General Observations and Summary of Ambient Water Column and Sediment Data Collected by the Washington Department of Ecology

A brief submitted for

The British Columbia/Washington Symposium on the Marine Environment

Prepared by: Kenneth A. Dzinbal
Manager, Ambient Monitoring Section
Washington State Department of Ecology
300 Desmond Drive, P.O. Box 47710
Olympia, Washington 98504-7710 U.S.A.

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This brief was prepared in response to an invitation to submit relevant information for the British Columbia/Washington Symposium on the Marine Environment (scheduled for 13-14 January, 1994). The brief is organized in three parts: 1) a relatively concise response to the set of six questions posed in the Symposium Announcement, 2) a general overview of Washington's long-term, ambient monitoring program in marine waters and sediments, and 3) abstracts of several recent reports published by the Washington Department of Ecology's Ambient Monitoring Section.

Part 1. Symposium Questions

1) **What transport mechanisms exist for transboundary exchange of human-caused contamination between the Strait of Georgia, Puget Sound, and Juan de Fuca Strait? To what extent can spills or discharges to these be transported across the international border and cause harm?**

Ecology's Marine Ambient Water Column Monitoring Program collects temperature and salinity data in part to "identify and track seawater and freshwater parcels which flow throughout the Sound, transporting and mixing pollutants" (Puget Sound Water Quality Authority 1988b). In addition, Ecology has recently employed the University of Washington's physical model to give some insight into the relative dispersion of water masses at our long-term sample stations (Albertson 1993). However, we have not yet been

able to collect current data, or to otherwise directly measure current flow at any of our long-term stations or seasonal monitoring sites. Consequently, the temperature and salinity data we have collected may provide some limited insight into transport processes in some specific locations (e.g. in a few semi-enclosed bays chosen for seasonal monitoring efforts). However, we do not have sufficient data to discuss transboundary exchange mechanisms in any meaningful way, or the potential for spills or discharges to be transported across the international border.

2) **To what degree do the biological resources of the Strait of Georgia, Puget Sound and Juan de Fuca Strait move across the international border? Biological resources include invertebrates, finfish, birds, and marine mammals.**

Monitoring data collected by Ecology's Ambient Monitoring Program does not address the movement of biological resources. We have, since 1989, collected benthic invertebrates annually from stations near the international boundary (see section 2 of this brief). We have not, however, attempted to determine movement of invertebrates or other biological resources within or between sample locations.

3) **What do we know about the status of the transboundary population of invertebrates, finfish, birds, and marine mammals of Strait of Georgia, Puget Sound, and the Strait of Juan de Fuca? Are there long term trends in the populations, and if so, what are the likely causes?**

In 1989, Ecology implemented a long-term, sediment monitoring program in Puget Sound. The program has two main objectives: 1) to describe baseline conditions in Puget Sound sediments, and 2) to determine spatial and temporal trends in Puget Sound sediment quality. The monitoring strategy relies on a triad approach that incorporates chemical analyses of sediment samples, toxicity testing through bioassays, and analyses of benthic invertebrate fauna. The monitoring strategy and specific methods currently employed are detailed in a comprehensive implementation plan (Striplin 1988).

To date, results of each year's monitoring effort have been compiled and reported separately (Tetra Tech 1990; Striplin et al. 1992; Dutch et al. 1993; Ecology 1993 *in press*). Results from benthic invertebrate data are valuable in describing spatial variation in benthic community composition throughout the variety of habitats in Puget Sound and the adjoining waters. However, temporal trends are much more demanding and difficult to demonstrate because of relatively large interannual variability. Ecology is currently assessing the four-year body of data, but analyses have not been completed. Where benthic invertebrate data from historic studies was collected at stations we currently sample (see Dutch *et al.*, 1993), potential trends are not apparent in comparison to interannual variability. Consequently,

although we currently have a solid monitoring program in place to assess long-term trends in benthic invertebrate populations, we do not at present have a sufficiently long or regular time-series of data to show specific temporal trends in benthic invertebrate populations.

