zero.

TABLE 1. CONSTANTS APPLICABLE TO EACH OF THE MONTHLY EQUATIONS TO DETERMINE MONTHLY REQUIREMENTS DESCRIBED.

Month X	Chipps Island		Roe Island (if triggered)	
	A	B	A	B
Feb	−[1]	−[1]	−14.36	+2.068
Mar	−105.16	+15.943	−20.79	+2.741
Apr	−47.17	+6.441	−28.73	+3.783
May	−94.93	+13.662	−54.22	+6.571

Appendix D.

Puget Sound Waterbody Assessment

Washington State Department of Ecology : Water Quality Program

Water Quality Assessment for Washington - Simple Query Form

Water Body Name:
Parameter:
Medium:
On 96 List ?:
On 98 List ?:
Category:
Listing ID:
Township: Range: Section: WRIA: 99

Basis

Execute Query

2004 Water Quality Assessment (Final) - Category 5 Sediment Listings

WRIA	Waterbody Name	Grid Cell Number or Twp-Rg-Sec	Combined Parameters	Basis
1	SQUALICUM CREEK	38N-02E-43	Sediment Bioassay	Blakely, 2004, shows significant Chironomus mortality in sediments collected at stations LSC02 and LSC03 in 2003. Blakely, 2004, shows significant Hyalella mortality in sediments collected at station LSC03 and LSC04 in 2003.
1	STRAIT OF GEORGIA	48122I7D1	1,2,4-Trichlorobenzene	Data from the Dept. of Ecology SEDQUAL database (stations H=INTLCO93!SIZ 012; M=INTLCO93!SIZ 014; L=INTLCO93!SIZ 013) show the average of 3 samples exceeds the Sediment Management Standards CSL chemical criterion on 4/13/1993.
1	STRAIT OF GEORGIA	48122I7E2	1,2,4-Trichlorobenzene; 1,2-Dichlorobenzene; Hexachlorobenzene; Indeno(1,2,3-cd)pyrene	Data from the Dept. of Ecology SEDQUAL database (stations H=INTLCO93!SIZ 016; M=INTLCO93!SIZ 004; L=INTLCO93!SIZ 002) show the average of 3 samples exceeds the Sediment Management Standards CSL chemical criterion on 4/13/1993.
3	PADILLA BAY, FIDALGO BAY, AND GUEMES CHANNEL	48122F5A6	Hexachlorobutadiene; 4-Methylphenol; 2-Methylphenol; Phenol; 4-Methylphenol; Pentachlorophenol; Benzyl alcohol; Benzoic acid; 2,4-Dimethylphenol; 1,2,4-Trichlorobenzene; 1,2-Dichlorobenzene	Data from the Dept. of Ecology SEDQUAL database (stations H=BIOEFF97!16-2; M=SHELL95!SDOWN; L=SHELL92!AShl3-03) show the average of 3 samples exceeds the Sediment Management Standards CSL chemical criterion on 6/4/1997.
3	PADILLA BAY, FIDALGO BAY, AND GUEMES CHANNEL	48122F5B7	1,2-Dichlorobenzene; 1,2,4-Trichlorobenzene	Data from the Dept. of Ecology SEDQUAL database (stations H=BIOEFF97!16-1; M=BIOEFF97!19-2; L=BIOEFF97!19-3) show the average of 3 samples exceeds the Sediment Management Standards CSL chemical criterion on 6/4/1997.
3	SAMISH BAY	48122F5I3	1,2,4-Trichlorobenzene; 1,2-Dichlorobenzene; 2,4-Dimethylphenol	Data from the Dept. of Ecology SEDQUAL database (stations H=PSAMP93!5; M=TXNPDS92!TX92REF3; L=PSAMP92!5) show the average of 3 samples exceeds the Sediment Management Standards CSL chemical criterion on 4/1/1993.
6	HOLMES HARBOR	48122A5D1	Hexachlorobenzene; Hexachlorobutadiene; 1,2,4-Trichlorobenzene; Benzyl alcohol; 1,2-Dichlorobenzene	Data from the Dept. of Ecology SEDQUAL database (stations H=SCLAIR94!449; M=SCLAIR94!476; L=EVTWE494!HM-05) show the average of 3 samples exceeds the Sediment Management Standards CSL chemical criterion on 5/24/1994.
6	SARATOGA PASSAGE	48122C6I3	2-Methylphenol; 2,4-Dimethylphenol; -Methylphenol; 1,2,4-Trichlorobenzene; Benzoic acid;Pentachlorophenol; Benzyl alcohol; 1,2-Dichlorobenzene	Data from the Dept. of Ecology SEDQUAL database (stations H=BIOEFF97!23-3; M=BIOEFF97!23-1; L=BIOEFF97!23-3) show the average of 3 samples exceeds the Sediment Management Standards CSL chemical criterion on 7/3/1997.

