Red Book

PUGET SOUND WATER QUALITY AUTHORITY

PUGET SOUND AMBIENT MONITORING PROGRAM

Monitoring Management Committee

Final Report
April 1988

PUGET SOUND WATER QUALITY AUTHORITY
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INTRODUCTION

The 1987 Puget Sound Water Quality Management Plan found that "... there is currently no long-term comprehensive program to monitor Puget Sound and its resources..." In response to this finding, the plan mandated that a comprehensive environmental monitoring program be developed for Puget Sound.

In 1986 the Puget Sound Water Quality Authority (the Authority) appointed an interdisciplinary committee, known as the Monitoring Management Committee (MMC), to design the Puget Sound Ambient Monitoring Program (PSAMP). The MMC consists of water quality professionals from federal, state and local agencies, universities, tribes, industry, and members of the public.

The MMC developed a comprehensive monitoring program referred to as the Puget Sound Ambient Monitoring Program. PSAMP includes a sampling design, an 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.

This report contains the recommendations of the MMC and was presented to the Authority in April 1988. After review and approval by the Authority, PSAMP will be incorporated into the 1989 Puget Sound Water Quality Management Plan.

GOALS OF THE MONITORING PROGRAM

The purpose of the Puget Sound Ambient Monitoring Program is to provide scientifically credible information which increases our understanding of Puget Sound, its resources, and the effects of human activities over time. PSAMP has been designed to ensure that high quality data are collected and analyzed, and that the results are made available to a wide audience.

The goals of PSAMP are to:

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

* 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).

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

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

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

PSAMP has been designed to complement existing monitoring programs in the Puget Sound basin. Standardized data formats and sampling and analysis protocols will enable PSAMP data to be used with data from other programs (such as the Puget Sound Dredge Disposal Analysis, ongoing urban bay studies and National Pollutant Discharge Elimination System compliance monitoring). The findings of PSAMP will be used to trigger intensive surveys to identify and investigate emerging problems.

INSTITUTIONAL STRUCTURE

Implementing the recommended program will require careful planning of individual monitoring tasks and central coordination and management.

Several state agencies will implement the monitoring program under memoranda of agreement with the Authority. Each implementing agency will be responsible for developing detailed monitoring plans, conducting sampling, managing data, and producing annual monitoring reports. Citizen volunteers will collect samples that cannot be collected by agency staff due to logistic or cost constraints.

During the startup phase the Authority will coordinate PSAMP, with the MMC acting as the technical body which provides overall coordination and management. A steering subcommittee, made up of representatives of the implementing agencies, will be responsible for short-term policy decisions and program direction. Major decisions made by the steering subcommittee will be ratified by the MMC. The Authority will act as the policy-making body and also as the mediator for unresolved disputes.

MMC monitoring program staff will coordinate PSAMP, providing technical assistance, maintaining a central monitoring database, and preparing special reports to integrate and interpret monitoring results. Until the Authority goes out of existence in 1991, the Authority will house the monitoring program staff. Then the staff will be transferred to another appropriate agency or organization.

PROGRAM SUMMARY

The MMC recommends monitoring of sediments, water quality, biological resources (fish, shellfish, marine mammals, and birds), nearshore habitats, and freshwater. The enclosed table summarizes the type of data to be collected.

Three types of monitoring stations are planned:

* Fixed stations which will be sampled each year;

* Rotating stations which will be sampled on a 3 year cycle; and

* A small number of floating stations which will be located at the discretion of the implementing agency.

Sediment Monitoring

Sediments are the final resting place for a mixture of materials, including organic and inorganic particulate matter, toxic metals, and organic substances. Benthic invertebrates, which live in the sediments, are sensitive indicators of environmental disturbances. They are also important prey for animals higher up the food chain, including many commercial fish.

PSAMP includes an integrated sediment monitoring program. Benthic macroinvertebrate populations, sediment toxicity (measured by bioassays) and sediment characteristics will be measured.

Once a year sediment samples will be collected from the upper two centimeters (cm) of sediment for sediment chemical analysis and bioassays, and from the upper five to 10 cm for benthic invertebrate population analysis. Samples will be taken in bays and deep basins, away from the influence of single point sources.

Sediment samples will be analyzed for selected EPA priority pollutant metals and organic compounds, and for additional compounds of particular concern in Puget Sound. The results will provide an estimate of the amount of toxic pollution reaching Puget Sound sediments. Measurements of conventional sediment parameters (e.g., particle size distribution, total organic carbon, and sulfides) will be used to interpret data on toxic chemicals and benthic macroinvertebrate populations.

Three types of bioassays (amphipod mortality, bivalve larvae mortality and abnormality, and bacterial physiology) will be performed on sediment samples to assess lethal and sublethal effects.

Water Column Measurements

Measurements taken in the water column will provide a basis for determining long-term changes in water quality and help to identify emerging problems. Water column measurements will help to provide an understanding of the basic processes of the Sound, and will aid in the interpretation of trends in other monitoring parameters.

ater quality parameters will be monitored monthly as well as more intensively at certain times of the year when water quality problems may be expected. Samples will be taken in the deep basins and in some of the urban and rural bays where sediment samples are collected.

Temperature and salinity measurements will be used to identify and track seawater and freshwater parcels which flow throughout the Sound, transporting and mixing pollutants. Dissolved oxygen measurements will help identify the areas where man-made disturbances are upsetting the balance of natural processes. Turbidity measurements will identify locations where little light is available for phytoplankton growth, because the amount of particles--which absorb sunlight--is so large.

Fecal coliform bacteria are considered to be an indicator that pathogenic microorganisms may be present. Fecal coliform bacteria will be measured in the water above recreational and commercial shellfish beds, where the presence of pathogenic microorganisms would pose a human health risk.

Nutrients are essential growth factors for attached algae and phytoplankton, but may cause water quality problems if present in excess. Samples will be taken daily in certain bays during midsummer and midwinter to assess yearly maximum and minimum nutrient levels.

Fish

The PSAMP fish task concentrates on fish tissue contamination rather than fish population estimates. The Washington Department of Fisheries routinely collect fish population data. PSAMP will sample the tissue from commercially and recreationally important fish species for toxic chemicals. In addition, English sole--a bottomfish--will be examined for liver abnormalities which may be linked to contaminants in the sediments. This information will be used to identify areas where the fish may be sufficiently contaminated to pose a health risk if eaten by humans and will aid in the management of recreational fisheries.

Pacific cod, rockfish and resident salmon will be sampled at recreational fishing piers around the Sound once a year. English sole will be caught in bottom trawls near many of the sediment sampling locations. The urban bays will be sampled for bottomfish every year while more pristine areas will be sampled less often.

Shellfish

Shellfish, (e.g., oysters, clams, crabs, and shrimp) are of ecological, economic, and recreational importance in Puget Sound. These animals are relatively stationary and may accumulate toxic substances from the water and sediments. The abundance of various shellfish species will be assessed at 35 beaches annually. Tissue of native littleneck clams will also be collected and analyzed for selected chemicals of concern.

Paralytic shellfish poison (PSP) is a serious threat to human health in Puget Sound. The organisms causing PSP are dilute in the water column but become concentrated in the tissues of shellfish, particularly during periods of warm weather. Sampling for PSP will be conducted every other week during May-July, a time of intensive shellfish harvesting. Samples will be taken occasionally throughout the rest of the year. Monitoring for other pathogen indicator organisms in shellfish will be conducted quarterly.

Birds

Birds are ecologically and aesthetically important to the Puget Sound ecosystem. Because many species are near the top of the food chain, they may bioaccumulate toxic chemicals. Many species are vulnerable to the loss, deterioration, or disturbance of nesting and feeding habitats, such as marshes, river deltas, and wetlands. The abundance and harvest of selected seabird species will be monitored using aerial and ground surveys to identify any significant changes that may be related to pollution, habitat loss, or disturbance over time.

Marine Mammals

Marine mammals constitute a key component of the Puget Sound ecosystem. Many are near the top of the food chain, and the effects of pollution on this group of animals may be similar to the possible effects on people. PSAMP will survey harbor seals as indicators of the abundance and health of marine mammals. Adult and juvenile seals will be surveyed by air and land every summer, during the peak of the pupping season. Chemical analysis for toxic chemicals may be carried out on dead seals found during surveys. In addition, siting of other marine mammal species will be recorded throughout the monitoring program.

Nearshore Habitat

The distribution of habitat types within Puget Sound is of fundamental importance to the structure and function of the Puget Sound ecosystem. Wetland habitat is key to maintaining and promoting the biological diversity and productivity of Puget Sound and adjacent waters. Extensive areas of marine, estuarine, and riparian habitats have been destroyed or contaminated in the Puget Sound basin.

The monitoring program will inventory intertidal and subtidal regions, with special emphasis on sensitive nearshore eelgrass meadows and kelp beds and nearshore wetlands. Aerial photography and groundtruthing will be used to inventory these habitats every three years.

Fresh Water

The Puget Sound basin has an extensive network of freshwater rivers, streams, and lakes. Point and nonpoint contaminants draining into fresh water affect Puget Sound, as well as particular watersheds. The monitoring program will establish a network of sampling stations on the major Puget Sound rivers and their tributaries, focusing on watersheds with known or suspected water quality problems. Monthly samples will be collected and analyzed for water quality parameters. Tissue of resident fish will be analyzed for toxicants to assess the risk to human health from eating fish in the watersheds.

River Mouths

Many of the contaminants washed into Puget Sound by rivers and streams are associated with sediment particles. These particles that are deposited in the nearshore region when fresh water enters the calmer waters of the Sound. The monitoring program will measure contaminant levels at the mouths of Puget Sound rivers. Stations at the mouths of major Puget Sound rivers will be sampled annually for the same sediment tests as described under sediment monitoring. In addition, water quality parameters will be measured monthly at these stations.

Citizens' Volunteer Monitoring Program

The PSAMP includes a citizens' volunteer monitoring program. Volunteers will collect samples and record observations that the regular monitoring program could not, due to logistic or cost constraints. The participation by concerned citizens can greatly increase the level of public awareness of water quality issues and can act as a catalyst to public involvement and education in the Puget Sound basin.

Citizens will be involved in verifying the presence of kelp, eelgrass, and fringing marshes seen from the air; in collecting chlorophyll and nutrient samples during intensive midsummer and midwinter sampling; in digging for native littleneck clams for pathogen indicator analysis; and in recording observations of weather, spills, odors, floatables, marine mammals, and birds.

A monitoring coordinator will supply all necessary equipment and training at the start of the program. Follow up training sessions will include quality control audits, speakers and written information on relevant topics, and opportunities for citizen monitors to share their expertise and experiences with other members of the public. Environmental groups, schools, and community colleges will be targeted for involvement in citizens' monitoring programs.

Data Management System

The PSAMP data management system has been designed to support the needs of decision-makers, planners, researchers, and the general public for up-to-date information on Puget Sound; to enable agencies to use the data they collect to meet their overall needs for information using a variety of data retrieval and analysis functions; and to be flexible and expandable to meet new and changing needs.

The data management system will consist of a central Puget Sound database, agency monitoring databases, and a geographic information system. The central Puget Sound database will contain an inventory of available data on Puget Sound, and will store summarized PSAMP data and other selected Puget Sound data. Each implementing agency will maintain a computerized database of PSAMP data collected

by that agency and will transfer data to the central Puget Sound database in a specified format.

A Puget Sound geographic information system (GIS) will initially be used to update the Puget Sound Environmental Atlas and to store nearshore habitat data. As part of the development of a state-wide GIS, it may later be expanded to meet the needs of state regulatory agencies for detailed resource management information.

Quality Assurance/Quality Control

PSAMP includes an organized and rigorous quality assurance/quality control (QA/QC) program. This will ensure that PSAMP data produces defensible answers to management questions and will be accepted by scientific researchers. Puget Sound protocols for sampling and analysis will be followed. Implementing agencies will prepare detailed QA/QC plans, and the MMC will be responsible for review of data and procedures.

FUNDING

The recommended PSAMP design will cost approximately $3.4 million a year to implement, with $690,000 needed during the first year for startup costs. Some funds will be obtained from redirecting existing agency ambient monitoring efforts in Puget Sound. The MMC recommends that funding for the program be included in the budget for the 1989 Puget Sound Water Quality Management Plan.

A major monitoring program like PSAMP requires a stable funding base to exist on a long-term basis. Like Chesapeake Bay, the Great Lakes and other large estuaries nationwide, Puget Sound must receive line item federal funding to assure the continuance of PSAMP.

SUMMARY TABLE

THE PUGET SOUND AMBIENT MONITORING PROGRAM

SEDIMENT

- Sediment Chemistry
- Bioassays
- Benthic Invertebrates

WATER COLUMN

- Temperature
- Salinity
- Dissolved Oxygen
- Turbidity
- Nutrients
- Chlorophyll
- Pathogen Indicators
- Odors, Floatables, Spills

FISH

- Toxic Chemicals in Fish
- Fish Disease
- Fisheries Harvests and Stock Assessments

Chapter 1.
Overview of the Puget Sound Ambient Monitoring Program (PSAMP)

INTRODUCTION

The 1987 Puget Sound Water Quality Management Plan found that "... there is currently no long-term comprehensive program to monitor Puget Sound and its resources..." In response to this finding, the plan mandated that a comprehensive environmental monitoring program be developed for Puget Sound to "...(1) assist decision-making of agencies by identifying problem areas and trends; (2) measure the success of the Puget Sound plan; and (3) provide an ongoing assessment of the health of the Sound...".

In October 1986 the Puget Sound Water Quality Authority (the Authority) created an interdisciplinary committee to design the monitoring program. The committee is known as the Monitoring Management Committee (MMC) and consists of more than 30 water quality professionals from federal, state and local agencies, universities, tribes, industry, and members of the public. This committee has met regularly since its creation. Working from a document originally written by a consultant to the U.S. Environmental Protection Agency (EPA), the MMC developed the monitoring program which is described in this document. The goals and objectives of the monitoring program, relationship to other programs, the process used to develop PSAMP, and the sampling strategy are all discussed in the next section. The technical design addresses sediment parameters, water quality monitoring, biological monitoring (including fisheries, shellfish, marine mammals and birds), monitoring of rivers, streams, and river mouths, and habitat monitoring. Collection of additional data and a citizens' volunteer monitoring program are also discussed.

GOALS OF THE PUGET SOUND AMBIENT MONITORING PROGRAM (PSAMP)

The purpose of ambient monitoring in Puget Sound is to provide coherent data which increases our understanding of Puget Sound, its resources and the effects of human activities. Such understanding by elected officials, scientists, engineers, regulators, educators, members of industry and agriculture, the media, and the public is necessary to preserve and protect Puget Sound. The results of the monitoring program will aid in setting water quality priorities and recognizing emerging problems.

Ambient monitoring is defined as the repeated measurement of selected parameters at several locations. The results of the ambient monitoring program will be analyzed for spatial and temporal differences, including temporal trends, and the results interpreted to provide an understanding of those trends.

The ambient monitoring program design, with its detailed quality assurance/quality control (QA/QC) requirements, will ensure that only high quality data are collected. The data will be entered into a central data base and made available for use by a wide audience.

The goals of the monitoring program are:

GOAL 1: Characterize and interpret spatial and temporal patterns of conditions of Puget Sound in relation to its natural resources and for humans, and recognize contamination.

GOAL 2: Take measurements to support specific program elements identified in the Puget Sound Water Quality Management Plan.

GOAL 3: Measure the success of programs implemented under the Puget Sound Water Quality Management Plan (as they relate to the overall ambient monitoring goal and the program goals of the plan).

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

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

To achieve these goals, the monitoring program will characterize and interpret spatial and temporal patterns for the following:

* Factors that endanger human health.
* Biological populations and communities.
* Factors affecting biological populations.
* Presence of pollutants in the Sound.
* Entry of pollutants into the Sound from rivers and streams.
* Estuarine and wetland habitats.
* Results of water quality degradation, such as shellfish bed closures.
* Improvements in water quality such as the reopening of shellfish beds.
* Factors that affect aesthetic conditions.

The monitoring program will identify areas where:

* Resources are damaged or contaminated.
* Resources or conditions are changing over time.
* Intermittent or periodic degradations are occurring.

RELATIONSHIP OF PSAMP TO OTHER PUGET SOUND PROGRAMS

There are numerous monitoring programs underway in the Puget Sound basin, most of which are carried out under the legal mandates of federal, state, and local agencies. In addition, selected studies by universities, private companies, and non-profit groups add to the wealth of information being gathered in the basin. PSAMP will be directly linked to a limited number of other programs through the use of standardized protocols and data formats. Compatibility with PSAMP data will be encouraged in many other programs. Those programs (and data types) to which PSAMP may be closely linked include:

* Timber/Fish/Wildlife.
* Nonpoint source control watershed monitoring.
* Puget Sound Dredge Disposal Analysis.
* Puget Sound Estuary Program (PSEP) urban bay studies.
* National Pollutant Discharge Elimination System compliance monitoring.
* Intensive surveys.
* NOAA National Status and Trends Program.
* Northwest Indian Fisheries Commission and member tribes.
* Research studies, historical information, and other studies.
* Climate/weather data.
* Demographic and socioeconomic conditions.
* Decision record-keeping.