4) **What evidence is there for harm from transboundary pollution and other anthropogenic influences to the habitats, aquatic biota, human uses, or public health of the Strait of Georgia, Puget Sound, and the Juan de Fuca Strait? As compared to five or ten years ago, is the severity of harm greater, less or the same?**

The ambient monitoring program has documented some water quality and sediment conditions that probably result from, or are likely exacerbated by, harmful anthropogenic impacts. For example, the concentrations of a variety of chemical contaminants are greater in urban, industrialized bays than in rural or undeveloped bays (e.g. Dutch *et al.*, 1993). Sediment toxicity (using amphipod bioassays) has been recorded at some stations (Tetra Tech 1990; Striplin *et al.* 1992). Water column monitoring has identified a number of locations that are poorly mixed (i.e. exhibit seasonally strong stratification) and exhibit nutrient enrichment, algal blooms (with subsequent nutrient depletion), and low dissolved oxygen concentrations (Prescott 1992; Janzen and Eisner 1993a,b). High fecal coliform bacteria counts are typically associated with urban bays, freshwater river discharges, or other anthropogenic sources (Janzen and Eisner 1993a).

However, showing time-specific trends in water or sediment quality remains difficult for several reasons: a) the sediment monitoring program was implemented only recently (1989) so a time series long enough to overcome the effects of normal interannual variability has not yet been established, b) the marine water column monitoring program also shows large interannual variability relative to likely trends, and was historically limited to collecting monthly samples not adjusted for time of day or tide, and finally c) the data processing and analytical tools needed to apply sophisticated trend analyses has only recently become practical for monitoring agencies to acquire.

Nevertheless, on a different level, there is considerable empirical evidence for anthropogenic impacts to local marine waters. For example, the decline in abundance of some upper-trophic level vertebrates (e.g. harbor porpoise, several fish stocks, some marine birds), closures of shellfish beds due to fecal coliform contamination, the apparent increasing frequency and expanding distribution of toxic algae blooms, declines in kelp and eel-grass beds, destruction of natural salt marsh wetlands, and the widespread distribution of synthetic and toxic chemical contaminants all suggest significant impacts to the marine ecosystem have occurred.

5) **Given forecasts of human population increases for the lands that drain to the Strait of Georgia, Puget Sound, and Juan de Fuca Strait, and assuming little or no change to the current level of pollution control, harvest management, and land use management**

activities, will the amount or severity of harm from transboundary pollution to the habitats, aquatic biota, human uses, or public health be greater, less or the same in 20 years? Are the transboundary populations of biological resources associated with these waters anticipated to increase, decrease, or stay the same in 20 years?

If recent history is indicative, the next 20 years will likely see an increase in harm from some pollutants (especially those most related to urban and rural runoff) and a decrease in harm from others (e.g. those industrial pollutants that can be controlled through restrictions and technology changes). Therefore it will be important to monitor changes in the type or kind of pollution, and to anticipate the resulting impacts to habitat quality and the stability of populations. Assuming little change in the current level of pollution control or land use activities, it is reasonable to conclude that harmful impacts from nutrient inputs, sedimentation, toxic contaminants, and habitat degradation will continue to increase as a function of human population increases.

It will also remain important that many pollutants are long-lived or cumulative in nature (at least over the short term of years or decades). Consequently, their impacts may persist over time. For example, non-degradable pollutants (e.g. mercury) could have long-term impacts to benthic invertebrate or demersal fish communities. Others might continue to bioaccumulate, or change in their bioavailability through mechanisms such as resuspension and/or changing oxidation potential of sediments. Episodic impacts from catastrophic spills will occur with every occurrence, despite preventive measures designed to decrease the probability of accidental spills. Finally, impacts from introduced exotic species tend to increase cumulatively over time since the rate of new exotic introductions almost always exceeds the rate of established exotics being removed.

6) **What components of the transboundary marine ecosystem appear to be most sensitive to harm from human activities? What types of harm appear to be most serious and should be the focus of monitoring, research, and management activities over the next ten years? Which types of human activities (i.e. discharges or spills of toxic compounds, nutrients, pathogens, physical land modification) need the most management attention? What indicators are recommended for future state of the environment reporting for the transboundary marine ecosystem?**