WRIA	Waterbody Name	Grid Cell Number or Twp-Rg-Sec	Combined Parameters	Basis
7	EVERETT HARBOR	48122A2A1	Sediment Bioassay	Data from the Dept. of Ecology SEDQUAL database (stations EVRT12TH*EV1205MC*EV12TH92C005*2/6/1992; EVRT12TH*EV1204MC*EV12TH92C004*2/4/1992; EVRT12TH*EV1202MC*EV12TH92C002*2/3/1992) show a significant response to sediment bioassay from samples tested in 1992.
7	PORT GARDNER AND INNER EVERETT HARBOR	47122J2H2	Phenol; Benzyl alcohol; 4-Methylphenol; 2-Methylphenol; Arsenic; 2,4-Dimethylphenol; Benzoic acid; Pentachlorophenol	Data from the Dept. of Ecology SEDQUAL database (stations H=BIOEFF97!31-3; M=BIOEFF97!31-3; L=BIOEFF97!31-2) show the average of 3 samples exceeds the Sediment Management Standards CSL chemical criterion on 6/25/1997.
7	PORT GARDNER AND INNER EVERETT HARBOR	47122J2I1	2-Methylphenol; Benzoic acid; Pentachlorophenol; 2,4-Dimethylphenol; Benzyl alcohol; 4-Methylphenol	Data from the Dept. of Ecology SEDQUAL database (stations H=BIOEFF97!29-1; M=BIOEFF97!29-1; L=BIOEFF97!29-2) show the average of 3 samples exceeds the Sediment Management Standards CSL chemical criterion on 6/26/1997.
7	PORT GARDNER AND INNER EVERETT HARBOR	47122J2I2	2-Methylphenol; 2,4-Dimethylphenol; Bis(2-ethylhexyl)phthalate; Phenol; Pentachlorophenol; 4-Methylphenol; Benzoic acid; Benzyl alcohol	Data from the Dept. of Ecology SEDQUAL database (stations H=BIOEFF97!30-2; M=BIOEFF97!30-2; L=BIOEFF97!29-3) show the average of 3 samples exceeds the Sediment Management Standards CSL chemical criterion on 6/27/1997.
7	SNOHOMISH RIVER	29N-05E-08	1,2,4-Trichlorobenzene; Hexachlorobenzene	Data from the Dept. of Ecology SEDQUAL database (stations H=EVTWE494!W4-03; M=EVTWE494!SR-01; L=EVTWE494!SR-02) show the average of 3 samples exceeds the Sediment Management Standards CSL chemical criterion on 3/31/1994.
8	ELLIOTT BAY	47122G3A3	2-Methylphenol; Acenaphthene; 2,4-Dimethylphenol; 1,2-Dichlorobenzene; 1,2,4-Trichlorobenzene; BENZO(A)ANTHRACENE; 2-Methylnaphthalene; Phenanthrene; Fluorene; Sediment Bioassay; Hexachlorobenzene; Dibenzofuran; Naphthalene; Benzoic acid; Mercury; Benzyl alcohol; LPAH; Silver; Hexachlorobutadiene	Data from the Dept. of Ecology SEDQUAL database (stations H=P53MON93!P53VG10; M=P53MON93!P53VG11; L=P53MON93!P53VG5) show the average of 3 samples exceeds the Sediment Management Standards CSL chemical criterion on 5/21/1993.
8	LAKE UNION	25N-04E-99	Sediment Bioassay	This segment will remain in Category 5 with a corrected Listing Basis field: Data from the Dept. of Ecology SEDQUAL database (stations TAMU02_E*LU-H-1*29-8107*3/13/2002; TAMU02_E*LU-H-2*29-8108*3/13/2002; TAMU02_E*LU-L-10*29-8116*3/13/2002) show a significant response to sediment bioassay from samples tested in 2002.
8	LAKE UNION	47122G3G9	Sediment Bioassay	Data from the Dept. of Ecology SEDQUAL database (stations SALIII97*5A2*97218294*5/21/1997; SALIII97*8A2*97218305*5/21/1997; SALIII97*8C3*97218307*5/21/1997) show a significant response to sediment bioassay from samples tested in 1997.