Timber/Fish/Wildlife (T/F/W)

The Timber/Fish/Wildlife coalition among the natural resource agencies, landowners, and tribes concerned with forested watersheds and logging activities is developing monitoring programs to examine the impact of logging regulations on freshwater fish, wildlife populations, and habitat. It is anticipated that monitoring protocols and data formats will closely resemble those for the freshwater task of PSAMP. T/F/W data will be brought into the PSAMP database as funding allows.

Nonpoint Source Control Watershed Monitoring

Baseline and long-term monitoring programs mandated by the Puget Sound Water Quality Management Plan and the Local Planning and Management of Nonpoint Source Pollution Rule (WAC 400-12) will employ protocols and data formats which are compatible with PSAMP. This data will be brought into the PSAMP database as funding allows.

Puget Sound Dredge Disposal Analysis (PSDDA)

PSDDA investigations into the suitability of deep-water disposal sites in Puget Sound for dredged material include baseline and long-term monitoring for contaminants and their biological effects. Sediment quality guidelines and data collected under PSDDA will have direct applicability to PSAMP. Efforts are underway to assure that similar sampling and analysis methodology is used and that databases are compatible between PSDDA and PSAMP. PSDDA data will be brought into the PSAMP database, and PSAMP data will be shared with PSDDA, where appropriate.

Puget Sound Estuary Program (PSEP) Urban Bay Studies

Considerable PSEP resources are focused on studies in Commencement Bay, Elliott Bay, Everett Harbor and other urban embayments. The purpose of the urban bay program is to identify contaminated areas, to understand the biological effects of the contaminants, and to propose remedial action programs. Urban bay program testing focuses on sediment quality and bottomfish contamination, which are also key elements of PSAMP. The urban bay programs focus on specific sources to a greater degree than PSAMP, but data generated under these programs will be directly applicable to the interpretation of PSAMP results and will be brought into the PSAMP database as needed.

National Pollutant Discharge Elimination System (NPDES) Compliance Monitoring

Historically, monitoring for point source permit compliance has focused primarily on conventional pollutants in the waste stream. The 1987 Puget Sound Water Quality Management Plan mandated that additional monitoring requirements be added to permits written after July 1, 1988. The requirements include environmental monitoring of conventional and toxic pollutants in the water column, sediment monitoring, and tests determining the effects on the biota.

The objectives of environmental compliance monitoring and PSAMP differ somewhat; monitoring for NPDES compliance focuses on a single point source in an attempt to isolate that source's effect on the environment. PSAMP stations will purposely avoid the influence of one or more point sources in order to establish the background conditions of the Sound. There will, however, be some overlap between compliance monitoring reference (control) stations and PSAMP stations for sediment, water quality, and biota. Wherever possible, results of compliance monitoring data from reference stations will be included in the PSAMP database. Other NPDES station data will be brought into the PSAMP database if a specific area of interest to the ambient program is addressed.

Intensive Surveys

Cost constraints prevent intensive surveys from being included in PSAMP. There is a very necessary link, however, between the findings of an ambient program and intensive investigations in areas of emerging problems or rapidly changing environmental variables. Some discretionary stations will be included in the budgetary process for PSAMP, but the majority of intensive studies must be funded through existing resource agency budgets. The departments of Ecology, Fisheries (WDF), Wildlife (WDW) and the department of Social and Health Services (DSHS) Shellfish Program currently have funds earmarked for intensive surveys or studies in Puget Sound. Ecology's FY 89 budget includes approximately $350,000 to $400,000 per year for intensive surveys in Puget Sound. Figures from other agencies are not currently available.

PSAMP findings will trigger portions of the implementing agencies intensive survey programs. Those survey data that apply to the ambient program will be entered into the PSAMP database. There are many other factors which will trigger intensive surveys, most notably NPDES compliance monitoring findings, and fish, shellfish, bird, or marine mammal kills. Data which do not relate to the objectives and goals of PSAMP will only be entered into the database if requested by the implementing agencies.

National Oceanic and Atmospheric Administration (NOAA) National Status and Trends Program

As a part of a nation-wide assessment and long-term monitoring program called the National Status and Trends Program, NOAA samples seven stations in Puget Sound annually for toxic chemicals in mussels and for conventional sediment variables. NOAA samples an additional three stations for toxic chemicals in bottomfish tissue and in sediment. Some protocols used for sample collection and chemical analysis in the National Status and Trends program do not coincide with those proposed for PSAMP. Data from the NOAA program will only be entered into the PSAMP database where protocols are the same, and where the NOAA data provide additional information to meet PSAMP objectives.

Northwest Indian Fisheries Commission (NWIFC) and Member Tribes

The NWIFC and member tribes carry out numerous monitoring programs in both fresh and salt waters, focusing on fish habitat, water quality, fish stock assessments, shellfish abundance, bacterial content, and temperature in streams. The NWIFC is coordinating data management and data sharing, including the development of a geographic information system for the member tribes. NWIFC data will be brought into the PSAMP database where appropriate and when funding allows.

Research Studies, Historical Information, and Other Studies

Results of research studies, historical data collected under agency programs, and miscellaneous data from other studies will be included in the PSAMP database as time and funding allow. Studies of greatest value to the PSAMP will be those which have measured the same or related sampling parameters and which occur in the vicinity of PSAMP sampling stations. In order to be included in the PSAMP database, the study data must have used the same or comparable protocols, and the quality of the data must be well-documented. Since the majority of studies are conducted in Puget Sound for regulatory, research, or other specific purposes, it is anticipated that most will not be likely candidates for the PSAMP database.

PSAMP results may give rise to questions that are best answered by focused research on natural processes, sampling and analysis methodologies, or other topics. These questions should be considered as research priorities for Puget Sound.

Climate/Weather Data

Climate and weather data are collected daily at many locations around the Sound, including Olympia, Port Angeles, Bellingham, and Sea-Tac Airport. These location represent a range of precipitation and weather extremes commonly observed in the Puget Sound basins

Climatological trends may affect the interpretation of physical, chemical and biological data collected by PSAMP. For example, El Nino events alter the characteristics of oceanic water entering Puget Sound, which in turn, may affect Puget Sound biota. Abnormally long spells of dry or wet weather will change the input of freshwater to the Sound, which may alter the habitat and biological populations of the nearshore estuaries.

Monthly and annual summaries of climatological data available from the National Weather Service and the State Climatologist's office may be analyzed for trends in local and regional weather patterns in order to interpret PSAMP data. Climatological information that may be examined includes wind speed and direction, precipitation, hours of daylight, air temperature, mean sea level, percent cloud cover, summaries of climatological anomalies (droughts, floods, El Nino events), and major storm events.

Demographic and Socioeconomic Conditions

Changes in demography and economic activity have an impact on water quality because anthropogenic impacts to Puget Sound are strongly influenced by the distribution of people and their economic activities. For example, bacteria from malfunctioning septic systems and from farm animals may significantly impact downstream commercial shellfish rearing areas. Toxic contamination of the sediments and biota may be associated with heavily populated or industrialized areas.

Information on demographic and socioeconomic conditions and changes is collected by Puget Sound county planning departments, the state Office of Financial Management, the Department of Ecology, the Puget Sound Council of Governments and the U.S. Army Corps of Engineers.

Variables which are presently tracked and may be compiled for use in PSAMP data interpretation include:

* Land use and zoning, including the rate of approval for zoning variances in the coastal zone and along rivers and streams. Use of this information may give early warning of trends such as encroachment on wetlands, displacement of water-dependent uses of shorelines, and reduction of public access.

* Construction permit awards, especially those for substantial development in shoreline areas and in rivers and streams. Optimally, use of this data would ensure that permit awards are consistent with the intent of the Shoreline Management Act and local Shoreline Master Plans.

* Population by census tract, especially in coastal areas and along rivers and streams. This information could identify damaging effects of increased population on water quality before they become serious. For example, rapid residential growth in a rural area may foreshadow a potential increase in bacterial contamination.

* Employment by economic sector, as an indicator of contaminant loading. For example, an increase in employment by electronics manufacturers may result in an increased discharges of solvents to municipal sewage treatment systems.

* Shoreline use records of the Washington Department of Ecology. These records include information needed to manage shoreline permits for projects with potential significant or cumulative environmental impacts.

Decision Record-Keeping

Records are kept of all relevant regulatory and resource management decisions, which potentially affect the Puget Sound environment and beneficial uses of its resources, by regulatory and resource management agencies and branches of federal, state, and local government, including Ecology, U.S. Environmental Protection Agency, U.S. Army Corps of Engineers, Department of Natural Resources, the Authority, other state agencies and county planning departments. Detailed records of permit-related decisions, planning activities, institutional changes, and legal changes within the Puget Sound area are recorded to aid in decisions related to environmentally significant projects and to planning, institutional, and legal activities.

Environmentally significant projects

The Environmental Impact Statement process provides good records for tracking all projects that are deemed to have significant environmental impacts. Also, permits are issued for a variety of activities, including aquatic disposal of effluent (NPDES permits), dredging and filling (Clean Water Act, Section 404 COE permits), storage and handling of hazardous or toxic substances and aquaculture (Washington Department of Natural Resources [DNR] submerged lands leases).

Planning activities

Planning is undertaken by all levels of government and can indicate trends that are significant to the monitoring program. Records could be collected on planning activities such as land use planning, public utility planning (especially wastewater treatment and disposal) and water quality planning.

Institutional and legal activities

A variety of institutional and legal activities may be recorded so that relevant information can be channeled to key organizations and key managers of the monitoring program. Changes in local ordinances (such as grading and drainage codes), state regulations (such as the Shoreline Management Act amendments and the Nonpoint Source Control WAC), and reorganization of government bodies (foundation of a new agency or reorganization of a government branch), may have far reaching consequences to the environmental management of Puget Sound.

Compilations of decision-making records may be summarized and added to the PSAMP database in order to interpret environmental trends and changes.

INSTITUTIONAL FRAMEWORK FOR PSAMP

Purpose and Need for Central Management

There is presently very little coordination among monitoring programs in the Puget Sound basin. PSAMP has been developed through an interdisciplinary committee representing all parties involved in and affected by monitoring. The implementation of this multifaceted program requires central coordination and management. In order to successfully implement an ambitious and wide-ranging program like PSAMP, a high degree of organization is needed to handle the data generated and to assure that all aspects of the program are carried out as designed.

Federal Estuary Designation

A major monitoring program can only exist on a long-term basis by gaining a stable funding base. Like Chesapeake Bay, the Great Lakes, and other large estuaries nationwide, Puget Sound must receive line item federal funding to assure the continuance of PSAMP. EPA has designated Puget Sound an estuary of national significance. The Estuaries of National Significance program requires centralized management and data analysis. These requirements will be satisfied by the organizational structure set up to manage PSAMP.

Managing the Monitoring Program

To achieve the required degree of organization and coordination, a management structure consisting of a technical advisory and policy group and a staff unit must be created. In addition, a forum for dispute resolution and release of public documents must be designated. The proposed management structure for PSAMP is shown in Figure 1-1.

The MMC will act as the technical and policy group, with membership representing all affected parties, much as it does now. The MMC will meet only once or twice a year. A steering subcommittee, made up of representatives of the lead agencies participating in PSAMP (the Authority, Ecology, WDF, WDW, DSHS and DNR), will be responsible for the policy decisions and direction of the program on a shorter time scale. Major technical and policy issues will be referred to the whole MMC.

The present MMC has recommended that a staff unit be housed in the Authority until the Authority goes out of existence in 1991. The unit will be made up of scien-

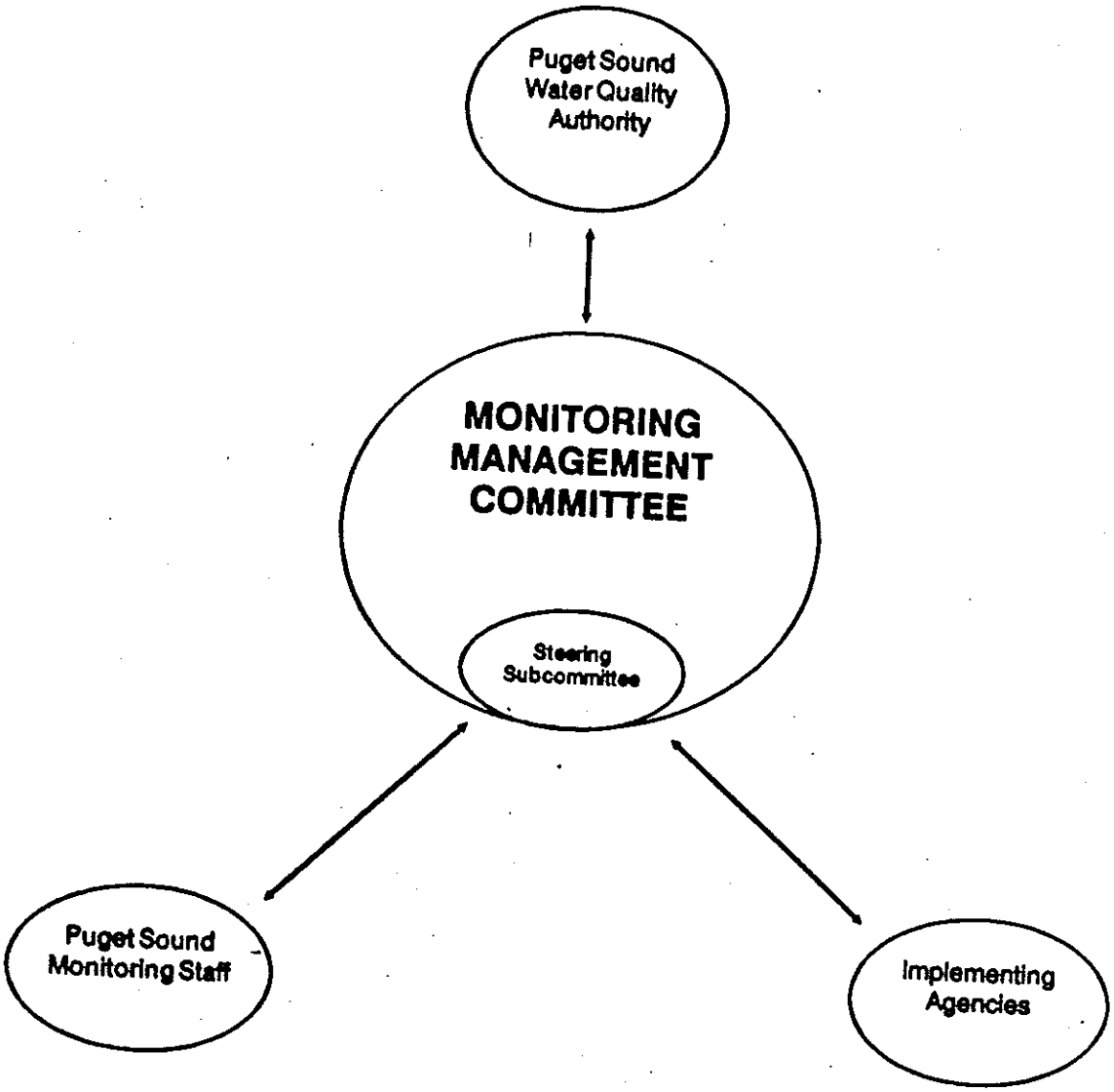

FIGURE 1-1. PROPOSED MANAGEMENT STRUCTURE OF THE PUGET SOUND AMBIENT MONITORING PROGRAM

tists capable of judging the quality of the data being generated, data management personnel, and necessary support staff. The unit will be given the responsibility for making minor program revisions which are recommended by the implementing agencies or by the staff themselves. Larger program revisions, or those which affect many agencies and cannot be resolved at the staff level, will be referred to the steering subcommittee or the full MMC. Decisions made by the staff unit or the MMC can be appealed to the Authority by the implementing agencies.

The Authority will act as the legislative advocate for PSAMP, will hear appeals of decisions made by the staff unit and/or the MMC, and will act as the public liaison for the release of documents.

Future of the Monitoring Management Structure After 1991

After the Authority sunsets in 1991, the advocacy, appellate, and public information functions of the Authority could be taken over by another agency, by an existing research organization, or by a successor to the Authority. The passage of these duties to another organization would depend on the ability of that organization to direct and house the staff unit and to ensure the continuing success of the program.

If PSAMP gets underway during 1988, the MMC will have 3 years to refine the methods best suited to managing PSAMP. At that time, the staff unit could be transferred intact to another state agency, such as DNR or Ecology, to a research organization (such as that described by the Committee on Research in Puget Sound [Puget Sound Water Quality Authority, 1988]) or it could be housed in some successor to the Authority.

The MMC or similar technical and policy group could carry on as an independent committee after the Authority sunsets. For practical purposes, the MMC would operate under the wing of the organization housing the staff unit, but would remain autonomous in its technical and policy making decisions.

Organizational Responsibilities Under the Proposed Monitoring Management Structure

The Authority

Until 1991, the Authority will:

* Serve as the advocate for the monitoring program at state and federal level.
* Facilitate implementing agency cooperation to carry out the monitoring program.
* Provide binding mediation for interagency disagreements concerning the monitoring program.
* Distribute integrated, interpreted reports.

MMC

The Monitoring Management Committee and--on a shorter time frame--the steering subcommittee will perform the following functions:

* Provide overall coordination of monitoring program.