Most of Ecology's ambient monitoring objectives have been designed to track violations of state water quality or sediment quality standards, and to focus on those components of the water column or sediments thought to be most susceptible to anthropogenic impacts (Puget Sound Water Quality Authority 1988b; Striplin 1988; Janzen 1992a). This approach assumes that the most serious anthropogenic impacts to water and sediment quality will be manifested in nutrient/phytoplankton/dissolved oxygen relationships, fecal coliform loads, accumulation of toxic contaminants in sediments, and altered benthic invertebrate community structure. Parameters currently monitored include, for example, nutrients,

chlorophyll *a*, dissolved oxygen, phytoplankton species abundance, and fecal coliform bacteria in the water column, and toxic contaminants and benthic community structure in the sediments. Assuming pollution impacts from non-point sources (urban and rural runoff) increase in importance over the next five or ten years, then all of these parameters certainly warrant continued monitoring to document long-term changes resulting from additional nutrient, sediment, contaminant, and bacteria loading, and from altered or exaggerated freshwater discharge patterns.

However, our knowledge of marine ecosystem processes is still very incomplete. Consequently, we probably underestimate many important impacts to significant ecosystem components. For example, we know relatively little about the long-term effect on the marine ecosystem of surface microlayer contamination by toxic chemicals. We also know little about the effects of seasonal hypoxia on benthic invertebrate communities. And we lack basic knowledge of current flow and circulation patterns that could help us predict the fate, transport, and deposition of inputs. Numerous other examples exist of potentially important relationships and processes that remain poorly understood.

Research needs in Puget Sound were addressed fairly recently by the Committee on Research in Puget Sound (Puget Sound Water Quality Authority 1988a). The Committee conducted an extensive survey and expert workgroup process to identify and rank research priorities. Many of the priorities listed through that process remain relevant today and still deserve support (Puget Sound Water Quality Authority 1988a).

Because ecosystem processes are complex and poorly understood, it is unlikely that a small set of simple, reliable, or inexpensive environmental indicators can be identified that would provide a "Dow Jones" average of ecosystem "health." Currently, we first compare our monitoring data to state water quality and sediment quality standards. We then also (informally) look for several indicators that help us identify areas that may warrant additional monitoring or intensive study. These include:

1) high chlorophyll concentrations, especially when inversely related to nutrient depletion and/or low (<5.0 mg/L) dissolved oxygen concentrations;

2) strong water column stratification;

3) reduced benthic invertebrate species diversity or abundance; and

4) relatively high concentrations of toxic contaminants in sediments.

In general, a multi-tiered monitoring program, in conjunction with additional fundamental research on basic ecosystem processes and linkages, is essential to track or predict changes in marine ecosystem health. Monitoring a variety of components at different functional levels will improve the likelihood of detecting subtle or synergistic impacts early, before potential solutions become impractical or too expensive. Ecology's ambient water quality and sediment quality monitoring programs comprise one part of a multi-agency, multiple component approach to monitoring coordinated through the Puget Sound Ambient Monitoring Program. See Part 2, below.

Part 2. General Overview of Ambient Monitoring in Puget Sound and Transboundary Waters by the Washington Department of Ecology

The Washington Department of Ecology (Ecology) conducts several, long-term, ambient monitoring programs focusing on the marine environment of Puget Sound, the adjoining transboundary waters, and the surrounding uplands. These include:

- Marine Water Column Monitoring
- Marine Sediment Monitoring
- Freshwater River and Stream Monitoring
- Lake Monitoring

Historically, Ecology's predecessor agencies initiated freshwater river monitoring in 1959, and marine water column monitoring in 1967. Both programs were conceived as long-term monitoring efforts built around monthly or periodic collection of discrete water samples at regular, long-term stations (the marine program initially sampled only during the spring, summer, and fall months). Samples were collected for laboratory analysis of conventional water quality parameters. After Ecology's inception in 1970, both monitoring programs evolved under Ecology's sole direction until 1986.

In 1986, the Puget Sound Water Quality Authority (Authority) mandated that a comprehensive environmental monitoring program be developed for Puget Sound

> "The Authority appointed an interdisciplinary committee, known as the Monitoring Management Committee (MMC) to design a comprehensive environmental monitoring program for Puget Sound. The MMC consisted of water quality professionals from federal, state and local agencies, universities, tribes, industry, and members of the public.
>
> "The MMC developed a program referred to as the Puget Sound Ambient Monitoring Program (PSAMP). PSAMP includes a sampling design, institutional structure, a data management approach, and a cost estimate. The draft design was reviewed extensively during public workshops, and by scientific and technical experts in the Puget Sound area" (Puget Sound Water Quality Authority 1988b).