WRIA	Waterbody Name	Grid Cell Number or Twp-Rg-Sec	Combined Parameters	Basis
8	PUGET SOUND (N-CENTRAL) AND USELESS BAY	47122I3A9	2,4-Dimethylphenol; Hexachlorobenzene; 1,2,4-Trichlorobenzene; N-nitrosodiphenylamine	Data from the Dept. of Ecology SEDQUAL database (stations H=EDMDUNOC!SD01; M=EDMDUNOC!SD07; L=EDMDUNOC!SD10) show the average of 3 samples exceeds the Sediment Management Standards CSL chemical criterion on 9/12/2000.
8	PUGET SOUND (N-CENTRAL) AND USELESS BAY	47122I3B8	2,4-Dimethylphenol; 1,2-Dichlorobenzene; Bis(2-ethylhexyl)phthalate; 1,2,4-Trichlorobenzene	Data from the Dept. of Ecology SEDQUAL database (stations H=EDMOND95!E01; M=EDMOND95!E02; L=EDMOND95!E03) show the average of 3 samples exceeds the Sediment Management Standards CSL chemical criterion on 8/22/1995.
8	PUGET SOUND (N-CENTRAL) AND USELESS BAY	47122I3E4	Bis(2-ethylhexyl)phthalate; 1,2,4-Trichlorobenzene; Hexachlorobenzene	Data from the Dept. of Ecology SEDQUAL database (stations H=LYNNWD95!LO3; M=LYNNWD95!LO1; L=LYNNWD95!LO4) show the average of 3 samples exceeds the Sediment Management Standards CSL chemical criterion on 8/22/1995.
9	DUWAMISH WATERWAY AND RIVER	23N-04E-04	N-nitrosodiphenylamine; 1,4-Dichlorobenzene; 1,2-Dichlorobenzene; Hexachlorobenzene; Total PCBs; Dibenz(a,h)anthracene; 1,2,4-Trichlorobenzene; Butylbenzyl phthalate; Sediment Bioassay; Hexachlorobutadiene	Data from the Dept. of Ecology SEDQUAL database (stations H=LODRIV98!DR257; M=LODRIV98!DR294; L=LODRIV98!DR295) show the average of 3 samples exceeds the Sediment Management Standards CSL chemical criterion on 9/15/1998.
9	DUWAMISH WATERWAY AND RIVER	24N-04E-18	4-Methylphenol; Total PCBs	Data from the Dept. of Ecology SEDQUAL database (stations H=HIRIPH2!K-10; M=HIRIPH2!K-03; L=HIRIPH2!K-04) show the average of 3 samples exceeds the Sediment Management Standards CSL chemical criterion on 10/14/1991. DR31 - Duwamish/Diagonal CSO. CERCLA-NRDA. Dredged.
9	DUWAMISH WATERWAY AND RIVER	24N-04E-29	1,2-Dichlorobenzene; 1,4-Dichlorobenzene; Total PCBs; Hexachlorobenzene; Butylbenzyl phthalate; Hexachlorobutadiene; 1,2,4-Trichlorobenzene; Phenol; N-nitrosodiphenylamine; Fluoranthene	Data from the Dept. of Ecology SEDQUAL database (stations H=LODRIV98!DR171; M=LODRIV98!DR115; L=LODRIV98!DR140) show the average of 3 samples exceeds the Sediment Management Standards CSL chemical criterion on 9/23/1998.
9	DUWAMISH WATERWAY AND RIVER	24N-04E-33	4-Methylphenol; Total PCBs	Data from the Dept. of Ecology SEDQUAL database (stations H=HIRIPH2!K-05; M=HIRIPH2!K-05; L=HIRIPH2!K-05) show the average of 3 samples exceeds the Sediment Management Standards CSL chemical criterion on 10/14/1991. Boeing Plant 2. RCRA. Remedial Investigation.
9	ELLIOTT BAY	47122F3I4	N-nitrosodiphenylamine; Hexachlorobenzene; Hexachlorobutadiene; 1,2,4-Trichlorobenzene; Butylbenzyl phthalate; 1,2-Dichlorobenzene; Bis(2-ethylhexyl)phthalate; 2-Methylphenol; Total PCBs; Pentachlorophenol; 2,4-Dimethylphenol; 1,4-Dichlorobenzene; Dibenz(a,h)anthracene	Data from the Dept. of Ecology SEDQUAL database (stations H=HIRIPH2!E-16; M=HIRIPH2!E-17; L=HIRIPH2!E-15) show the average of 3 samples exceeds the Sediment Management Standards CSL chemical criterion on 10/2/1991.