* Decide on major program revisions.
* Refer disagreements among implementing agencies to the Authority.
* Review data reports and integrated reports.
* Sanction protocols for use in the monitoring program.
* Meet only as needed, once or twice a year.

Staff

The Puget Sound monitoring program staff, which will be housed in the Authority until 1991, will undertake the following:

* Implement MMC and steering subcommittee decisions.
* Coordinate the monitoring program.
* Make minor program revisions.
* Manage the central database system.
* Provide QA/QC review of data.
* Prepare technical assessment of PSAMP progress for the MMC.
* Ensure that program revisions are coordinated among agencies.
* Provide technical assistance to program participants in areas of data analysis and interpretation, as well as field and laboratory activities.
* Organize outside technical assistance, where needed, to help in the review of monitoring data and program revisions.
* Prepare integrated reports from data reports.
* Coordinate with other monitoring and research efforts.

Implementing Agencies

Implementing Agencies (& other organizations) will do the following:

* Monitor Puget Sound.
* Maintain in-house monitoring databases and QA/QC programs.
* Prepare data reports, consisting of data listing, data analysis, and some data interpretation.
* Participate in program changes through membership on the MMC and steering subcommittee.
* Make recommendations to staff concerning program revisions.

Data Transfer

Each implementing agency will maintain its own computerized database for PSAMP data. In addition, each agency will transfer data to the central database, which will be maintained by the PSAMP staff. Data transfers must be accomplished

in a timely manner and in the format approved by the MMC. (Further detail for all data management tasks can be found in Chapter 3: Data Management.)

Data Reports

Reports will be prepared annually by each implementing agency and will include synthesized data, statistical analyses, and interpretation. These reports may become part of the implementing agency's mandated reporting procedure for all agency functions, but will be transmitted to the MMC as stand-alone documentation of the assigned monitoring duties for PSAMP.

The data reports will be forwarded to the MMC as draft reports (not raw data) and already will have undergone in-house review by the agency. The MMC will provide peer review of the reports before they are finalized by the agency.

Integrated Reports

Reports that integrate and interpret the monitoring program findings will be written by the PSAMP staff, reviewed by the MMC, and published by the Authority once a year. PSAMP staff will verify data quality and scrutinize conclusions drawn by the implementing agencies. Ecological correlations and trends will be examined by comparing the findings from different portions of the program, and the results will be documented.

The integrated scientific findings will be translated into language which is readable to the public and a report will be published annually by the Authority.

The Authority is under legislative mandate to produce the *State of the Sound Report* biennially and will use results of the monitoring program to do so. Data from PSAMP will also be used to update the Puget Sound Environmental Atlas, which was recently completed under the auspices of the Authority, EPA, and the U.S. Army Corps of Engineers (COE).

MONITORING PROGRAM TASKS

Eight program tasks have been chosen to address the PSAMP goals and objectives. Long-term temporal and spatial trends in water quality, the condition of resources, and contamination will be addressed in these areas. Key questions to be answered by PSAMP are:

* **Sediment Quality** - What are the patterns of contamination of Puget Sound bottom sediments? What effect do these sediments have on marine organisms?
* **Water Column** - What are the characteristics of Puget Sound water, and how do they change over time? What are the pathways for the transport of contaminants in Puget Sound?
* **Fish** - How healthy are the fish living in Puget Sound, and what is the potential human health threat from consuming fish living in contaminated areas?
* **Shellfish** - Are the shellfish in Puget Sound contaminated, and what is the potential risk to human health from consuming contaminated shellfish?
* **Birds** - How large are the populations of Puget Sound birds?
* **Marine Mammals** - How many marine mammals live in Puget Sound? Are they healthy and reproducing well?
* **Fresh Water** - What is the condition of the freshwater resources in the Puget Sound basin?

- **River Mouths** - What effect does contamination from freshwater have on Puget Sound?

- **Nearshore Habitat** - What types of nearshore marine habitats are there in Puget Sound and what condition are they in?

PROCESS FOR DEVELOPING PSAMP

During the summer and early fall of 1986, a monitoring design was developed by a private contractor (Tetra Tech) under the direction of the Office of Puget Sound, Region X, EPA. In October 1986, the Authority appointed the MMC to develop an ambient monitoring program for Puget Sound. The draft monitoring design produced by the contractor was given to the MMC in November 1986 for further refinement.

In early 1987, the Office of Puget Sound compiled the results of a survey on existing monitoring programs in Puget Sound. Federal, state and local agencies, special purposes districts (water districts, sewer districts, etc.), tribes, selected professional organizations, and the shellfish industry were asked about their monitoring programs, legal mandates for monitoring, cooperation with other agencies, data needs, and capabilities. The survey results were used to identify overlaps between existing monitoring programs and to help assign field collection and analysis efforts for PSAMP.

Throughout 1987 and early 1988, the MMC worked on changes and refinements to the monitoring program design. The committee met monthly to discuss changes to the sampling design and to develop a data management system, an institutional framework for implementing PSAMP, and a cost estimate for the program. The consensus process was used throughout for decision-making. Full-time staff provided technical support.

The MMC presented this final report and recommendation to the Authority in April 1988. The committee recommends that the PSAMP design be incorporated into the 1989 Puget Sound Water Quality Management Plan, along with specific recommendations for funding and program implementation. Memoranda of agreement are being written between the Authority and each implementing agency to ensure that the PSAMP design is followed, that data flow from the agencies is fast and efficient, that periodic reporting on program progress occurs, and that the agencies continue to participate in the MMC and monitoring program.

Eleven technical subcommittees met during the course of PSAMP development. The membership of the subcommittees was drawn from the MMC and from outside experts. The subcommittees and their responsibilities were:

- **Strategy** - sampling strategy and station locations.

- **Shellfish** - shellfish program design.

- **Nutrient/Phytoplankton** - sampling design for nutrients & phytoplankton.

- **Rivers** - freshwater program design.

- **Bioassays** - technical detail in bioassays.

- **Habitat** - nearshore habitat program design.

- **Turbidity** - turbidity sampling design.

* **Costing** - development of a cost estimate for PSAMP.

* **Institutional** - institutional framework development.

* **Data Users'** - data management needs for water quality managers.

* **Data Systems** - data management system design.

In addition, a workshop on remote sensing was convened in September 1987 to discuss remote sensing technology and its potential application to PSAMP. The workshop was attended by MMC members as well as experts in remote sensing from the Puget Sound region and beyond.

The draft PSAMP design was reviewed by a broad audience; workshops were held for the general public and for local government and tribal staff during September 1987. Scientific review of the draft design was received as written comment from members of the Puget Sound Estuary Program (PSEP) Technical Advisory Committee (TAC) and other eminent scientists in the Puget Sound area in December 1987 and January 1988.

Many sampling schemes and experimental designs beyond those which appear in this report were proposed, reworked, and dropped during the course of PSAMP development. The most notable of these follow, by program task. Many of the strategies rejected for this initial PSAMP design should be given serious consideration in future iterations of the program, when funding levels and/or technological advances may provide appropriate tools for their inclusion.

Sediment Quality:

* Additional bioassays including trout anaphase, and worm respiration, as well as infaunal species index were considered to be too costly and/or not sufficiently well-developed tools for this program.

* Replicate sediment chemistry samples were rejected as too costly and unnecessary.

* Tributyl tin was considered for addition to the sediment chemistry suite, but lack of protocols or understanding of the results led to its exclusion.

* Revisiting sediment quality stations every 5 or more years was considered, but the need for a well-defined baseline of data determined that certain stations be sampled each year.

Water Column:

* Monthly water column sampling at a large number of stations was considered to be an inadequate sampling scheme; additional sampling schemes were added.

* Bacterial analysis at all water column stations was rejected due to the extremely low numbers of fecal bacteria viable in open water.

Fish:

* A single composite sample for chemical tissue analysis was considered to provide insufficient information for measuring the natural variability of a biological population.

Shellfish:

* Quarterly sampling year-round of shellfish meat was not considered to provide a sufficiently detailed estimate of bacterial contamination.

* Butter clams were considered as the target organism for all shellfish sampling, but their lack of ready availability on some beaches and their retention of PSP over the winter caused them to be rejected in favor of native littleneck clams.

Birds:

* Measures of reproductive success and toxic contamination in birds were not incorporated into the program, as necessary background studies and protocols are not yet available.

Nearshore Habitats:

* Detailed groundtruthing for certain habitat parameters, including species composition, diversity and percent cover, was not incorporated into PSAMP due to cost constraints.

Fresh Water:

* A pilot program for partitioning loading of organics by land use type was considered to be inappropriate for an ambient monitoring program.

Data Management:

* A single completely centralized database was considered but was rejected due to high development costs. Also, large centralized database would not provide the implementing agencies direct access or management of PSAMP data.

* Storing data in databases dispersed among the implementing agencies, without a central system, would not provide for analysis or interpretation of integrated information on Puget Sound.

Overall Program Strategy:

* Intensive surveys to examine emerging problems were recognized as a vital link to the ambient program but were not included due to cost constraints. Existing and planned intensive monitoring activity by the implementing agencies was considered adequate to fill this gap.

* The importance of measuring fluxes (water current speed, and sediment falling out of the water column) was recognized but was considered to be beyond the capabilities of this program.

SAMPLING STRATEGY

The agency or agencies responsible for implementing PSAMP will be limited by the financial resources available. The monitoring program has been designed to maximize the return of information for the resources expended, using the following criteria:

* Sampling stations should be placed in locations and sampled at frequencies which will yield a maximum amount of useful data.

* Samples should be taken and analyzed according to scientifically valid and consistent protocols, to ensure that all data obtained during the program is comparable.

Reference stations have not been specifically chosen in the sampling scheme, as the long-term trend concept of PSAMP allows each station to act as its own control or reference over time. Stations selected in relatively remote and pristine locations for each sampling task may act as reference stations in the short-run.

The recommended sampling strategy consists of four types of sampling stations or surveys. This strategy will be used consistently for sediment, water column, and resource population sampling. Exceptions to this sampling strategy are necessary for habitat sampling, marine mammal and bird surveys, and in certain other areas. The recommended station/study types which are applicable to most of the program are:

* Fixed stations will be sampled at set recurring intervals (annually for sediment parameters and bottom fish, monthly for water column parameters etc.).

* Rotating stations will be grouped geographically, sampling a portion of the Sound during a given year. Rotating stations will be grouped in either the northern, central, or southern part of the Sound each year, completing a rotation every three years. Rotating stations will always be grouped in proximity to a fixed station used as a frame of reference.

* Floating stations are discretionary stations to be placed in areas with emerging problems or to aid in the interpretation of data from fixed or rotating stations.

* Intensive surveys concentrate resources in a short timeframe and in a limited geographic area in order to answer specific scientific questions. Intensive surveys by agencies will be triggered by findings of the ambient program, but will not be undertaken as a part of this program.

Chapter 2:
Monitoring Program Design

MARINE SEDIMENT QUALITY

Rationale

Sediments are the final resting place or sink of most contaminants discharged into Puget Sound. The chemicals of concern for Puget Sound (Table 2-1) have generally been found to accumulate in much higher concentrations in marine and estuarine sediments than in the water column. Monitoring sediment quality parameters will include the examination of the distribution of contaminants that have entered Puget Sound in the recent past, the biological communities living in the sediments, and the potential effects of toxicants on the biological community.

Bottom sediments are created by a rain of organic and inorganic particulate matter settling out of the water column. The particulate matter may contain a mixture of materials, including toxic metals and organic compounds. The biological communities associated with the sediments are influenced by the physical structure of the sediments, by the availability of food, and by the incidence of toxic materials present. Grain size and other attributes of the particulate matter determine the physical structure of the sediments, while the organic portion of the particulate matter provides food. Toxic metals and organic compounds readily adsorb onto particulate matter in the water column, later to accumulate as bottom sediment. Potential toxic effects of these substances on the benthic community depend upon the physical, chemical, and biological interactions taking place in the sediments.

Historical trends of chemical use in the Puget Sound basin are reflected in sediment cores taken in the Sound. Such data are available from research studies, and show that the use of some chemicals has decreased over time, while the use of many more has increased. Sediment cores will not be taken as a part of this program. PSAMP is concerned with establishing baseline conditions for sediment quality throughout Puget Sound, and with documenting temporal and spatial trends of sediment quality.

Meeting the Program Goals

Sediment quality data will provide a record of the health of Puget Sound sediments and of the quality of the sediment entering the Sound from rivers, streams, point and nonpoint sources. Specific program elements of the Puget Sound plan which require sediment quality data include a multi-user confined disposal sites study (S-6)

and an inventory of contaminated sediment sites (S-8). Programs in the plan which are directed at limiting the amount of contaminants entering the sediment include portions of :

TABLE 2-1: LIST OF TARGET CHEMICALS FOR SEDIMENT ANALYSIS

METALS

Metals and Metalloids

Antimony	Lead	Zinc
Arsenic	Mercury	Aluminum[a]
Cadmium	Nickel	Iron[a]
Chromium	Silver	Manganese[a]
Copper		

VOLATILES

Volatile Halogenated Alkanes (neutrals)

chloromethane	carbon tetrachloride[c]
bromomethane	bromodichloromethane[c]
chloroethane[c]	1,2-dichloropropane
dichloromethane	chlorodibromomethane[c]
1,1'-dichloroethane	1,1,2-trichloroethane[c]
chloroform	bromoform[c]
1,2-dichloroethane[c]	,1,2,2-tetrachloroethane[c]
1,1,1-trichloroethane[c]	

Volatile Halogenated Alkenes (neutrals)

vinyl chloride	cis-1,3-dichloropropene
1,1'-dichloroethene	trans-1,3-dichloropropene
trans-1,2-dichloroethene	trichloroethene
tetrachloroethene	

Volatile Aromatic and Chlorinated Aromatic Hydrocarbons (neutrals)

benzene	styrene (ethenylbenzene)
toluene	total xylenes
ethylbenzee	chlorobenzene

ACID EXTRACTABLES

Phenols (organic acids)

phenol	2-methylphenol
4-methylphenol	2,4-dimethylphenol

Substituted Phenols (organic acids)

2-chlorophenol	2,4,5-trichlorophenol
2,4-dichlorophenol	pentachlorophenol
4-chloro-3-methylphenol	2-nitrophenol
2,4,6-trichlorophenol	2,4-dintrophenol
	4,6-dinitro-o-cresol

TABLE 2-1: Continued

Miscellaneous Organic Acids (selected samples only)

2-methoxyphenol[b]
3,4,5-trichloroguaiacol[b]
4,5,6-trichloroguaiacol[b]
tetrachloroguaiacol[b]
mono- and di- chlorodehydroabietic acids[b]

BASE/NEUTRALS

Low Molecular Weight Aromatic Hydrocarbons (neutrals)

naphthalene
acenaphthylene
acenaphthene
fluorene
phenanthrene
anthracene

High Molecular Weight PAH (neutrals)

fluoranthene
pyrene
benzo(a)anthracene
chrysene
benzo(b)fluoranthene
benzo(k)fluoranthene
benzo(a)pyrene
indeno(1,2,3-c,d)pyrene
dibenzo(a,h)anthracene
benzo(g,h,i)perylene

Chlorinated Aromatic Hydrocarbons (neutrals)

1,3-dichlorobenzene
1,4-dichlorobenzene
1,2-dichlorobenzene
1,2,4-trichlorobenzene
2-chloronaphthalene
hexachlorobenzene (HCB)
Total PCBs (mono- through decachlorobiphenyls)

Chlorinated Aliphatic Hydrocarbons (neutrals)

hexachloroethene
trichlorobutadiene isomers[c]
tetrachlorobutadiene isomers[c]
pentachlorobutadiene isomers[c]
hexachlorobutadiene

Phthalate Esters (neutrals)

dimethyl phthalate
diethyl phthalate
di-n-butyl phthalate
butyl benzyl phthalate
bis(2-ethylhexyl)phthalate
di-n-octyl phthalate

Miscellaneous oxygenated compounds (neutrals)

isophorone
benzyl alcohol
benzoic acid
dibenzofuran
polychlorodibenzofurans[d]
polychlorodibenzodioxins[d]
coprostanol[a]

Organonitrogen Compounds (bases and neutrals)

N-nitrosodiphenylamine
9(H)-carbazole

Pesticides (neutrals)

p,p'-DDE
p,p'-DDD
p,p'-DDT
aldrin
endosulfan sulfate[e]
endrin
endrin aldehyde[e]
heptachlor

TABLE 2-1: Continued

dieldrin	heptachlor epoxide[e]
alpha-chlordane	alpha-HCH
alpha-endosulfan[e]	beta-HCH
beta-endosulfan[e]	delta-HCH
	gamma-HCH (lindane)

[a] Not of concern as pollutants, but to be analyzed as ancillary variables used in interpretation of data.

[b] Recommended for analysis only near pulp mill facilities (chlorinated guaiacols are only of concern near kraft mills).

[c] Recommended for analysis only where a major source of chlorinated butadienes is suspected.

[d] Chlorinated dibenzofurans and dioxins are recommended as special analyses only, as determined by specific project goals.

[e] This compound is seldom or not reported, but it can be easily analyzed for with other recommended analytes.the nonpoint, municipal and industrial discharges, contaminated sediments and dredging, and stormwater and CSO programs. Results of sediment quality monitoring will provide information on the effectiveness of these program elements. Both natural and anthropogenic changes to sediment quality will be documented through trend data obtained under PSAMP, and invaluable data will be made available to researchers concerned with sediment quality.