The specific Puget Sound Ambient Monitoring Program goals (Puget Sound Water Quality Authority 1988b) are:

1) Characterize the condition of Puget Sound in relation to its natural resources and for humans, and recognize contamination problems.

2) Take measurements to support specific program elements identified in the Puget Sound Water Quality Management Plan, (including the municipal and industrial discharge, nonpoint, shellfish, wetlands, and contaminated sediments and dredging programs).

3) Measure the success of programs implemented under the Puget Sound Water Quality Management Plan.

4) Provide a permanent record of significant natural and human-caused changes in key environmental indicators in Puget Sound over time.

5) Support research activities through the availability of consistent, scientifically valid data.

The PSAMP strategy targets a variety of functional levels in the marine ecosystem, including sediments, water column, fish, shellfish, marine mammals, birds, nearshore habitat, and freshwater rivers and streams. Monitoring tasks are implemented by state and federal agencies having relevant responsibility and authority, using standardized protocols for sampling, laboratory analysis, and data management. Efforts are coordinated through a Steering Committee made up of agency representatives that meets monthly to discuss progress, results, and program design changes. Monitoring programs are guided by Implementation Plans drafted by the lead agency, and reviewed (as are most all products) by the other PSAMP agencies (Puget Sound Water Quality Authority 1988b).

Two PSAMP monitoring components conducted by Ecology, the Marine Water Column Monitoring and Marine Sediment Monitoring Programs, are directly relevant to marine ecosystem monitoring in Puget Sound and the transboundary waters.

Marine Water Column Monitoring

The Marine Water Column Monitoring Program was initiated by the Department of Ecology in 1967. It was originally implemented as a network of stations throughout Puget Sound where discrete water samples were collected monthly for laboratory analysis of conventional chemical parameters.

Currently, the program is operated as one component of the Puget Sound Ambient Monitoring Program (coastal estuary monitoring is not addressed here). Monitoring involves both a long-term monitoring component and a seasonal monitoring component. The long term component involves monthly sampling at a fixed network of 16 core and 30 rotating stations (about 10 rotating stations are sampled each year). The seasonal monitoring component provides more intensive monitoring of one or two semi-enclosed embayments during each growing season (approximately April - October). In both components, discrete water samples are collected for laboratory analyses, supplemented with vertical profiles of major parameters collected with a CTD profiling instrument (See Janzen 1992a; Janzen 1992b; Janzen and Eisner 1993a; Janzen and Eisner 1993b).

Marine Sediment Monitoring

The Marine Sediment Monitoring Program was initiated in 1989 following recommendations by the Monitoring Management Committee (Puget Sound Water Quality Authority 1988b). The

program involves annual sampling of a fixed network of 16 core stations and 48 rotating stations (roughly 34 rotating stations are sampled each year). Monitoring is designed around a triad approach that incorporates chemical analyses of sediment samples, bioassay toxicity testing, and analyses of benthic invertebrate fauna (see Striplin 1988; Tetra Tech 1990; Striplin *et al.*, 1992; Dutch *et al.*, 1993).

Current Directions in Marine Water Column and Marine Sediment Monitoring

Considerable experience has been gained in both the marine water column and marine sediment monitoring programs since 1989 and the implementation of the PSAMP monitoring structure. Although program changes are implemented only after review through PSAMP, several important near-term goals for improving the marine water quality and sediment quality monitoring programs include:

1) Improving the resolution of water column data through more frequent sampling, by accounting for time-of-day and tidal variation, and/or employing continuous, in situ monitoring for pertinent parameters.

2) Revising the target list of chemicals analyzed in the sediment monitoring program, based on the first five years of monitoring results and considering the pollutants of highest concern in Puget Sound and the transboundary waters.

3) Exploring more efficient assessment methods (or functional analyses) for benthic invertebrate community analyses.

4) Incorporating physical current data (water mass circulation) into water column and sediment monitoring analyses to better interpret fate and transport issues.

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Part 3.

Abstracts of Recent Reports Published by the Washington Department of Ecology's Ambient Monitoring Section