WRIA	Waterbody Name	Grid Cell Number or Twp-Rg-Sec	Combined Parameters	Basis
9	ELLIOTT BAY	47122F3I6	2,4-Dimethylphenol;N-nitrosodiphenylamine; Pentachlorophenol; 1,4-Dichlorobenzene; 4-Methylphenol; 2-Methylphenol; Hexachlorobenzene; Dibenz(a,h)anthracene; Dimethyl phthalate; 1,2,4-Trichlorobenzene; 1,2-Dichlorobenzene, Hexachlorobutadiene	Data from the Dept. of Ecology SEDQUAL database (stations H=HIRIPH2!N-11; M=HIRIPH2!N-11; L=HIRIPH2!N-20) show the average of 3 samples exceeds the Sediment Management Standards CSL chemical criterion on 10/15/1991.
9	ELLIOTT BAY	47122F3I7	Hexachlorobenzene; 2,4-Dimethylphenol; 1,2,4-Trichlorobenzene	Data from the Dept. of Ecology SEDQUAL database (stations H=SEACRE97!10537-2; M=SEACRE97!10537-1; L=SEACRE97!10537-4) show the average of 3 samples exceeds the Sediment Management Standards CSL chemical criterion on 3/21/1997.
9	PUGET SOUND (S-CENTRAL) AND EAST PASSAGE	47122E3A3	Benzyl alcohol; 2-Methylphenol; 2,4-Dimethylphenol	Data from the Dept. of Ecology SEDQUAL database (stations H=MIDWAY95!1-106; M=MIDWAY95!1-108; L=MIDWAY95!1-105) show the average of 3 samples exceeds the Sediment Management Standards CSL chemical criterion on 4/6/1995.
9	PUGET SOUND (S-CENTRAL) AND EAST PASSAGE	47122E3A4	Benzyl alcohol; 2,4-Dimethylphenol; 2-Methylphenol	Data from the Dept. of Ecology SEDQUAL database (stations H=MIDWAY95!1-102; M=MIDWAY95!1-101; L=MIDWAY95!1-102) show the average of 3 samples exceeds the Sediment Management Standards CSL chemical criterion on 4/6/1995.
9	PUGET SOUND (S-CENTRAL) AND EAST PASSAGE	47122E3E6	2,4-Dimethylphenol	Data from the Dept. of Ecology SEDQUAL database (stations H=SWSSD96!SEDM5a; M=SWSSD96!SEDM7a; L=SWSSD96!SEDM4) show the average of 3 samples exceeds the Sediment Management Standards CSL chemical criterion on 8/29/1996.
9	PUGET SOUND (S-CENTRAL) AND EAST PASSAGE	47122E3I7	2,4-Dimethylphenol; Benzyl alcohol	Data from the Dept. of Ecology SEDQUAL database (stations H=SWSSD96!SEDS8; M=SWSSD96!SEDS1; L=SWSSD96!SEDS3) show the average of 3 samples exceeds the Sediment Management Standards CSL chemical criterion on 8/28/1996.
9	SPRINGBROOK (MILL) CREEK	22N-04E-01	Sediment Bioassay	Data from the Dept. of Ecology SEDQUAL database (stations MILLCRP2*MS139*9201146*9/28/1992*none; MILLCRP2*MS140*9201147*9/28/1992*none; MILLCRP2*MS141*9201148*9/28/1992*none) show a significant response to sediment bioassay from samples tested in 1992. Era-Miller, B., (2004), sediment samples from stations UPPER MILL, MILL-1, MILL-2, MILL-3 showed a significant toxicity determined by the 20-day Chironomus tentans test.
9	SPRINGBROOK (MILL) CREEK	23N-04E-36	Sediment Bioassay	Data from the Dept. of Ecology SEDQUAL database (stations MILLCRP2*MS104*9201136*9/23/1992*none; MILLCRP2*MS102*9201134*9/23/1992*none; MILLCRP2*MS103*9201135*9/23/1992*none) show a significant response to sediment bioassay from samples tested in 1992.