Methods

A three-pronged approach to sediment monitoring will be used in order to look at the animal populations which are living in the sediments, the chemicals which are also present in the sediments, and the effect the sediments have on living organisms. This combination of benthic macroinvertebrate monitoring, sediment quality, and bioassays forms the "triad" of sediment monitoring variables recommended by Chapman and Long (1983). Field and laboratory methods are well developed for the recommended parameters.

Frequency and Timing of Sampling

Because chemicals accumulate in sediments by adhering to particles settling from the water column, the rate at which chemicals of concern accumulate in the bottom sediments of Puget Sound depends on the sedimentation rate. Sediment accumulation rates in Puget Sound are such that changes in the concentration of chemicals are unlikely to be seen in less than five years. In the first five years of PSAMP, sediment sampling will take place annually, until an established baseline is determined. After that time, sediment quality sampling will occur every five years, with more frequent sampling in areas where contamination has been found (such as urban bays) and even less frequently where sources of contaminants are rare.

The stability of most chemicals of concern in Puget Sound sediments allows representative annual sampling to occur at any time of the year. Similarly, bioassays can be conducted during any season. Benthic macroinvertebrate communities are highly seasonal, however, and must be measured when population numbers are stable, in order to ensure repeatability over time. Early spring (March-April) sampling of benthic communities allows for a determination of the stable adult population which has survived over the winter, but does not yet measure recruitment of juveniles (Tetra Tech, 1987). All sediment quality sampling will be carried out at this time of year in order to correlate results of chemical analysis, bioassay results,

and benthic community structure. Interannual variation of benthic invertebrate populations will occur, further necessitating annual sampling for several years to establish a reasonable baseline of data.

Location of Sampling Stations

Criteria

Sampling stations will be located according to criteria which will optimize the likelihood of obtaining representative sediment samples. These criteria are:

* Some stations will be located close enough to shore to assess integrated effects of multiple sources of contamination.
* Some stations will be located at the centers of the main basins to assess cumulative, long-term changes in entire basins.
* Stations will not be located adjacent to major anthropogenic sources of contaminants. Site-specific monitoring of the receiving environments near contaminant sources will be covered by compliance monitoring programs.
* Many stations will be located at relatively shallow depths (meters) to be in biologically productive areas.
* Whenever possible, stations will be located in, on, or near historical sediment stations in order to facilitate comparisons with earlier data.

Additional criteria will be applied when specific stations are established:

* Stations will be located in depositional areas, as determined by grain size analysis.
* When applicable, stations in rural bays will be located near river mouths in order to detect contamination (such as pesticides) from nonpoint sources and to determine the effects from that contamination.
* Stations in urban bays will be located down-current from major sources of contaminants, such as major industrialized areas in inner harbors or industrial waterways such as the Duwamish River.
* Stations will be grouped by sediment characteristics, such as grain size, to allow for comparisons of benthic infauna data among areas with similar characteristics.

Depth

Stations will be chosen in three depth intervals:

* Stations located at the centers of the Puget Sound basins;
* Stations located at 20 meter (m) depth; and
* Stations located at water depths as close to 20 m as possible (water depth in some bays does not reach 20 m).

Stations at the centers of the basins are furthest from anthropogenic disturbances. However, Nichols (1985) has shown that major changes in benthic macroinver-

tebrate communities can occur at such stations over relatively short periods of time (about five to 10 yr).

The 20-m depth was chosen because:

* Monitoring of productive nearshore areas is a high priority, and total abundances of benthic organisms are often greatest at approximately the 20 meter depth (Stober and Chew, 1984b). These habitats are often of great importance to juvenile salmonids. Shorebirds and diving birds forage in intertidal and shallow areas which often have sediment quality consistent with areas at 20 m depth.

* Depth and distance offshore are usually sufficient for a 20 m station not to be unduly influenced by any single point source of contaminants.

In shallow embayments where the 20 m sampling depth cannot be attained, a shallower depth will be sampled. In order to compare data among sediment stations, efforts will be made to sample at 20 m whenever possible.

Recommended locations

Areas to be sampled for fixed sampling stations are shown in Table 2-2. The actual detailed locations of the stations will be worked out later in the planning process.

The locations of the rotating stations have not yet been decided upon, but they will be grouped around the fixed stations and distributed in smaller bays. Bays which will be considered for rotating stations include:

Guemes Channel
Kilisut Harbor
Port Ludlow
Liberty Bay
Hammersley Inlet
Padilla Bay
Sequim Bay
Quartermaster Harbor

Number of Sampling Stations

A total of 50 fixed stations (six in deep basins, 14 shallow transects in basins and 30 in bays) will be sampled each year. Seventeen rotating stations and six floating stations will also be sampled annually.

Use of the Data

Data collected for sediment quality as a part of PSAMP will be used to establish spatial and temporal trends of:

* Sediment contamination by chemicals of concern;

* Benthic macroinvertebrate communities; and

* Toxicity of sediments to experimental animals (bioassays).

TABLE 2-2: FIXED SAMPLING STATIONS FOR SEDIMENT TRIAD

	----------Basins----------	
	DEEP	SHALLOW
	(depositional)	(transects)
South Sound	1	2
Central Basin	2	4
Hood Canal	1	2
Strait of Georgia	1	2
Str. of Juan de Fuca	(?)	2
Whidbey Basin	1	2
TOTAL	6	14
	----------Bays----------	
Port Angeles Harbor		2
Drayton Harbor		1
Bellingham Bay		2
Fidalgo Bay		1
Port Townsend		1
Port Gardner (Everett)		2
Eagle Harbor		1
Elliott Bay		3
Sinclair Inlet		2
Dyes Inlet		1
Commencement Bay		3
Budd Inlet		2
Oakland Bay		1
Samish Bay		1
Port Susan		1
Discovery Bay		1
Dabob Bay		1
Port Madison		1
Carr Inlet		1
Case Inlet		1
Hood Canal (near the Great Bend)		1
Total (Bays)		30
Deep (Mid channel)		6
Shallow (0 & 20 m)		14
TOTAL		50

Sediment Chemistry

Rationale

Measuring toxic chemicals of concern (Table 2-1) will provide data to:

* Assess the potential for sediment toxicity to resident biota.
* Identify areas of Puget Sound that have been, or are, accumulating substantial amounts of toxic chemicals.
* Evaluate temporal changes of toxic chemicals accumulating in sediments.
* Interpret biological and sediment toxicity bioassay data.

Methods

Samples for sediment chemistry will be collected from the upper two centimeters (cm) of sediment, using either a 0.06 m^2 box corer or a 0.1 m^2 van Veen grab. Three grab samples will be taken at each station and composited. The same composite will be used for sediment toxicity bioassays and conventional sediment variables. A minimum of the upper five to 10 cm of sediment will be collected for benthic macroinvertebrate abundance determination. Each sampling device has advantages and disadvantages. Although a box corer takes a deeper and possibly less disturbed sample than does a van Veen grab, the box corer is more difficult and more expensive to use. An evaluation of benthic sampling equipment for use in PSAMP is in progress.

Variables to be monitored will include selected EPA priority pollutant metals and selected EPA priority pollutant organic compounds, as well as additional compounds of concern in Puget Sound (Table 2-1).

Miscellaneous organic acids and volatile organic compounds will be measured only where a suspected source is present. Intensive surveys conducted by individual agencies under other programs may be triggered by results from this program.

Tributyl-tin has recently been implicated as a human health risk (U.S. EPA, 1985). Studies from other parts of the country have shown accumulations in sediments and animal tissue around large marinas and harbors. The present concern warrants a comprehensive survey for tributyl-tin in sediments and bottom fish tissue in Puget Sound, but it is not included in the monitoring program at this time due to inconclusive sampling results from other parts of the country. Periodic spot checks for this and other contaminants are recommended. Costs of such analyses have not been included in cost estimates for the ambient monitoring program.

Replication and statistical sensitivity

Replicate samples will not be collected for sediment chemistry, thereby precluding statistical analyses among individual stations within a survey. Replicated sampling at all stations was precluded because of the high cost of laboratory analysis and has not been recommended by PSEP sampling and analysis protocols. The variability of sediment chemistry estimates will be reduced however, by the compositing technique recommended. Field and laboratory replication will be required for sediment chemistry samples as part of the quality assurance program. Stations for field replicates will be chosen so as to be representative of certain areas or embayments and sediment types.

Statistical analyses may be performed for related groups (clusters) of stations within a survey or for selected stations over time.

Replicate data from studies on the chemical composition of sediments within the Commencement Bay waterways indicated that coefficients of variation for several groups of organic chemicals ranged from 17-61 percent (Tetra Tech, 1985a). Given a coefficient of variation of 30 percent and three to four replicates (in space or time), the minimum detectable difference in mean chemical concentration among stations, at the 95 percent confidence level with a power of .8, would be equal to about 100 percent of the overall mean among stations.

Protocols

* Field and Laboratory References: Tetra Tech (1986c,f,g).
* Supporting literature: U.S. EPA (1983), Plumb (1981), U.S. EPA (1982).

Sediment Toxicity Bioassays

Rationale

Bioassays on Puget Sound sediment will provide information on the potential toxicity of contaminated sediments to test organisms. Coupled with sediment chemistry data, these results will determine the potential damage that has already happened to Puget Sound resources and which may continue to occur in the future.

Methods

Samples collected for sediment chemistry will also be used for bioassays. As recommended by Chapman and Long (1983), separate toxicity tests should be conducted to assess acute lethality as well as sublethal [chronic] effects. In the initial implementation phase of PSAMP only acute bioassays will be used, due to a lack of accepted methodology for chronic marine bioassays. As progress is made in this area, chronic bioassays appropriate for the West Coast will be considered for inclusion in PSAMP.

A range of bioassay methods and test organisms will be used including the amphipod, *Rhepoxynius abronius*, acute lethality (survival and emergence) test; the bivalve larvae (survival and abnormalities) test; and the Microtox (bacterial luminescence) test. All three tests will be conducted on subsamples of a single composite sample that will also be used for chemical analysis. All stations will be assessed using all three tests at the start of the monitoring program. Later refinements of the program may require that only certain tests are carried out at certain stations.

Replication and statistical sensitivity

Five laboratory replicates are required to achieve an acceptable level of statistical sensitivity using any of the recommended sediment toxicity bioassay tests. For the amphipod bioassay test using 20 organisms per replicate, five replicates are capable of detecting a difference between two survival means of 2.8 amphipods, at the 95 percent confidence level, and a power level equal to 0.8. This equates to a 15 percent reduction in survival, and is considered adequate for most applications (Swartz et al., 1985).

Protocols

* Field and Laboratory Reference: Tetra Tech (1986c), Tetra Tech and E.V.S. Consultants (1986a).
* Supporting literature: Chapman and Long (1983).

Conventional Sediment Variables

Rationale

Particle size distribution, total organic carbon, sulfides, redox interface depth, and pore water salinity are needed to interpret data on the distributions and abundances of benthic macroinvertebrates. Moreover, many chemicals tend to be sorbed in higher concentrations on finer-grained materials, so that the concentrations of many chemicals in the sediments are highly correlated with the proportions of silt- and clay-sized particulates. Particle size distribution and total organic carbon also provide a qualitative indication of hydrographic conditions at a given site.

Methods

Particle size distribution, total organic carbon, and sulfides will be determined on the same bulk sediment samples used for sediment chemistry. The salinity of pore water will also be measured.

Replication and statistical sensitivity

Single estimates of grain size distribution and total organic carbon will be collected for each station from the composite sample used for chemical analysis. These data are intended to provide "snapshots" of conditions in the Sound and to provide data on how these conditions vary through time. Their primary purpose, however, is to provide information necessary for the interpretation of other data on sediment quality. For this reason, routine statistical characterizations of sampling error are not necessary.

Protocols

* Field and Laboratory Reference: Tetra Tech (1986c,e).
* Supporting literature: Buchanan (1984), Folk (1968), Krumbein and Pettijohn (1938), Plumb (1981), and U.S. EPA (1983).

Benthic Macroinvertebrate Abundances

Rationale

Subtidal benthic macroinvertebrates will be monitored because they are important biological components of the Puget Sound ecosystem. Benthic invertebrates (especially infauna) are sensitive indicators of both the intensity and areal extent of environmental perturbations. They are also important mediators of nutrient recycling from the detrital food web, providing nutrients for primary production in the water column. Infauna and epifauna are important prey items for species at higher trophic levels, especially large epifaunal invertebrates and fishes, many of which are harvested commercially or recreationally.

Monitoring populations of large epibenthic invertebrates is not recommended, because there are not yet adequate tools for interpreting the results, in terms of population dynamics and the effects of contamination. Research is continuing in this area, and epibenthic sampling should be considered as an important addition to PSAMP in the future.

Intertidal macroinvertebrate populations often vary in species composition and abundance due to natural extremes in physical, chemical, and biological factors, and are therefore too variable to be used as a lone monitoring component (Gray et al., 1980; Paine, 1986).

Methods

Benthic macroinvertebrate abundances will be sampled from five replicate sediment grabs taken at the same location, using the same sampling gear as samples collected for sediment chemistry. All samples will be washed on screens having 1.0 millimeter (mm) mesh openings. All taxa will be identified to the lowest practical taxonomic level and enumerated. Because species are the basic ecological units, changes in species composition and abundance may be used to document temporal trends in community composition (Nichols, 1985), and to interpret those trends with respect to anthropogenic impacts (Gray et al., 1980; Tetra Tech, 1985a). Abundances of pollution sensitive, pollution tolerant, and opportunistic taxa are especially useful for this purpose. Abundance data from individual species can be grouped into these categories for analysis. Major taxonomic groups such as molluscs, crustaceans, and polychaetes as well as community variables such as total number of taxa and total abundances are also useful monitoring parameters.

Replication and statistical sensitivity

Replicate data are not available for all types of benthic infaunal habitats within Puget Sound. Coefficients of variation have been determined from representative tativetativetativetativetativetativedata sets from stations in Elliott Bay (Elliott Bay Urban Bay Program). Power analyses of these data indicate that the use of five replicate 0.1-m^2 van Veen grab samples washed on 1.0-mm mesh enable detection of differences of 11-42 percent (of the overall mean among stations) in total numbers of species and 12-30 percent or more in numbers of individuals, based on coefficients of variation of 3-19 percent and 3-12 percent, respectively ($\& = .05$, $B = 0.2$). The use of five 0.06-m^2 box core samples per station may provide greater precision and therefore greater statistical power, but cannot be recommended for PSAMP because cost will become prohibitive.

Protocols

* Field and Laboratory Reference: Tetra Tech (1986c,h).

* Supporting literature: Swartz (1978), McIntyre et al., (1984), Eleftheriou and Holme (1984).

MARINE WATER COLUMN

Rationale

The moving water masses in Puget Sound are a major form of transport and mixing for all contaminants and for biological populations during at least some part of their life cycle. By monitoring water column parameters, information on pathways and rates of transport of chemicals and biological populations can be gleaned. An understanding of transport mechanisms of pollutants will provide management tools for setting discharge standards and will point to other areas of the environment where contamination should be examined. Water column parameters will be monitored because:

* Knowledge of water quality conditions throughout Puget Sound is essential to document long-term trends in the open basins.

* Water quality information is needed to identify possible emerging problems in bays.

* Development of a better understanding of the functional processes in Puget Sound is needed.

* Water quality data will help interpret spatial patterns and temporal trends in many other monitoring components.

Meeting the Program Goals

Monitoring of the water column will provide information on the overall health of Puget Sound. Knowledge of contaminant transport mechanisms can provide tools for reducing the threat to Puget Sound resources and human health. Water column data from PSAMP is needed for certain Puget Sound plan elements including the identification of "no discharge" areas for recreational boats (MB-7) and the search for unpermitted discharges (P-20). PSAMP will measure the success of certain programs in the plan which are directed at limiting the amount of contaminants entering the water column, including portions of the nonpoint, municipal and industrial discharges, stormwater and CSOs, and oil spill response planning programs. Data gathered during PSAMP will add to the body of knowledge concerning water column trends which has been collected sporadically since 1930. Records of data stored on the PSAMP database will be available to researchers in the area.

Methods

Due to recent advances in instrumentation, water column data can be automatically collected. Water column samples will be collected with a conductivity-temperature-depth (CTD) sensor system, equipped with a rosette of hydrographic bottles.

Like any electronic instrumentation, a CTD package must be calibrated frequently and completely against laboratory analyzed samples, traceable to the National Bureau of Standards. A calibrated CTD system provides continuous profiles versus depth of high quality data of temperature, salinity, dissolved oxygen, and light penetration. Profiles are important for determining the internal structure of the water column. For example, depth of mixing as well as major and minor pycnoclines can be defined. Specific sampling depths, and the precision of the information to be collected at those depths, will be resolved later in the monitoring program.

Discrete water column samples will be collected for calibration purposes and for analysis of those parameters which cannot be readily measured electronically, including chlorophyll and nutrients. Bacteria samples from the water column will be collected by different methods and will be discussed under "Pathogen Indicators in Water."

Frequency and Timing of Sampling

Water quality components will be monitored on three different schedules:

* Three to four times a week during times of the year when water quality problems are anticipated in selected embayments. The most notable example of poor water quality conditions of this type is low dissolved oxygen levels which may result in fish kills, unpleasant odors, and unsightly scum. These conditions typically peak in late August or early September in embayments like Budd Inlet.

* Monthly at selected open basin and embayment stations to maintain a long-term record of water column conditions. Year round sampling is necessary because certain parameters, such as chlorophyll, nutrients, and dissolved oxygen, show their peak values (or highest rates of change) during the summer, while others (fresh water, pathogen indicators) peak during the winter. Sampling should be conducted during all 12 months to ensure that all major hydrographic trends are observed, and to provide a complete data set for analysis of temporal trends.

* Intensively for 28 days surrounding the summer and winter solstices for dissolved nutrients and chlorophyll at selected embayment stations. (See the section on nutrient concentrations for rationale.)

Some floating stations will be sampled during high spring and neap tides because the largest changes in water quality features occur at the times of maximum and minimum tidal exchange. All samples will be collected during daylight hours in order to obtain data on light transmittance.

Location of Sampling Stations

Stations will be located in the center of each deep basin and in some of the urban/industrialized and rural bays where sediment quality samples are collected. Individual water masses with their inherent water quality parameters are not fixed with respect to the bottom but move with prevailing currents. Thus, water column properties often show less variability over short distances than sediment parameters. For this reason, a system of fewer fixed and more rotating stations is recommended for water quality monitoring. The actual locations of water quality stations will be determined when detailed monitoring plans are written by the participating agencies.

Sampling stations are located to correspond with those used for the sediment quality triad and bottomfish sampling. A single station in the center of each deep basin and a station in selected bays will provide the minimal adequate data to characterize large-scale spatial and temporal trends. Additional information will be obtained from rotating stations.

Number of Sampling Stations

The total number of fixed, rotating, and floating water column stations will be determined when detailed monitoring plans are written.

Use of the Data

Water column information collected during this program will be used to:

* Establish spatial and temporal trends in nutrient and microbial concentrations in nearshore and deep basin water masses.
* Characterize the movement of water in Puget Sound.
* Help interpret data from other portions of the monitoring program.
* Identify emerging pollution problems.

Hydrographic Conditions

Rationale

In order to understand the movement of water parcels in Puget Sound, changes in temperature and salinity (the components of water density that control the depth at which many contaminants reside in the water column) must be closely followed. The normal seasonal cycles of temperature (which is largely determined by the seasonal warming effects of sunlight) and salinity (which is strongly influenced by river runoff) are important for determining biological growth cycles in the Sound. In addition, unusual changes in temperature, salinity, and oxygen in response to abnormal climatic events, such as drought or flooding, may cause substantial alteration of biological communities.

Methods

Temperature and salinity will be recorded continuously versus depth on the CTD downcast, with a suitable data recording depth interval to be decided later in the monitoring planning process. Hydrographic calibration samples will be taken on the upcast, with a minimum of one set of samples per station. Temperature will be checked against calibrated reversing thermometers, and salinity samples taken for analysis on a salinity bridge.

Replication and statistical sensitivity

Single vertical profiles will be collected at each station. These measurements are intended to provide "snapshots" of conditions in the Sound and to provide data on how these conditions vary through time. Between-station and interannual variation of hydrographic conditions will be calculated by season, however. Rigorous calibration of the electronic sensors in the field will yield a measure of confidence in the profile values.

Protocols

* Field and Laboratory Reference: PSEP Protocols (expected in 1988).

Dissolved Oxygen

Rationale

Dissolved oxygen is a critical variable for characterizing Puget Sound marine habitats. An adequate oxygen concentration is essential for all higher life forms. Oxygen levels in the Sound are largely controlled by natural processes. In certain areas of the Sound, oxygen levels show strong seasonal changes in response to varying concentrations of oxygen in incoming ocean water, and to plant production and decay processes. Oxygen levels are also sensitive to anthropogenic perturbations, and can change in response to direct or indirect loadings of nutrients and biochemical oxygen demand (BOD).

Methods

Continuous profiles of dissolved oxygen will be collected by means of a membrane oxygen probe mounted on the CTD package. Electronic data will be collected on the downcast and calibration samples on the upcast. Profiles will be taken all the way to the bottom in the deep basins. Calibration samples should be analyzed, using the Carpenter method (a variation of the Winkler method) for oxygen analysis.

Dissolved oxygen sensors require a longer equilibration time in the water column than the other recommended electronic sensors. In order to save sampling time, particularly during the short winter days, oxygen sampling may be carried out by discrete water bottle samples at several depths in the water column.

Replication and statistical sensitivity

Single oxygen profiles will be collected at each station, thereby precluding statistical analyses among individual stations within a survey. Dissolved oxygen concentrations respond to a number of physical-chemical variables. Hence, the natural range and short-term variations in oxygen concentrations tend to be large. Between-month changes at any site and depth are generally much smaller than short-term changes, and have a standard deviation on the order of ± 20 percent of the monthly mean oxygen concentration (Ebbesmeyer et al., 1982). At present, eutrophication and other factors that are reflected in oxygen changes are major problems only in very restricted areas of the Sound.

Protocols

* Field and Laboratory Reference: PSEP (in preparation).

Turbidity/Transparency

Rationale

Particle loading from terrestrial sources, resuspension of bottom sediments, and the growth of particulate algae in the water column result in cloudiness, known as turbidity.

Particle loading from both natural and anthropogenic sources occurs in nearshore areas due to shoreline erosion. Erosion may be due to natural processes or to the effects of anthropogenic changing of those shorelines. Rivers and streams are also large contributors of sediment to the Sound. Some of the river-borne sediment is natural, while some has been artificially induced by increased development in the watersheds.

Turbidity clouds the waters of Puget Sound and decreases the depth to which sunlight can penetrate. The decrease in transparency narrows the depth to which phytoplankton can live which, in turn, may limit the overall productivity of biological resources in certain areas of the Sound.

Through a natural process, sediment may be resuspended off the bottom and remain in a high turbidity layer, known as the benthic nephloid layer. Long-term changes in this layer may provide insights into changing input rates of sediment by humans.

Methods

Turbidity and transparency measurements will be made electronically throughout the water column to establish baseline and long-term conditions.

Profiles of incident light in the upper layer of the water column will be measured on the downcast using a quantum meter mounted on the CTD package. The quantum meter should be calibrated electronically on a regular basis. Secchi disc depths will also be determined at each station. Secchi data are inexpensive to collect and provide a measure of the transparency of the water column which can be used to measure the depth to which sunlight penetrates the upper layer.

Turbidity profiles will be made with the use of either a transmissometer or nephelometer mounted on the CTD package. Turbidity profiling information will be taken on the downcast throughout the water column. Turbidity calibration samples will be collected on the upcast.

Replication and statistical sensitivity

Relatively large natural variations in the depth of the sunlit layer and in turbidity occur, particularly over a seasonal cycle. Secchi disc measurements vary greatly, depending on who takes the reading. As a result, it is recommended that all secchi data be taken by a group of persons who have been trained together to achieve consistent readings. Single profiles for turbidity and light will be taken, precluding statistical verification.

Protocols

* Field and Laboratory Reference: Tetra Tech (1986c).

Odors, Floatables, Slicks, Water Color

Rationale

Unsightly water conditions and objectionable odors can develop from the presence of floatable materials, slicks, discolored water, and excessive turbidity. These conditions can impair the aesthetic qualities of the Sound and the use of the Sound for recreation. Oil spills may also have disastrous effects on birds and other marine life.

Methods

Notes on odors, floatables, slicks, and water discolorations will be taken as part of the routine water column survey and during sampling at the shellfish beaches.

There is an existing system of reporting whereby citizens can report oil spills, floatables, or other aesthetic problems in Puget Sound or its watersheds to the U.S. Coast Guard (Puget Sound only) or to Ecology. Information from these reports will be assessed quarterly and relevant data added to the PSAMP database. Certain problems exist with the Coast Guard data system, however. At present, spills and other problems are entered into a computer file that records location only to the nearest minute of latitude and longitude. More precise locations (i.e., to the second or less) are highly desirable for anticipating and documenting the impacts of such events on Puget Sound resources. Additional data collected by water quality professionals and citizens during PSAMP and other related monitoring programs will help fill in any gaps until the Coast Guard system is upgraded.

Replication and statistical sensitivity

The data that will be collected will consist of subjective observations of sporadic occurrences. They will not be replicated or quantified, thereby precluding rigorous statistical analyses. Consistency among observations will be sought by providing training to water quality professionals and citizens who will collect these data.

Protocol

- Field and Laboratory Reference: None. (Separate blanks will be provided on the field log sheets for the purpose of recording information on odors, floatables, slicks, and water color.)

Nutrient Concentrations

Rationale

Nutrients are essential for the growth of attached algae and phytoplankton. Nutrient enrichment can constitute a water quality problem when it stimulates such excessive plant growth that the resulting decay causes oxygen depletion. Research also suggests that the changes in absolute or relative nutrient availability may shift the composition of the plant community to non-edible or noxious species. In Puget Sound, nutrients apparently do not play a major role in controlling plant growth except in a few poorly flushed embayments, such as Budd Inlet (Collias and Lincoln, 1977). Nutrient enrichment may have had some role in the apparent increased incidence of PSP organisms in the Sound (Cardwell et al., 1979; Saunders et al., 1982), but this relationship has not been conclusively established.

Recent studies in the open basins and moderately-flushed areas of Puget Sound, notably Metro's Seahurst baseline studies, have shown that monthly sampling for nutrients throughout the year yields less useful information than daily sampling for two weeks before and after the summer and winter solstices (Stober and Chew, 1984a).

Concentrations of dissolved nutrients in Puget Sound change in a cyclical fashion throughout the year. At any moment, nutrient concentrations are dependent on sunlight and phytoplankton abundances in the water column. In December and January when phytoplankton are growing at the slowest rate and the surface waters are well-mixed, nutrient concentrations are the highest. In June and July, when the upper layer of the water column is stratified, nutrients are depleted due to the growth of phytoplankton populations. The summer maximum and the winter minimum of phytoplankton growth occur right around the summer and winter solstices, (June 21st and December 21st) respectively (Stober and Chew, 1984a). Measurements of nutrients taken at these times will determine the annual maximum and minimum concentrations--necessary information for establishing trends in dissolved nutrient concentrations and phytoplankton population changes. During the other months of the year, nutrient concentrations change rapidly. Knowing the annual maximum and minimum will allow determination of long-term temporal and spatial trends in nutrients.

The annual cycle of nutrients and phytoplankton in enclosed embayments of Puget Sound differs from that of the open Sound, requiring a different sampling approach. The relative isolation of water masses in certain bays, such as Dabob Bay, can lead to significant algal blooms as early in the year as January (Copping, 1982). Stratification of the surface waters in some isolated bays causes nutrient depletion and collapse of the phytoplankton population in midsummer. Algal blooms in some bays, such as Budd Inlet, do not correlate with the summer solstice and must be sampled throughout the year in order to determine the nutrient dynamics.

Monthly samples of nutrients alone do not yield statistically valid data, due to natural variability of phytoplankton populations (Campbell et al., 1977). Monthly nutrient data can be interpreted, however, by relating them to the annual maxima and minima of nutrient concentrations determined during the solstices.

Nutrient concentrations in the open areas of the large urban bays, including Elliott and Commencement Bays, correlate well with the open Sound stations (Stober and Chew, 1984a). Large rivers discharging into urban embayments can have a significant influence on nutrient concentrations in the biologically sensitive nearshore regions of the bays, however. If sampling of nutrients in the urban bay samples is coordinated with sampling at the mouths of the rivers which discharge into those bays (Nooksack, Snohomish, Green/Duwamish, and Puyallup), trends in river influence on urban bays may be clarified.

Data on rural bays which are experiencing significant development indicate that nutrient enrichment from nonpoint source runoff may be a significant emerging problem. Discerning long-term trends for nutrient concentrations in rural bays requires more intense sampling. Areas of particular concern include those with rapidly developing watersheds, particularly in south Puget Sound.

Nutrient studies have indicated that nitrate is the primary nutrient of interest in the determination of phytoplankton growth in Puget Sound (Campbell et al., 1977; Winter, et al., 1971). Phosphate and silica are of lesser importance. Dissolved ammonia is seldom seen in the natural marine water column, but the intense anthropogenic influences make it common in Puget Sound. Ammonia measurements over time may yield information about the sensitivity of the system to man-made pollutants.

Methods

Samples for dissolved nutrient analysis will be collected monthly on the CTD upcast at water column stations in the open basin and in sensitive bays (e.g., Dabob Bay, Budd Inlet). In addition, more frequent nutrient samplings will be done during the

solstices at four to eight shore-based stations. Bathymetry will be used to determine which bays have limited water circulation and are therefore the most sensitive to nutrient depletion. The sensitive bays are candidates for the shore-based monitoring during the summer and winter solstices. Citizens, as well as water quality professionals, will collect nutrient samples during the solstices.

During monthly ship-board sampling, two samples will be taken for nutrient determination from each CTD upcast:

* A composite sample from the layer above the thermocline (or within the photic zone if no thermocline exists) which will also be used for chlorophyll a determinations. Where the photic zone is less than 30 m deep, as determined by secchi disc or quantum meter, a composite sample will be collected from the photic zone.

* A discrete sample collected from 10 meters or less below the bottom of the photic zone and/or below the thermocline.

During shore-based solstice sampling discrete water samples will be collected at one meter below the surface in water depths of one to two meters. All nutrient samples will be filtered after collection to exclude phytoplankton which may contribute nutrients from internal cellular pools after death.

Replication and statistical sensitivity

Lack of replicated sampling will preclude statistical comparisons among individual stations within a survey. Examination of long-term trends will be based on qualitative analysis of graphic data, supported by time-series analysis.

Protocols

* Field and Laboratory Reference: Tetra Tech (1986c), Parsons et al., (1984).

Phytoplankton Standing Stock

Rationale

The concentration of chlorophyll a in surface water will be measured as a convenient, quantitative measure of phytoplankton standing stock. As primary producers, phytoplankton are critical to the functioning of the marine ecosystem. Under conditions of nutrient enrichment in enclosed bays, phytoplankton blooms may depress dissolved oxygen levels and thereby lead to fish kills.

Phytoplankton populations are dependent on sunlight for growth. Since phytoplankton are passively carried by tidal currents and wind waves, currents and wind waves can determine the size of phytoplankton populations in isolated embayments and at times in the open basins. Accurate meteorological measurements are needed in conjunction with all monitoring efforts.

Phytoplankton species identification and quantification will not be included in the present design, but may be considered in future iterations of PSAMP.

Methods

Total chlorophyll a will be determined on the same shipboard composite sample analyzed for nutrient concentrations during monthly sampling, and from the same shore-based sample collected during solstice monitoring. Total chlorophyll a is to be measured by fluorometric or spectrophotometric methods. The rationale for sta-

tion locations, frequency, and timing is given in the previous section on Nutrient Concentrations.

Ambient sunlight, tidal height and timing, and wind speed and direction will be recorded at several locations in the Puget Sound basin to aid in the interpretation of phytoplankton population data.

Replication and statistical sensitivity

Phytoplankton populations are highly variable in space and time, and very frequent sampling is often needed to perform statistical comparisons of population abundances among areas. Replicate samples will not be collected, thereby precluding statistical analysis among individual stations within a survey. However, statistical time-series analyses will be performed for one or more stations.

Protocols

* Field and Laboratory Reference: Tetra Tech (1986c), Parsons et al., (1984).
* Supporting literature: Stofan and Grant (1978), American Public Health Association (1985), Tetra Tech (1986c), and Conover et al., (1986).

Pathogen Indicators in Water

Rationale

Indicator bacteria found in shellfish meat can be related to the presence of these organisms in the overlying water. The fecal coliform group are generally considered to be indicators of fecal pollution. The presence of fecal contamination may indicate the presence of pathogenic bacteria and viruses. Recreational and commercial shellfish beds represent locations where contaminated shellfish pose the greatest threat to a large number of people. The use of recreational beaches for contact water sports, including swimming and fishing, can also bring humans into contact with pathogens. Water will be analyzed for indicator bacteria at beaches where shellfish are harvested commercially and recreationally. Pathogenic bacteria and viruses will not be examined during the ambient monitoring program, although intensive surveys may be initiated if specific problems are identified from monitoring data.

Bacterial counts tend to be highly variable. Therefore, monthly sampling is needed to provide adequate data to characterize the average count and range.

Methods

Pathogen indicators will be measured in the water column at the stations established for intertidal shellfish monitoring, in commercial and recreational shellfish beds, and at the river mouth stations. Some of these areas are within the influence of point or nonpoint sources of contaminants.

Replication and statistical sensitivity

Statistical sensitivity of measurements of pathogen indicators in water is unknown. Composite samples are typically collected for ongoing compliance monitoring. Tests on composite samples are used to determine whether public health criteria have been exceeded, not to test for differences in levels within or among stations. Although replicate field data on bacterial counts in Puget Sound are unavailable, American Public Health Association (1985) provides 95 percent confidence intervals for counts (most probable number) of fecal coliforms based on analytical replication.

Concentrations of pathogen indicators are known to be highly variable in space and time. Three replicates are needed for statistical comparisons among areas. To determine the statistical power of this preliminary design would require replicated daily samples over a period of 10-20 days. A special study should be conducted to determine the statistical sensitivity of the present monitoring design, and to recommend an alternative (if needed) to achieve reasonable statistical sensitivity.