WRIA	Waterbody Name	Grid Cell Number or Twp-Rg-Sec	Combined Parameters	Basis
10	COMMENCEMENT BAY (INNER)	21N-03E-99	Copper	Data from the Dept. of Ecology SEDQUAL database (stations H=HYLE9496!5215; M=HYLE9496!HC-HY-04; L=HYLE9496!HC-HY-06) show the average of 3 samples exceeds the Sediment Management Standards CSL chemical criterion on 12/20/1995.
10	COMMENCEMENT BAY (INNER)	47122C4G2	N-nitrosodiphenylamine; 1,2-Dichlorobenzene; 2,4-Dimethylphenol; 1,4-Dichlorobenzene; 1,2,4-Trichlorobenzene; Hexachlorobutadiene	Data from the Dept. of Ecology SEDQUAL database (stations H=SITCUMHA!04296-02; M=STPAUL93!SS-1; L=STPAUL93!SS-2) show the average of 3 samples exceeds the Sediment Management Standards CSL chemical criterion on 4/6/1994.
10	COMMENCEMENT BAY (INNER)	47122C4H2	1,2-Dichlorobenzene; Benzoic acid; 1,2,4-Trichlorobenzene	Data from the Dept. of Ecology SEDQUAL database (stations H=SITCUMHA!04296-05; M=SITCUMHA!04296-07; L=SITCUMHA!04296-03) show the average of 3 samples exceeds the Sediment Management Standards CSL chemical criterion on 4/6/1994.
10	HYLEBOS WATERWAY	21N-03E-36	Sediment Bioassay	Data from the Dept. of Ecology SEDQUAL database (stations HYLE9496*1135*1135 S*4/9/1996; HYLE9496*1122*1122 S*4/8/1996; HYLE9496*1212*1212 I*4/5/1996) show a significant response to sediment bioassay from samples tested in 1997.
10	HYLEBOS WATERWAY	21N-03E-99	Sediment Bioassay	Data from the Dept. of Ecology SEDQUAL database (stations HYLE9496*5116*5116 S*7/15/1996; HYLE9496*5113*5113 S*7/13/1996; HYLE9496*4104*4104 S*7/12/1996) show a significant response to sediment bioassay from samples tested in 1997.Data from the Dept.
12	PUGET SOUND (SOUTH)	47122B5I8	Hexachlorobenzene; 1,2,4-Trichlorobenzene	Data from the Dept. of Ecology SEDQUAL database (stations H=BCWTAC95!Outfl_Md; M=BCWTAC95!Outfl_No; L=BCWTAC95!Outfl_No) show the average of 3 samples exceeds the Sediment Management Standards CSL chemical criterion on 9/28/1995.
12	PUGET SOUND (SOUTH)	47122B5J8	1,2,4-Trichlorobenzene; Hexachlorobenzene; 1,2-Dichlorobenzene	Data from the Dept. of Ecology SEDQUAL database (stations H=CHAMBR95!STN+30; M=CHAMBR95!STN-310; L=CHAMBR95!STN+310) show the average of 3 samples exceeds the Sediment Management Standards CSL chemical criterion on 11/6/1995.
15	DYES INLET AND PORT WASHINGTON NARROWS	47122F6I8	2,4-Dimethylphenol; 1,2,4-Trichlorobenzene; 2-Methylphenol; Hexachlorobutadiene; 1,2-Dichlorobenzene; Hexachlorobenzene; N-nitrosodiphenylamine; Pentachlorophenol	Data from the Dept. of Ecology SEDQUAL database (stations H=JCKSON94!340; M=JCKSON94!341; L=JCKSON94!321) show the average of 3 samples exceeds the Sediment Management Standards CSL chemical criterion on 7/15/1994. USN Jackson Park Ostrich Bay. CERCLA-MTCA. Feasibility study.