Protocols

* Field and Laboratory References: Tetra Tech and E.V.S. Consultants (1986b).
* Supporting literature: American Public Health Association (1985), Russek and Colwell (1983).

FISH

Rationale

The importance of Puget Sound fish economically, recreationally, and as sensitive indicators of environmental contamination require that a fisheries component be included in PSAMP. Fisheries harvest and stock assessment data are collected by WDF for all important recreational and commercial species. The focus of the PSAMP fish task is on tissue contamination, rather than population trends. Biomonitoring of Puget Sound fish will supply information in two important areas: the human health risk of eating fish from Puget Sound waters, and the health of Puget Sound bottom fish.

Levels of chemical contamination found in edible fish tissue represent the best information available to the public concerning the risk of consuming fish from Puget Sound. These data can be used to identify problem areas and to manage recreational fisheries.

Data on fisheries harvests and stock assessments will be summarized and added to the database for use in the interpretation of fish health data.

Meeting the Program Goals

The fish health task will measure the health of a major Puget Sound resource, as well as the health risk to humans from consuming fish. Data collected as part of this task may be used in conjunction with monitoring data required under the Puget Sound plan element P-8, monitoring requirements in permits. Several programs in the plan are directed at limiting contaminants which may bioaccumulate in pelagic and demersal fish. Such programs include portions of the nonpoint, municipal and industrial discharges, contaminated sediments and dredging, stormwater and CSOs, and oil spill response planning programs. Results of fish health monitoring will provide information on the effectiveness of these programs. Both natural and anthropogenic changes to the health and toxicant body burdens of fish will be documented through trend data obtained under PSAMP, and data will be made available to researchers concerned with fish health.

Methods

The health of Puget Sound fish will be evaluated by microscopic analysis of liver tissue taken from English sole. This species is likely to be found in adequate abundances at all monitoring stations throughout the Sound, and is known to be affected by liver lesions in contaminated areas of the Sound (Malins et al., 1984, 1985a,b; Tetra Tech 1985a; Krahn et al., 1986).

The risk to human health from consuming contaminated fish will be evaluated in recreationally important fish (Pacific cod, salmon, and rockfish) and in English sole, a representative bottom-feeding fish. Contaminant measurements in English sole liver also provide a link between levels of toxicants in fish tissue and the incidence of fish disease.

All fish caught in trawls during collection for chemical and histopathological analysis will be examined for length, weight, sex, reproductive condition, and external pathology. The results will be noted but are not intended to represent an assessment of fish community structures.

Frequency and Timing of Sampling

As the turnover rates of fish are relatively slow, populations can be adequately assessed on an annual or less frequent basis. Annual monitoring of Pacific cod, salmon, rockfish, and English sole is recommended in the initial stages of PSAMP, due to the importance of this information for the assessment of human health risks. After a baseline of fish health and human health risk data is established, the frequency of fish sampling will be reassessed and recommendations made for a less frequent sampling interval. In the future, areas of Puget Sound which have few known sources of contaminants will be sampled less frequently than those in known areas of contamination.

The optimum time of year to trawl for resident bottom fish populations (English sole) is July. Some flexibility in this timing is possible if trawling can be piggy-backed with other WDF and National Marine Fisheries Service (NMFS) field programs. Pacific cod, fall-run salmon, and rockfish will be collected in September to October, coinciding with a period of intensive recreational harvest activity. Resident chinook salmon will be caught for toxics analysis in January.

Location of Sampling Stations

Stations for bottomfish (English sole) trawling will be placed in the open basins of the Sound and in many of the major and minor embayments (Table 2-3). All stations used for collecting English sole will be located close to sediment quality stations so that information on fish health and sediment chemistry results can be correlated.

Recreational fish will be collected from major fishing areas, which are generally near urbanized areas to provide information for worst-case assessments of human health risks from eating chemically contaminated fish. Salmon and Pacific cod will be sampled at one location in each of north, central, and south Sound. The coverage supplied by three station locations should be representative of Soundwide contamination for the pelagic sportfish because pelagic sportfish do not generally feed for extended periods of time in specific locations.

Rockfish are more commonly associated with certain specific locations and will be sampled at five stations locations.

Number of Sampling Stations

A total of 20 bottom fish stations will be sampled each year of which six will be fixed stations, 12 rotating and two floating stations.

Chemical contamination of muscle tissue from Pacific cod, fall-run salmon, and resident chinook salmon will be monitored at three major fishing areas: Possession Point, Shilshole Bay, and Point Defiance. Rockfish will similarly be sampled at five major fishing areas associated with artificial reefs: Toliva Shoals (off Fox Island),

TABLE 2-3: BOTTOM FISH SAMPLING STATIONS

Location	Number of Fixed Stations	Number of Rotating Stations
Main Basin	3	3
Whidbey Basin	2	2
South Sound	1	3
Hood Canal	2	3
Strait of Georgia	1	3
Strait of Juan de Fuca	2	3
Port Angeles Harbor	1	2
Drayton Harbor	1	1
Bellingham Bay	1	3
Fidalgo Bay	1	2
Port Townsend	1	2
Port Ludlow	0	3
Port Gardner	1	3
Eagle Harbor	1	2
Elliott Bay	1	4
Liberty Bay	0	2
Sinclair Inlet	1	3
Dyes Inlet	1	2
Commencement Bay	1	4
Budd Inlet	1	3
Oakland Bay	1	2
Lummi Bay/Hale Passage	0	2
Samish Bay	1	3
Padilla Bay	0	3
Eastsound	0	3
Friday Harbor	0	3
Skagit Bay	0	3
Penn Cove	0	2
Port Madison	1	2
Port Susan	1	3
Holmes Harbor	0	2
Discovery Bay	1	2
Port Gamble	0	2
Dabob Bay	1	2
Lynch Cove	0	3
Port Orchard	1	2
Quartermaster Harbor	0	2
Gig Harbor	0	2
Carr Inlet	1	3
Case Inlet	1	3
Totten Inlet	0	3

Blake Island, The Trees (south of Edmonds), Gedney Island (off Everett), and Misery Point (Hood Canal).

Use of the Data

Fish health data collected under this program will be used to:

* Establish spatial and temporal trends in the incidence of bottom fish tumors.
* Establish spatial and temporal trends in the bioaccumulation of toxicants of pelagic and demersal fish.
* Supply data which can be used to calculate the human health risk of consuming Puget Sound fish.

Toxic Chemicals in Fish

Rationale

Concentrations of toxic chemicals will be determined in Pacific cod, salmon, and rockfish muscle tissue in order to assess toxicant levels which may be ingested by humans.

Pacific cod is among the most sought after and most frequently consumed species in Puget Sound, ranking fifth in number and sixth in weight in the recreational catch evaluated by Landolt et al., (1985). Pacific cod was also found to have relatively high levels of PCBs in muscle tissue. Four of the five most abundant species of the recreational catch belong to the Pacific cod family Gadidae. Thus, Pacific cod is representative tativetativetativetativetativetativetativeof the major kinds of fishes that dominate the recreational catch of Puget Sound.

Salmon were chosen for evaluation because of their importance as a recreational and commercial resource. Moreover, many chinook salmon are resident in Puget Sound for the entire marine portion of their lifetimes.

Rockfish similarly make up a significant portion of the recreational fish catch in Puget Sound. The non-migratory lifestyle and longevity of rockfish make them excellent candidates for bioaccumulation of contaminants.

Toxicant analysis of English sole liver tissue will act as a "worst case" for potential bioaccumulation from contaminated sediments. For comparison, toxic concentrations in English sole muscle tissue will be measured. These concentrations are what people are exposed to when they eat the fish. English sole is recommended as the preferred non-migratory bottom-feeding fish for pesticide and PCB testing by the U.S. Food and Drug Administration (1985). The bioaccumulation data can also be related to the patterns of lesion prevalence in the same fish.

Methods

Pacific cod (*Gadus macrocephalus*), salmon species such as (*Oncorhynchus tshawytscha*, *Oncorhynchus kitsutch*, *Oncorhynchus gorbusha*), and rockfish such as coppers or quillbacks will be caught at recreational fishing piers. English sole (*Parophrys vetulus*) will be caught in trawls. All fish caught will be analyzed for the chemicals of concern used for sediments (Table 2-1), except that metals other than mercury, acid extractable, and volatile organic compounds will not be analyzed; high levels of these chemicals are not expected to accumulate in fish muscle tissue. Periodic checks of these chemicals during intensive surveys are recommended.

Lipid content will also be measured in each fish tissue sample, to aid in the interpretation of chemical data.

Samples of English sole to be analyzed for chemical contamination will also be used for histopathological analysis.

Replication and statistical sensitivity

Because of the presumed high level of variability, three composite samples will be analyzed for each species at each station. Each composite will contain equal weights of tissue from five individual fish. There is little information about statistical variability of toxic chemical concentrations in any of the target species (Landolt et al., 1985, Tetra Tech, 1986a). Preliminary data suggest that coefficients of variation for concentrations of some chemical contaminants in individual samples of selected species of flatfish are on the order of 40-60 percent (Tetra Tech, 1985b).

The composite sampling strategy recommended here will substantially increase statistical precision. For example, the variance of the mean estimated by the sampling design using five individuals per composite sample will be one-fifth of the underlying population variance (Tetra Tech, 1986a). If the coefficient of variation of the mean of individual samples is 50 percent, then that of the composite samples will be 10 percent. In this case, the minimum detectable difference in the mean concentration of a chemical among stations would be about 35 percent of the overall mean among stations (A = .05, B = 0.2). More precise estimates of statistical sensitivity will be obtained after data are available for the composite samples recommended here.

Protocols

* Field and Laboratory Reference: Tetra Tech (1986c,f,g).

Histopathological Abnormalities in Fish

Rationale

The prevalence of liver lesions in English sole (*Parophrys vetulus*) from contaminated areas of Puget Sound is above background levels (e.g., Malins et al., 1984; Tetra Tech, 1985a). Because of the potential link between liver lesions and contamination, PSAMP will evaluate English sole livers for the presence of lesions. Three primary groups of liver lesions will be evaluated microscopically: neoplasms (tumors), foci of cellular alteration (putative pre-neoplasms), and megalocytic hepatosis (a specific degenerative condition).

Analyses will be conducted on fish 3 years old because these individuals are most likely to be affected with liver lesions (Malins et al., 1982).

Methods

In the field, only specimens 23 cm total length will be sampled, to ensure that each fish is 3 years old. Otoliths will be collected from each fish selected for histopathological analysis so that age can be determined. The age distribution of each sample must be determined because prevalence of several liver lesions correlate positively with age of English sole (Tetra Tech, 1985a).

To allow comparisons of fish condition and fish growth each specimen selected for histopathological analysis will be measured and weighed and external signs of disease, including lesions and gross abnormalities will be noted prior to necropsy. Gross visible internal abnormalities, sex, and reproductive state will also be noted for each individual selected for histopathological analysis.

The nomenclature used for describing individual lesions and for grouping them into neoplasms, foci of cellular alteration, and megalocytic hepatosis should be consistent with that described by Myers et al., (in prep.).

Replication and statistical sensitivity

A sample size of 60 English sole is recommended for histopathological analysis at each station. This sample size will provide a 95 percent confidence level that at least one fish having a particular kind of lesion will be sampled if the prevalence of that lesion in the population is 5 percent. In addition, a 10 percent elevation in prevalence above a reference prevalence of zero percent will be distinguishable statistically (Sokal and Rohlf, 1981).

Protocols

* Field and Laboratory References: Tetra Tech (1986c,d).

Fisheries Harvest

Rationale

Fisheries harvest information is collected by WDF for marine and anadromous species and by WDW for freshwater, non-migratory species and steelhead, in order to satisfy regulatory mandates. These data are important for interpreting PSAMP monitoring data and assessing the biological impacts of contamination. For example, commercial shellfish harvest may vary considerably among various areas of Puget Sound, depending on the degree of bacterial contamination of the water column in those areas. Similarly, the sizes of wild stocks of salmonids are closely related to the availability of adequate nursery and feeding habitat in rivers and nearshore marine waters.

Methods

Catch statistics and estimates of population abundances for finfish and shellfish will be assembled from WDF and WDW catch statistics for all commercially and recreationally important species. WDF collects information on both finfish and shellfish in Puget Sound. For simplicity, both are included in this section (rather than being split into finfish and shellfish). The species for which catch data may be assembled include:

Salmonids	Bottom fish	Bait fish	Shellfish
Chinook salmon	Halibut	Herring	Butter clams
Coho salmon	English sole	Surf smelt	Littleneck clams
Pink salmon	Rock sole	Anchovy	Horse clams
Chum salmon	Petrale sole	Sand lance	Cockles
Sockeye salmon	Dover sole		Manila clams
Steelhead trout	Sand sole		Dungeness crab
Rainbow trout	Rex sole		Red rock crab
Dolly Varden	Butter sole		Shrimp
	Starry flounder		Oysters
	Arrowtooth flounder		Abalone
	Sable fish		Geoduck
	Surfperch		
	Dogfish		
	Rockfish		

Lingcod
Pacific cod
Pollock
Whiting

Other species to be considered include sea urchin and octopus.

SHELLFISH

Rationale

Shellfish (in particular oysters, clams, crabs, and shrimp) are of ecological, economic, and recreational importance in Puget Sound. Stock assessments of bivalve shellfish at PSAMP sampling beaches will provide estimates of the population base of the resource. Enumeration of crab and shrimp from bottomfish trawls will provide a qualitative estimate of these populations. Harvest data collected by WDF will be added to the PSAMP database to complement this information, as described under the finfish task. In addition, aquaculture sites and yield data collected by DNR and WDF will also be summarized. For simplicity, the use of aquaculture and yield data is described under this task for both shellfish and finfish.

Bivalve shellfish live a relatively stationary life, and have the potential to bioaccumulate bacteria and toxic substances from the water and sediments. These organisms are likely vectors for the transfer of toxics and/or bacteria to humans, creating a potential health risk. Commercial shellfish areas are monitored for bacterial contamination, but data collection and controls on recreational harvesting of shellfish, and on the toxic content of all shellfish, have only recently been addressed in the Puget Sound basin. A baseline, as well as long-term trends of shellfish contamination, will be established through this program.

The target species chosen for determining toxicant and bacterial accumulation levels is the native littleneck clam (*Prototheca staminea*). This species is distributed throughout Puget Sound and is harvested intensively for both recreational and commercial purposes. There is extensive information available on the location and biology of the native littleneck, making this species a useful indicator of the status of shellfish stocks.

Meeting the Program Goals

Data collected for this task will assess the health of the Puget Sound shellfish resource, as well as the potential human health threat of consuming shellfish. Elements of the Puget Sound Water Quality Management Plan which will be aided by ambient monitoring data include SF-3, testing selected shellfish beds for toxicants; SF-4, recreational shellfish program; and SF-5, annual inventory of shellfish bed contamination. Programs in the Puget Sound plan which are directed at reducing contamination reaching shellfish include portions of the nonpoint, shellfish, municipal and industrial discharges, stormwater and CSOs, and oil spill response planning. Storage of shellfish contaminants and associated stock assessment data on the PSAMP database will ensure a permanent record of the distribution and trends of shellfish stocks and contamination levels. These data will meet the needs of scientific researchers and water quality managers.

Methods

Bivalves will be collected for population density and chemical and bacterial analysis from recreational shellfish beaches around the Sound. All specimens will be collected at low tide from shore and will be within the size range harvested recreationally and commercially.

Much of this program task will be undertaken as part of existing or planned shellfish assessment programs by the Department of Social and Health Services (DSHS). Data collected by DSHS under other programs will be consistent with PSAMP requirements for protocols and quality control and will satisfy the needs of this monitoring program.

Frequency and Timing of Sampling

Shellfish will be sampled from beaches annually for population density and for toxic contamination in native littlenecks, quarterly for bacterial contamination in native littlenecks (with additional monthly sampling during the summer months), and biweekly in other bivalve species during the summer growing period for PSP.

Annual collection of shellfish will occur during suitable low tides in the spring; quarterly, monthly, and biweekly sampling schedules will be determined by suitable tides and the convenience of laboratory operation.

Location of Sampling Stations

A subset of the recreational beaches to be sampled by DSHS in 1988 will be chosen as PSAMP fixed and rotating stations. Criteria for this choice include geographic distribution, ample recreational use, accessability, and the presence of potential contaminant sources.

Number of Sampling Stations

A total of 35 beaches will be sampled each year, of which 15 will be fixed stations, 15 rotating stations and five floating stations.

Use of the Data

Data collected on shellfish will be used to calculate and record the following:

* Spatial and temporal trends of shellfish stock levels;
* Spatial and temporal trends of bacterial and toxic contamination, including PSP; and
* Identification of existing and potential problem areas for shellfish contamination.

Shellfish Abundances

<u>Rationale</u>

Commercial harvest rates for oysters and catch statistics for other shellfish stocks are monitored by WDF. There is presently little data available on recreational shellfish abundances or harvest rates, including those for crab and shrimp, that can be used to estimate the size of the resources or the potential for stock decreases due to overharvesting. PSAMP shellfish data will help to provide a system for the management of recreational shellfish.

Because shellfish populations have a slow turnover rate, monitoring on an annual basis will provide an adequate assessment of abundance. Population estimates will be made during the spring, at a time when the population is stable and that coincides with assessments of toxins in shellfish.

Methods

Crab populations will be assessed from bottom trawl catches made during bottom-fish studies.

Shellfish abundances will be monitored in conjunction with other shellfish components (pathogen indicators, PSP,and toxic chemicals). Abundances of the native littleneck as well as other shellfish including butter clams, Japanese littleneck clams, oyster species, and mussels will be assessed at all stations.

Replication and statistical sensitivity

Based on data obtained by Stober and Chew (1984b) for Puget Sound intertidal communities, 15 replicate samples, taken to a depth of 30 cm, are generally required to adequately assess intertidal native littleneck clam populations.

Protocols

* Field and Laboratory References: Stober and Chew (1984b).

Toxic Chemicals in Shellfish

Rationale

Contamination levels of shellfish are expected to be highest during the spring, due to elevated levels of lipid stored in the tissue. The importance of toxics data to human health risk assessment necessitates sampling on at least an annual basis.

Methods

Toxic chemicals in native littleneck clam tissue will be examined at the same time that population abundances are being determined. Whole animal tissue will be used for analysis, with a subsample of tissue analyzed for total lipid content.

Shellfish tissue will be analyzed for many of the same target chemicals as those looked for in sediment (Table 2-1). Analysis should be carried out for volatile organic compounds and acid extractable compounds only if there is evidence of these chemicals in nearby sediments or from nearby sources.

Replication and statistical sensitivity

Analysis of three composite tissue samples consisting of equal weights of tissue will be used. Statistical sensitivity of the composite-sampling strategy is unknown but can be estimated theoretically. Preliminary data suggest that coefficients of variation for some chemical contaminants in selected species of shellfish are on the order of 40-60 percent, based on a grab sampling strategy (Tetra Tech, 1986a).

The composite sampling strategy recommended here will substantially increase statistical precision. The variance of the mean estimated by the sampling design using multiple individuals per composite sample will be less than the underlying population variance (Tetra Tech, 1986a). For example, if five individuals per composite are used, and the coefficient of variation of the mean of individual samples is 50 percent, then that of the composite samples will be 10 percent. In this case, the minimum detectable difference would be about 35 percent of the overall mean among stations.

Protocols

* Field and Laboratory References: Stober and Chew (1984b),Tetra Tech (1986c, 1986f,g).

PSP in Shellfish

Rationale

PSP (Paralytic Shellfish Poison) is a serious threat to human health in Puget Sound. The organisms causing PSP are dilute in the water column but become concentrated in the tissues of shellfish, particularly during periods of warm weather. PSP in native littleneck clams and many other species is monitored at over 300 stations in Puget Sound, throughout each summer, by DSHS. Data from the DSHS program will be used for the ambient monitoring program at the same stations where other shellfish parameters are collected.

Methods

Clam specimens collected for testing will be within the size range harvested recreationally and commercially. Analyses for PSP will be conducted using mouse bioassay techniques.

Many of the bivalve samples analyzed for PSP are brought to DSHS by commercial shellfish growers, while others are collected by DSHS personnel. This random collection scheme maximizes the number of PSP estimates made each summer but leads to data which are often difficult to interpret. Samples collected by DSHS personnel will be the major contribution of PSP data to the PSAMP database, with data from shellfish growers' samples added only if they meet the QA/QC guidelines for the program.

Frequent sampling is needed to characterize PSP concentrations in shellfish due to high variability. Intensive sampling is required during the organism's summer growing period, with a less extensive effort needed year round. Biweekly sampling will occur during May to July, a time of intensive harvesting of butter clams and other shellfish, with occasional sampling throughout the rest of the year.

Replication and statistical sensitivity

Statistical sensitivity is unknown. At present, a single sample is taken at each sampling location, precluding any statistical analysis of the results. A special study should be conducted to determine the number of replicates needed to achieve reasonable statistical sensitivity and an alternative sampling design recommended for future sampling of PSP.

Protocols

* Field and Laboratory References: Stober and Chew (1984b), Greenberg and Hunt (1984), Sullivan and Wekell (1984), and Sullivan et al., (undated), American Public Health Association (1985).

Pathogen Indicators in Shellfish

Rationale

Pathogens in shellfish are a serious human health risk in both recreationally and commercially harvested shellfish. During the summer months, favorable low tides occur during daylight hours and clam diggers are most likely to encounter contaminated clams.

Methods

Native littleneck clams will be sampled quarterly at the same station locations as other shellfish parameters. Whole animal tissue will be analyzed for fecal coliforms by MPN (most probable number) or by MF (membrane filtration) technique.

The ongoing DSHS monitoring program, which covers several shellfish species in commercial harvest areas, complements this component of PSAMP.

Replication and statistical sensitivity

Analyses of three composite tissue samples are recommended. Statistical sensitivity of this design is unknown. At present, composite samples are routinely tested for determining levels of pathogen indicators in shellfish. With a few exceptions, one composite sample is used to perform the test. These tests are conducted solely for the purpose of determining whether public health criteria are exceeded. Hence, there has been no effort to determine the statistical sensitivity of this sampling design or alternate designs.

Protocols

* Reference: Stober and Chew (1984b), Chapman et al., (1985), Tetra Tech (1986h).

Aquaculture Sites and Yields

Rationale

Information on aquaculture sites and yields is valuable to the monitoring program because it provides information about Puget Sound's value to industries dependent on water, and because routine monitoring at aquaculture sites may act as an early warning system for decreases in water quality before monitoring of shellfish beaches picks up signs of contamination.

Methods

As part of a new program, WDF will be collecting production-related information on aquaculture sites including the age and type of operation, quarterly yields, and species composition of aquaculture operations. These data may be summarized and added to the PSAMP database annually, for the following species:

* Crayfish
* Trout and other freshwater finfish species
* Salmon
* Oysters
* Clams
* Geoducks
* Mussels
* Marine algae

BIRDS

Avian Abundances and Reproductive Success

Rationale

Birds are important ecological and aesthetic components of the Puget Sound ecosystem. As many species are near the top of the food chain, they are vulnerable to bioaccumulation of potentially toxic chemicals. Many species are also vulnerable to the loss, deterioration, or disturbance of breeding and foraging habitats. The abundance of selected avian species will be monitored to identify any significant changes that may be related to pollution, habitat loss, or disturbance.

The long-term goal of this task is to establish trends of bird populations and to examine pollution problems and the loss and disturbance of breeding and foraging habitat, particularly for colonially breeding seabirds and other species that breed widely throughout the Sound. Species selected for long-term monitoring will also be considered for their vulnerability to oil spills.

There have been only a limited number of investigations of reproductive variables (nesting success, clutch size, fledgling success and thinning of eggshells) for marine birds in the Puget Sound basin. Federal agencies including NOAA and the U.S. Fish and Wildlife Service (USFWS) have been funding studies of reproductive success and its relationship to contaminants in tissues. Species and species groups presently considered at risk in Puget Sound, and for which data on contamination are available, include the pigeon guillemot, grebe, cormorant, scoter, great blue heron, and rhinoceros auklet. Glaucous-winged gulls, brant and other geese and ducks, and bald eagles should also be considered as target species for monitoring because both breed and feed in the marine waters of Puget Sound (Calambokidis, personal communication).

PSAMP will not include a design for measuring reproductive success in birds until ongoing preliminary studies have been completed, and the extent of potential reproductive problems has been defined. Similarly, a design for measuring contaminants in bird tissue will not be included in this report, although serious consideration should be given to its inclusion in the future. Evidence from monitoring carried out in Canada, notably in great blue herons on the Fraser River, show that resident seabirds are good indicators of toxic bioaccumulation.

Waterfowl harvest data collected by WDW will be added to the PSAMP database in order to aid in the interpretation of population estimates.

Meeting the program goals

Surveys of birds, their reproductive success, and body burdens of toxicants address the health of Puget Sound resources and may act as indicators of the overall health of the Sound. The Puget Sound plan does not specifically address data needs or source control programs directed at birds, but the overall ecosystem approach of the plan is supported by examining the Puget Sound birds. Data on bird abundances will be entered into the PSAMP database and be available for research or management purposes.

Methods

WDW carries out surveys for bird abundances under several existing programs. Data from these and other programs conducted by the USFWS, the Audubon Society, and others will be inventoried and, where appropriate, added to the

PSAMP database. Several of these surveys are described here. At present, no additional surveys are recommended as a part of this program.

Abundances of many species are presently monitored during the winter by USFWS and WDW, using aerial survey techniques. The primary purpose of the aerial surveys is to census migrant waterfowl, including snow geese, *Chen caerulescens*; black brant, *Branta bernicla*; and ducks. Other birds are sometimes counted, but the data are not currently analyzed. WDW and the USFWS also conducts waterfowl breeding pairs and brood surveys statewide, including the Puget Sound area. Between the two agencies, surveys are conducted from Bellingham to Olympia. Ground surveys of seabird colonies have also been conducted by the USFWS and other investigators in the San Juan Islands, on Protection Island, and elsewhere in the Sound. Many of these data are included in the Coastal Zone Atlas and the Catalog of Washington Seabird Colonies (in preparation). The Audubon Society conducts an annual "Christmas Bird Count" of all species in some areas of the Puget Sound basin.

Frequency and timing of sampling

Monthly aerial surveys, with groundtruthing, will be carried out for avian abundances from October through March. Seasonal waterfowl brood surveys and surveys of seabird colonies will be carried out during the birds' respective nesting periods.

Location of sampling

Current survey efforts concentrate in the area from Bellingham to Olympia, exclusive of the San Juan Islands. This area will continue to be surveyed during the initial phase of PSAMP. Seabird breeding colonies will be surveyed in the intertidal, nearshore, and upland areas, wherever known colonies nest. Nesting and brooding areas will be delineated.

Use of the data

Avian abundance data will be used to establish spatial and temporal trends in Puget Sound, and to provide an overall environmental indicator of the state of the Sound.

Replication and statistical sensitivity

Statistical sensitivity is unknown, and there are no current plans for replication. Avian abundances can be extremely variable, and current sampling techniques can add to statistical uncertainty. To determine the extent to which replication may be necessary, existing survey data for birds in the Sound should be analyzed. If data prove inadequate for making a judgment on replication, more surveys should be conducted to determine coefficients of variation and to establish the necessary level of sampling replication. It is expected that future monitoring efforts will be focused on species that exhibit the least unexplained variance in abundance, and that are judged to be the best indicators of environmental change.

Protocols

* Wahl & Speich, 1983.

Waterfowl Harvest

Rationale

Waterfowl harvest statistics are derived from hunter surveys. These data are useful to the monitoring program because they provide an indication of the value of the Puget Sound estuaries as waterfowl habitat and as an associated recreational resource, and because a downward trend in waterfowl harvest may indicate possible adverse impacts to bird populations from contamination or habitat loss.

Methods

Waterfowl harvest statistics and estimates of populations, by hunting area, for the following species may be summarized by WDW and added to the PSAMP database:

Ducks		Geese
Mallard	Ruddy duck	Taverner's Canada
Shoveler	Blue-winged teal	Lesser Canada
Redhead	Canvasback	Dusky Canada
Gadwall	Scoters	Western Canada
Pintail	Cinnamon teal	Greater White-fronted
Goldeneyes	Scaup	Cackling Canada
Widgeons	Mergansers	Snow
Wood duck	Oldsquaw	Brant
Bufflehead	Harlequin	
Green-winged teal		
Ring-necked duck		

MARINE MAMMALS

Abundances and Contamination

Rationale

Marine mammals constitute an important ecological and aesthetic component of the Puget Sound ecosystem and are protected by the Marine Mammal Protection Act of 1972. Many are near the top of the food chain, and any effects of pollution on this group of animals may serve as an early warning for potential effects on humans.

The purpose of the marine mammal component of PSAMP is to provide consistent population estimates of the marine mammals living in Puget Sound, and to increase the level of knowledge of toxic body burdens and their effects on marine mammals. A single target species will be monitored in the initial phase of PSAMP, with other populations being added in later iterations of the program.

Of the variety of marine mammals found in Puget Sound, the harbor seal (*Phoca vitulina*) is the most appropriate species for monitoring as it is the only common resident marine mammal that breeds in Puget Sound. Unlike more migratory species, the harbor seal is not exposed to contaminants from other areas. Harbor seals feed in waters influenced by industrial activities, and eat many of the same fish species as humans. Studies have shown that harbor seals in the Sound can have high levels of toxic chemicals and may be vulnerable to the effects of pollution (Calambokidis et al., 1984). Data are available on concentrations of contaminants in Puget Sound harbor seals. Experimental research to investigate the effects on harbor seals of eating contaminated fish is in progress in Europe.

Meeting the program goals

Monitoring of marine mammals, including their population size, reproductive success, and tendency to bioaccumulate toxicants addresses the health of Puget Sound resources, and may act as an indicator of the overall health of the Sound. The Puget Sound plan does not specifically address data needs or source control programs directed at marine mammals, as they are already protected by federal and interna-

tional law but monitoring selected marine mammal species supports the overall ecosystem approach of the plan. Data on abundances of harbor seals will be entered into the PSAMP database and be available for research or management purposes.

Methods

WDW carries out marine mammal surveys under several existing programs. Additional investigations are occasionally undertaken by NOAA. Results of these programs will be added to the PSAMP database. At present, no additional surveys are recommended as a part of this program.

The abundance of harbor seals (adults and pups) is determined by WDW using aerial survey counts. Annual counts are made at the peak of the four to six week pupping period, when the highest percentage of harbor seals are hauled-out on shore. This ensures that the maximum possible number of individuals is observed. To determine the peak of the pupping period, aerial and/or land-based surveys will be conducted in each region of Puget Sound. Land-based surveys in selected areas will provide additional information on the number of pups.

Tissues from dead harbor seals will be analyzed for toxics. EPA and the marine mammal laboratory at Western Washington University have committed to analyze six samples apiece per year, as appropriate specimens become available. All animals used for tissue analysis must appear to have been healthy and robust prior to death.

Permits from the U.S. Department of Commerce are required for all studies and surveys, following regulations outlined in the Marine Mammal Protection Act.

Frequency and timing of sampling

Annual aerial surveys, with groundtruthing, will be used to track population trends in these long-lived, slowly reproducing species. In addition, land-based surveys will be carried out in some selected areas from June to September in order to determine the peak of the pupping period. Once the pupping period has been determined, annual three to five day aerial surveys should be conducted during the peak of the pupping season in each region. In north Puget Sound, the pupping season is typically during the second or third weeks of August, and in south Puget Sound, during the second or third weeks of September.

Land-based surveys will be conducted from June to August in North Puget Sound and from August to October in south Puget Sound.

Aerial survey flights in each region will be conducted during low tides and, if possible, on the same or consecutive days.

Location of sampling

Aerial surveys will be conducted in areas known to be used for breeding and non-breeding activities (primarily haul-out areas). In north Puget Sound these areas are the San Juan Islands, Smith Island, Protection Island, Dungeness Spit, and the eastern Puget Sound bays (Skagit, Padilla, Samish, Boundary). In south Puget Sound, the primary haul-out areas are Gertrude Island, Henderson Inlet, McMicken Island, Cutts Island, Budd Inlet, Eld Inlet, Nisqually Delta, and Eagle Island. Haul-out and nursery sites will also be surveyed in Hood Canal. Due to the proximity of many of the preferred seal haul-outs to a major roadway, Hood Canal seal habitat and populations will be extensively surveyed from land. Haul-out and pupping habitats will be delineated.

Use of the data

Harbor seal abundance and reproductive success data will be used to determine:

* Spatial and temporal trends in abundance; and
* Spatial and temporal trends in body burdens of resident marine mammals.

Replication and statistical sensitivity

The statistical sensitivity is unknown, but repeated aerial flights over the three to five day survey period will help to determine the natural variability of seal pup populations.

Protocols

* Beach et al., (1985).
* Protocols for sampling and analysis of dead animal tissue are in preparation (Calambokidis, in preparation).

NEARSHORE HABITAT

Rationale

The distribution of habitat types within Puget Sound is of fundamental importance to the structure and function of the Puget Sound ecosystem. In addition to being an area of aesthetic appeal to humans, the nearshore estuarine habitat of Puget Sound is a vital resource to many inhabitants of the Sound. Juvenile fish, particularly salmonids, depend on eelgrass and kelp beds as rearing and feeding grounds. Shorebirds and diving birds feed regularly on biota in the intertidal and shallow subtidal zones, and many species of invertebrates and plants make their homes in this region. Fringing marshes can have a significant hydraulic and pollutant-filtering value for land runoff.

The long-term goal of the PSAMP habitat task is to inventory aquatic habitats in the Puget Sound basin including the marine waters of Puget Sound, tidally influenced portions of rivers discharging into the Sound, riparian areas, river deltas, and wetlands adjacent to the Sound. Upland habitat to the crest of the mountains will be addressed by the wetland program of the Puget Sound Water Quality Management Plan, to be implemented by DNR, Ecology, and local governments.

During the initial phase of PSAMP, only marine and estuarine habitats will be examined, including intertidal and subtidal regions, with special emphasis on sensitive nearshore eelgrass meadows, kelp beds, and fringing wetlands. Other habitat types will be mapped also, including unvegetated shoreline, herring spawning beaches, and diked or rip-rapped shoreline.