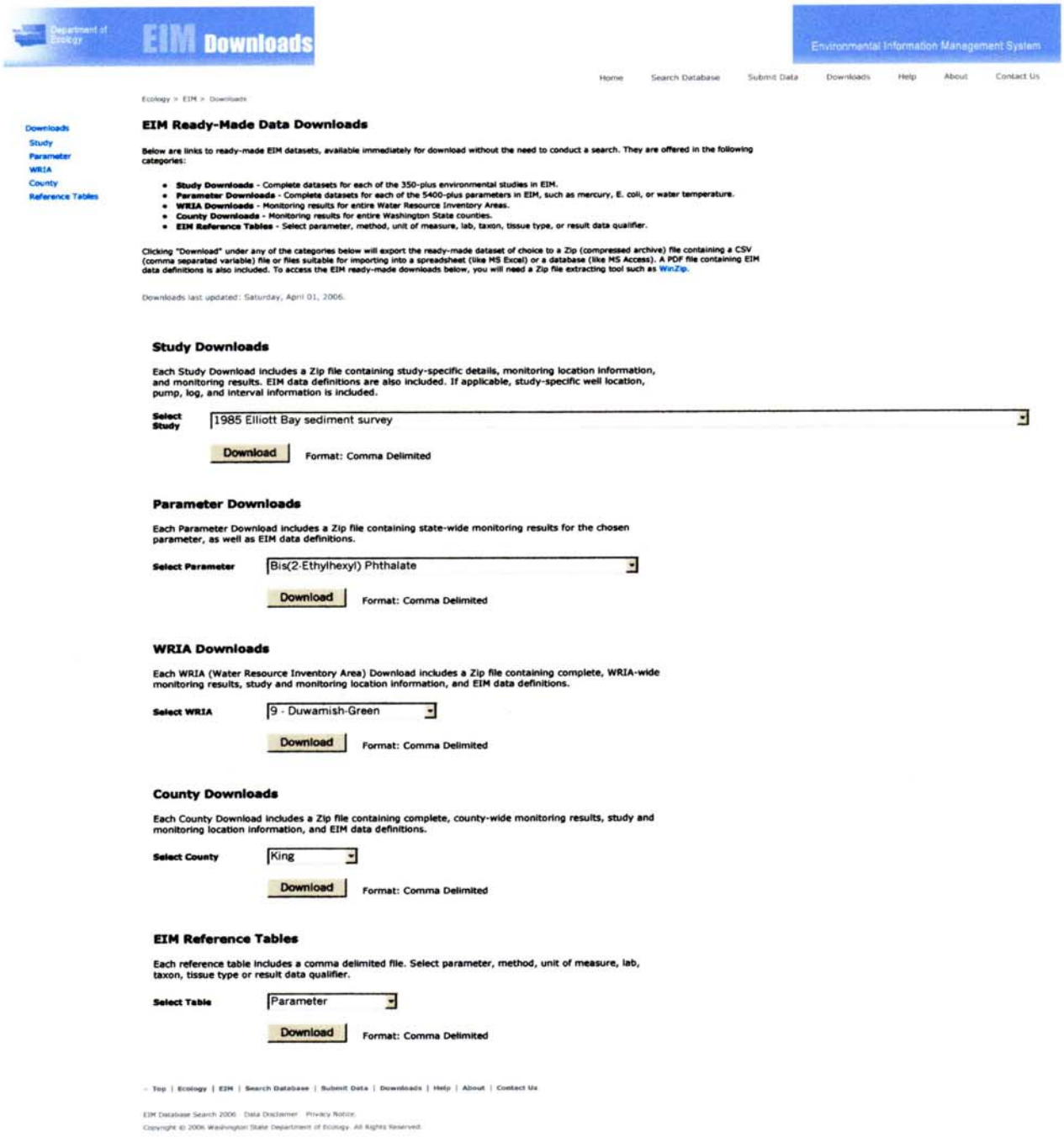
WRIA	Waterbody Name	Grid Cell Number or Twp-Rg-Sec	Combined Parameters	Basis
15	DYES INLET AND PORT WASHINGTON NARROWS	47122F6J8	2,4-Dimethylphenol; 1,4-Dichlorobenzene; 2-Methylphenol; Hexachlorobenzene; Dibenz(a,h)anthracene; Hexachlorobutadiene; N-nitrosodiphenylamine; 1,2,4-Trichlorobenzene; 1,2-Dichlorobenzene	Data from the Dept. of Ecology SEDQUAL database (stations H=JCKSON94!336; M=JCKSON94!336; L=JCKSON94!311) show the average of 3 samples exceeds the Sediment Management Standards CSL chemical criterion on 7/14/1994. USN Jackson Park Ostrich Bay. CERCLA-MTCA. Feasibility study.
15	SINCLAIR INLET	47122F6E6	2,4-Dimethylphenol; Mercury	Data from the Dept. of Ecology SEDQUAL database (stations H=BREMTP98!W-000; M=BREMTP98!E-000; L=BREMTP98!E-200) show the average of 3 samples exceeds the Sediment Management Standards CSL chemical criterion on 4/28/1998. USN PSNS - Sinclair West. CERCLA-MTCA. Cleanup and monitoring. Has ROD that only partially addresses contaminated sediments in this area.
15	SINCLAIR INLET	47122F6E7	Mercury	Data from the Dept. of Ecology SEDQUAL database (stations H=BREMTP98!W-400; M=BREMTP98!W-600; L=BREMTP98!W-200) show the average of 3 samples exceeds the Sediment Management Standards CSL chemical criterion on 4/29/1998. USN PSNS - Sinclair West. CERCLA-MTCA. Cleanup and monitoring. Has ROD that only partially addresses contaminated sediments in this area.
15	SINCLAIR INLET	47122F6F1	Benzyl alcohol; 2,4-Dimethylphenol; Hexachlorobenzene; Hexachlorobutadiene; 1,2,4-Trichlorobenzene; 2-Methylphenol; 1,2-Dichlorobenzene; 1,4-Dichlorobenzene	Data from the Dept. of Ecology SEDQUAL database (stations H=SCLAIR94!487; M=SCLAIR94!493; L=SCLAIR94!486) show the average of 3 samples exceeds the Sediment Management Standards CSL chemical criterion on 5/2/1994. USN PSNS Sinclair East. CERCLA-MTCA Cleanup and monitoring. Has ROD that only partially addresses contaminated sediments in this area.
15	SINCLAIR INLET	47122F6F3	1,2,4-Trichlorobenzene; Benzyl alcohol; 1,2-Dichlorobenzene; 2,4-Dimethylphenol; Hexachlorobenzene; 2-Methylphenol; Hexachlorobutadiene; Mercury	Data from the Dept. of Ecology SEDQUAL database (stations H=SCLAIR94!473; M=SCLAIR94!472; L=SCLAIR94!474) show the average of 3 samples exceeds the Sediment Management Standards CSL chemical criterion on 5/19/1994. USN PSNS - Sinclair East. CERCLA-MTCA. Cleanup and monitoring. Has ROD that only partially addresses contaminated sediments in this area.
15	SINCLAIR INLET	47122F6F4	Mercury	Data from the Dept. of Ecology SEDQUAL database (stations H=PIER_D95!E-3-95; M=PIER_D95!E-1-95; L=PIER_D95!E-5-95) show the average of 3 samples exceeds the Sediment Management Standards CSL chemical criterion on 12/17/1994. USN PSNS - Sinclair West. CERCLA-MTCA. Cleanup and monitoring. Has ROD that only partially addresses contaminated sediments in this area.
15	SINCLAIR INLET	47122F6F5	Benzoic acid; Mercury; Benzyl alcohol; 2,4-Dimethylphenol	Data from the Dept. of Ecology SEDQUAL database (stations H=PIER_D95!W-1-95; M=SCLAIR94!468; L=SCLAIR94!451) show the average of 3 samples exceeds the Sediment Management Standards CSL chemical criterion on 3/7/1995. USN PSNS - Sinclair West. CERCLA-MTCA. Cleanup and monitoring. Has ROD that only partially addresses contaminated sediments in this area.

WRIA	Waterbody Name	Grid Cell Number or Twp-Rg-Sec	Combined Parameters	Basis
18	ADMIRALTY INLET (OUTER)	48123A0I3	1,2,4-Trichlorobenzene;Hexachlorobenzene;1,2-Dichlorobenzene	Data from the Dept. of Ecology SEDQUAL database (stations H=SEQUIM97!ST-103; M=SEQUIM97!ST-101; L=SEQUIM97!ST-102) show the average of 3 samples exceeds the Sediment Management Standards CSL chemical criterion on 8/14/1997.
22	GRAYS HARBOR (INNER)	46123J8G5	2,4-Dimethylphenol	Data from the Dept. of Ecology SEDQUAL database (stations H=GRAYH_99!9S; M=PGHT294!1; L=PGHT294!6) show the average of 3 samples exceeds the Sediment Management Standards CSL chemical criterion on 3/30/1998.
22	GRAYS HARBOR (INNER)	46123J8G7	Benzyl alcohol; 2,4-Dimethylphenol; 4-Methylphenol	Data from the Dept. of Ecology SEDQUAL database (stations H=GRAYH_99!2C-2; M=GRAYH_99!2C-1; L=GRAYH_99!2C-3) show the average of 3 samples exceeds the Sediment Management Standards CSL chemical criterion on 3/31/1998.
28	COLUMBIA RIVER	45122G7E4	Sediment Bioassay	Data from the Dept. of Ecology SEDQUAL database (stations VALCOA93*C*VALCHC*9/21/1993*Columbia River; VALCOA93*E*VALCHE*9/21/1993*Columbia River; VALCOA93*D*VALCHD*9/21/1993*Columbia River) show a significant response to sediment bioassay from samples tested in 1993.
31	COLUMBIA RIVER	45120H6C8	Sediment Bioassay	Data from the Dept. of Ecology SEDQUAL database (stations COLALU94*B*CA-CH-B*11/4/1993*Columbia River; COLALU94*B*CA-CH-B*11/4/1993*Columbia River; COLALU94*B*CA-CH-B*11/4/1993*Columbia River) show a significant response to sediment bioassay from samples tested in 1993. This segment is listed as Category 5, the listing criteria requires 3 points per segment to be listed in Category 5.
53	FRANKLIN D. ROOSEVELT LAKE	47118J8E4	Sediment Bioassay	Data from the Dept. of Ecology SEDQUAL database (stations LKROOS01*SWAWILLA*1198049*5/9/2001*Lake Roosevelt; LKROOS01*SWAWILLA*1198049*5/9/2001*Lake Roosevelt; LKROOS01*SWAWILLA*1198049*5/9/2001*Lake Roosevelt) show a significant response to sediment biossays tested in 2001. This segment is listed as Category 5, the listing criteria requires 3 points per segment to be listed in Category 5.
61	FRANKLIN D. ROOSEVELT LAKE	48117J6H4	Sediment Bioassay	Data from the Dept. of Ecology SEDQUAL database (stations LKROOS01*AUXGAGE*1198042*5/8/2001*Lake Roosevelt; LKROOS01*AUXGAGE*1198042*5/8/2001*Lake Roosevelt; LKROOS01*AUXGAGE*1198042*5/8/2001*Lake Roosevelt) show a significant response to sediment bioassay. This segment is listed as Category 5, the listing criteria requires 3 points per segment to be listed in Category 5.
61	FRANKLIN D. ROOSEVELT LAKE	48117J6J3	Sediment Bioassay	Data from the Dept. of Ecology SEDQUAL database (stations LKROOS01*BOUNDARY*1198043*5/8/2001*Lake Roosevelt; LKROOS01*BOUNDARY*1198043*5/8/2001*Lake Roosevelt; LKROOS01*BOUNDARY*1198043*5/8/2001*Lake Roosevelt) show a significant response to sediment bioassay. This segment is listed as Category 5, the listing criteria requires 3 points per segment to be listed in Category 5.

WRIA	Waterbody Name	Grid Cell Number or Twp-Rg-Sec	Combined Parameters	Basis
61	FRANKLIN D. ROOSEVELT LAKE	48117J7E3	Sediment Bioassay	Data from the Dept. of Ecology SEDQUAL database (stations LKROOS01*GOODEVCK*1198041*5/8/2001*Lake Roosevelt; LKROOS01*GOODEVCK*1198041*5/8/2001*Lake Roosevelt; LKROOS01*GOODEVCK*1198041*5/8/2001*Lake Roosevelt) show a significant response to sediment bioassay. This segment is listed as Category 5, the listing criteria requires 3 points per segment to be listed in Category 5.

Appendix E.

EIM Sediment Monitoring Data - Examples



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EIM Ready-Made Data Downloads

Below are links to ready-made EIM datasets, available immediately for download without the need to conduct a search. They are offered in the following categories:

- **Study Downloads** - Complete datasets for each of the 350-plus environmental studies in EIM.
- **Parameter Downloads** - Complete datasets for each of the 5400-plus parameters in EIM, such as mercury, E. coli, or water temperature.
- **WRIA Downloads** - Monitoring results for entire Water Resource Inventory Areas.
- **County Downloads** - Monitoring results for entire Washington State counties.
- **EIM Reference Tables** - Select parameter, method, unit of measure, lab, taxon, tissue type, or result data qualifier.

Clicking "Download" under any of the categories below will export the ready-made dataset of choice to a Zip (compressed archive) file containing a CSV (comma separated variable) file or files suitable for importing into a spreadsheet (like MS Excel) or a database (like MS Access). A PDF file containing EIM data definitions is also included. To access the EIM ready-made downloads below, you will need a Zip file extracting tool such as WinZip.

Downloads last updated: Saturday, April 01, 2006.

Study Downloads

Each Study Download includes a Zip file containing study-specific details, monitoring location information, and monitoring results. EIM data definitions are also included. If applicable, study-specific well location, pump, log, and interval information is included.

Select Study: 1985 Elliott Bay sediment survey

Download Format: Comma Delimited

Parameter Downloads

Each Parameter Download includes a Zip file containing state-wide monitoring results for the chosen parameter, as well as EIM data definitions.

Select Parameter: Bis(2-Ethylhexyl) Phthalate

Download Format: Comma Delimited

WRIA Downloads

Each WRIA (Water Resource Inventory Area) Download includes a Zip file containing complete, WRIA-wide monitoring results, study and monitoring location information, and EIM data definitions.

Select WRIA: 9 - Duwamish-Green

Download Format: Comma Delimited

County Downloads

Each County Download includes a Zip file containing complete, county-wide monitoring results, study and monitoring location information, and EIM data definitions.

Select County: King

Download Format: Comma Delimited

EIM Reference Tables

Each reference table includes a comma delimited file. Select parameter, method, unit of measure, lab, taxon, tissue type or result data qualifier.

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