The presence of wetland habitat is a key factor in maintaining and promoting the biological diversity and productivity of Puget Sound and adjacent waters. Extensive areas of benthic habitat in marine, estuarine, and riparian regions has been destroyed or contaminated in the basin. Deterioration of both the quality and the quantity of wetland habitat has resulted in a corresponding decline of several important resource populations. The overall ecology of Puget Sound resource populations could be severely harmed by the further loss and deterioration of wetlands, as nearshore habitats provide the majority of organic carbon to shallow water food webs.

Changes in the quantity and quality of habitats has been used extensively as a management tool in other estuarine systems, including Chesapeake Bay, San Francisco Bay, the Potomac River, and the Columbia River estuary. In each of these

areas there have been marked declines in wetland habitat. These declines have been used to describe major changes in the ecological condition of the system, and to explain changes in the biological resources.

Meeting the Program Goals

The nearshore habitat is a sensitive indicator region for the overall health of Puget Sound and its resources. Specific program elements in the plan which will benefit from data collected under this task include W-2, identification of wetlands to be preserved; W-3, wetland preservation; W-4, state standards; and W-5, local program development. Programs in the plan which are directed at limiting contaminants entering the nearshore estuarine habitat include portions of the nonpoint, municipal and industrial discharges, and wetland protection programs. Results of nearshore habitat monitoring will provide information on the effectiveness of these program elements. Both natural and anthropogenic changes to nearshore habitat will be documented through trend data obtained under PSAMP, and invaluable information will be made available to researchers concerned with habitat quality and quantity.

Methods

During the initial phase of PSAMP, only the quantity of nearshore habitat will be addressed. Habitat quality will be investigated as a part of resource agencies' intensive survey programs. As funding allows, more detailed investigations of habitat quality will be incorporated into PSAMP.

The type and areal extent of nearshore habitats will be monitored using a combination of remote sensing imagery (including aerial photography) and site visits (groundtruthing). At present, the remote sensing systems under consideration are the Multi-Spectral Scanner (MSS) flown on low-flying aircraft by the EPA environmental monitoring support laboratory, and aerial photographs taken annually by the Seattle District U.S. Army Corps of Engineers. Currently the Corps of Engineers program does not consistently fly at low tide, but redirection of that program in the future may correct this problem.

Protocols for mapping habitat types by remote sensing will be developed, ensuring that scans and photographs are taken in a systematic manner. Remote sensing images must be taken on days with low cloud cover and at low tide to expose the maximum amount of nearshore habitat. For kelp and eelgrass, mean low low water (MLLW) is appropriate, while marshes can be photographed at up to +3 feet. Subtidal eelgrass and kelp will have to be examined by other means and may not be assessed during the initial phase of PSAMP.

A consistent protocol for groundtruthing will also be developed. This effort will involve five to 10 replicate sites in each of the three main habitat types (kelp, eelgrass, and marshes) in each of the north, central, and south basins of Puget Sound.

Supplementing the inventory of habitat types and quantity, assessments of marine habitat quality will be made through intensive surveys by resource agencies. Representative habitats will be chosen from different river drainage basins to obtain geographic coverage. Intensive surveys associated with PSAMP will further examine the quality and functions of habitats by determining percent cover, density, and standing stock for each major plant species (macrophytes and microflora), as well as species diversity. In addition, sediment quality, animal diversity, and the presence of indicator species will be noted.

The PSAMP database will have the capability to store digitized information for the generation of habitat maps and future manipulations of the data.

Frequency, Location, and Timing of Sampling

Remote sensing surveys and groundtruthing efforts will be carried out along the entire Puget Sound coastline every three years. Analysis of remote sensing results will involve a minimum of one third of the Sound each year.

The dual requirements of low cloud cover days and low tides during daylight hours necessitate that habitat imagery be collected during the summer, preferably during the month of July.

Use of the Data

Nearshore habitat maps will be generated through a geographic information system (GIS) from the data collected from this task and will be used to provide the following information:

* Spatial and temporal trends in habitat type and areal extent; and
* Identification of areas of habitat deterioration and impending loss.

Replication and Statistical Sensitivity

There will be no replication for imagery of acceptable quality. Areal resolution and accuracy of habitat identifications from imagery will be determined by groundtruthing. Studies are presently being undertaken by Thomas Mumford, DNR, to determine the level of groundtruthing required for the collection of accurate data.

FRESH WATER

Rationale

The Puget Sound basin has an extensive network of freshwater rivers, streams, and lakes, providing most of the fresh water that flows into Puget Sound. Point and nonpoint sources of contaminants draining into fresh water affect the water quality and resource health of Puget Sound, as well as that of the watersheds.

The major river basins draining into Puget Sound include the Nooksack-Sumas basins, Skagit-Samish basins, Stillaguamish basin, Snohomish basin, Cedar-Green basins, Puyallup basin, Nisqually-Deschutes basins, West Sound basins, and parts of the Elwha-Dungeness basins.

Meeting the Program Goals

The freshwater portion of PSAMP will measure the health of Puget Sound and its resources in the watersheds. Human health considerations in fresh water will also be monitored. Watershed monitoring that is proposed in conjunction with other aspects of the 1987 Puget Sound Water Quality Management Plan will make use of the ambient data to be collected in this program, as indicated in NP-1, selection of priority watersheds; NP-3, watershed management committees; NP-4, plan adoption and implementation; and NP-6, technical assistance for watershed plans. FP-1, Timber/Fish/Wildlife project, will benefit from information, protocols, and data formats developed in PSAMP. The success of the plan will be evaluated by this portion of PSAMP, particularly the nonpoint source pollution, shellfish protection, stormwater and CSOs, and household hazardous waste programs. Permanent records of watershed data will be available to researchers and others through the PSAMP database.

Methods

Samples will be collected from the water column at midchannel for analysis of water quality parameters and conventional pollutants. Flow measurements will be taken from USGS gauging stations, when available. Alternative flow measurements will be collected when necessary.

The absence of sediment deposits in most fast-moving fresh water makes it impossible to use sediment toxicant measuring techniques that have been proposed in marine waters. Measuring freshwater sediment quantity and quality are important issues to be resolved and will be addressed in future iterations of PSAMP. In the meantime, stations located in marine water at or near the mouths of the major rivers will be used as a surrogate measure for the sediment which enters Puget Sound from freshwater rivers and streams.

Bioaccumulation of toxic chemicals in resident fish tissue in the watersheds will be used to assess the risk to human health from eating contaminated fish tissue, and as a surrogate for human exposure to toxins in Puget Sound fresh water.

Estimates of the loading of pollutants from specific land use types holds the key for management decisions concerning nonpoint pollution problems. Unfortunately baseline data are not available for loading from freshwater rivers and streams draining into Puget Sound. Loading of conventional water quality parameters can be inferred from flow measurements and monthly water column measurements, but toxicant analysis presents further problems in terms of both cost and available sampling techniques. Due to these difficulties, PSAMP will not attempt to address the loading of organic toxicants from different land use types during the initial phase of the program. Studies which may be funded by the National Estuary Program during 1988 will provide valuable insight towards incorporating organic loading into PSAMP in the future.

Frequency and Timing of Sampling

All fixed and rotating stations will be sampled for water column parameters on a monthly basis. Freshwater fish tissue will be sampled once a year, during the summer.

Location of Sampling Stations

Criteria for station selection in freshwater rivers and streams is as follows:

* Major rivers of the Puget Sound basin.
* Rivers and streams with known water quality problems, or where beneficial uses (such as recreational or commercial shellfish beds, fish habitat, or drinking water) are impaired.
* Overall coverage of the Puget Sound basin.
* Rivers and streams in watersheds which have a likelihood of intensified land or water use, including a likelihood of being logged, in the next ten years.
* Rivers and streams with suspected water quality problems, or where beneficial uses (such as recreational or commercial shellfish beds, fish habitat, or drinking water) are potentially threatened by pollution from nonpoint sources.
* Locations which complement other water quality programs aimed at protecting Puget Sound water quality, wetlands and shellfish.
* Historical station locations.

Wherever possible, stations will be located both near the mouth and upstream on major rivers or tributaries. During the initial phase of PSAMP, no stations will be

located in freshwater lakes, but during the next iteration of the program stations may be located near the outflow of important recreational lakes.

Number of Sampling Stations

A grid of 10 fixed stations was chosen on the 10 largest rivers in the Puget Sound basin. Twenty rotating and five floating stations will be sampled each year, for an annual total of 35 stations.

Use of the Data

Information from freshwater river and streams will be used to:

* Determine spatial and temporal trends in toxic metal and conventional water quality parameters.
* Determine trends in fish tissue contamination and the related threat to human health.
* Identify potential problem areas in watersheds that can be addressed by non-point source control programs.
* Prepare preliminary loading estimates for Puget Sound from freshwater input.

Conventional Water Quality Parameters and Metals

Rationale

Measuring conventional pollutant parameters and metals in the water column will provide estimates of relative loading to Puget Sound, by major river, and will identify river reaches where source control measures should be incorporated.

Methods

Conventional water column variables which will be measured monthly include:

* Temperature.
* Dissolved oxygen.
* Conductivity.
* Turbidity.
* Total suspended solids.
* Flow.
* Five nutrients (nitrate, nitrite, ammonia, total phosphorus and orthophosphorus).
* Fecal coliforms.
* Total hardness.
* Alkalinity.

* pH.

Flow stations will be established in areas which are not currently served by the USGS grid. Establishing and maintaining flow monitoring stations can be extremely costly, but the data are essential to all other aspects of the freshwater and other watershed monitoring programs. Other less expensive methods of measuring flow are also currently being investigated.

Analysis for 13 metals (aluminum, antimony, arsenic, cadmium, chromium, copper, iron, lead, manganese, mercury, nickel, silver, and zinc) will be carried out on bulk water samples from the same network of sampling stations on a quarterly basis. Total cations and anions will be analyzed once a year.

Replication and statistical sensitivity

Replication and statistical sensitivity is unknown. At present, a single sample is recommended at each sampling location, precluding any statistical analysis of the results. A study should be conducted to determine the number of replicates needed to achieve reasonable statistical sensitivity and an alternative sampling design recommended for future freshwater sampling.

Protocols

No protocols are available at this time. Plans are underway to develop freshwater protocols in 1988.

Toxicants in Fish Tissue

Rationale

Fish which are resident in rivers and streams act as biological indicators of toxicant accumulation in the freshwater environment. Analysis for priority pollutants and pollutants of concern in Puget Sound will allow for an assessment of the potential human health risk of consuming resident fish from specific river and stream reaches. In addition, the presence of certain chemicals of concern to Puget Sound found in river and stream reaches will help pinpoint sources of the contaminants. The health of the fish will be investigated by external examination only; no detailed internal examination is proposed at this time.

Methods

Two species of resident fish will be collected monthly from each water column station. The choice of target species for chemical analysis should include one bottom feeding species and one species commonly caught by anglers. The species used should be standardized as much as possible among river basins in order to compare the relative contamination among watersheds. The data will provide an assessment of the potential for human exposure to contaminants as well as a "worst-case" assessment of bioaccumulation by a demersal fish.

The target fish will be examined for length, sex, reproductive status, and gross external abnormalities. Composites of muscle tissue and of liver tissue from several fish will be sampled for toxics analysis. The chemicals to be measured in fish tissue will include chemicals of concern for Puget Sound (Table 2-1). Because freshwater fish tend to accumulate metals more readily than marine fish, all 13 priority pollutant metals will be analyzed (as opposed to only mercury in marine fish tissue). Pesticides commonly used in the Puget Sound basin may be more prevalent in freshwater systems and will be included in the fish tissue analysis.

Replication and statistical sensitivity

Replication and statistical sensitivity is unknown. Compositing of tissue samples will reduce the variability of data. At present, a single composite sample is recommended at each sampling location, precluding any statistical analysis of the results. A study should be conducted to determine the number of replicates needed to achieve reasonable statistical sensitivity and an alternative sampling design recommended for future freshwater fish tissue sampling.

Protocols

None are available at this time. Protocols for freshwater fish tissue analysis are expected to be developed sometime in 1988.

RIVER MOUTHS

Rationale

The rivers and streams draining the Puget Sound basin are sources of both fresh water and contaminants. Freshwater inflow to the nearshore region creates a series of estuarine habitats which are highly productive and vulnerable to deterioration.

Many of the contaminants washed into Puget Sound by rivers and streams are associated with sediment particles which remain suspended in the water column during their rapid transit downstream. When the flowing fresh water enters the relatively quiescent waters of Puget Sound, much of this sediment load is deposited. Dissolved contaminants and those associated with fine grained particles are be present in high concentrations in the nearshore region, prior to extensive mixing with salt water. In order to examine the effects of freshwater and river-borne contaminants to Puget Sound, sediments and water will be sampled at the mouths of the major inflow sources.

The primary objectives of monitoring at the mouths of the major rivers are to estimate the relative annual inflow of contaminants from freshwater inflow to Puget Sound, and to establish baseline conditions for nearshore estuarine habitats.

Meeting the Program Goals

The river mouths portion of PSAMP will measure the health of Puget Sound and its resources in the very nearshore estuarine region. Data from this task will be used in nearshore areas for the marina and recreational boating program of the Puget Sound plan, specifically MB-7, study of "No Discharge" areas; and MB-8, "No Anchorage" areas. This portion of PSAMP will measure success of the plan in the nonpoint source pollution, shellfish protection, stormwater and CSOs, and household hazardous waste programs. Permanent records of nearshore data will be available to researchers and others through the PSAMP database.

Methods

Sediments will be sampled for sediment chemistry, benthic invertebrates, and conventional sediment variables, as described earlier. Bioassays appropriate to low salinity conditions (oyster embryo development and Microtox) will be used. Water quality sampling for hydrographic conditions, dissolved oxygen, turbidity, nutrients, and chlorophyll will be carried out as previously described. Pathogen indicators will also be measured in the water column.

Frequency and Timing of Sampling

All fixed and rotating stations will be sampled for water column parameters on a monthly basis. Sediment stations in marine water will be sampled annually, in conjunction with the sediment quality task.

Location of Sampling Stations

River mouth stations will be located at the mouths of each of the major rivers draining into Puget Sound, in areas with known or suspected water quality problems, at historical stations, and in conjunction with stations sampled by other programs.

Fixed stations will be placed within tidal influence at the mouths of the ten rivers with the greatest mean annual flow, because contaminant loading is largely a function of discharge and degree of urbanization. These rivers are the Skagit, Snohomish, Stillaguamish, Nooksack, Puyallup, Sammamish-Cedar, Green-Duwamish, Skokomish, Nisqually, and Deschutes. These rivers are widely distributed geographically, and with the exception of the Skokomish and the Nisqually, drain extensively developed watersheds and discharge into confined bays with moderately to extensively developed sensitive habitats, or into bays with known contamination problems.

Rivers that discharge into receiving waters with low flushing potential, known contaminant problems, and extensive biological resources will be sampled by rotating stations. Although these smaller rivers are expected to account for less contaminant loading to the Sound than the major rivers, they may have significant local influences, especially when discharging into small confined bays. The rotating sampling scheme will also be used as an initial screening tool to rate the importance (relative to Puget Sound contaminant loading) of the smaller Puget Sound tributaries.

Number of Sampling Stations

The river mouths will be sampled at the rate of 26 stations per year, of which 10 will be fixed stations, 11 rotating and five floating.

Use of the Data

Data from river mouth stations will supplement the water column and sediment quality tasks in developing spatial and temporal trends in water column and sediment parameters in the nearshore region.

Replication and Statistical Sensitivity

See the sections on sediment quality and water column.

Protocols

- **Field References:** Guy and Norman (1970), Stevens et al., (1980), Richey et al., (1986), Tetra Tech (1986c), Ongly and Blackford (1982), McCrea and Fischer (1984).
- **Laboratory:** Parsons et al., (1984), Tetra Tech (1986c,f,g), Tetra Tech and EVS Consultants (1986b).

Chapter 3.
Data Management System

INTRODUCTION

In this chapter, the purposes, goals, types of data, and user requirements for a data management system for PSAMP are discussed, and recommendations made for components of the system.

The terms database, computerized database, and data management system are used in very specific ways, as defined in Table 3-1.

PURPOSE OF THE DATA MANAGEMENT SYSTEM

The data management system will support the goals of PSAMP by managing data from the monitoring program and will provide for analysis of data to:

* Support ongoing agency activities in the enforcement of environmental laws and management of biological resources.
* Assess risk to human health.
* Identify past trends and predict future conditions in environmental measurements.
* Identify problem areas.
* Assess and measure the impacts of discrete projects and general development in the Puget Sound basin.
* Define background or reference conditions.
* Support Puget Sound research.
* Evaluate the effectiveness of the Puget Sound Water Quality Management Plan.

TYPES OF DATA

The primary information stored in the PSAMP data management system will be data collected under the nine monitoring tasks (see chapter 1). In addition, certain data from other programs may be needed to interpret monitoring results. These programs include:

trends in environmental quality in the Sound, and to understand the processes by which human activities impact the Sound.

Some of the information that will be collected under PSAMP is currently collected under existing programs which are linked to agency mandates. Data that are collected during PSAMP will need to be integrated with these other data. A data management system developed for PSAMP should be useful to agencies in managing and integrating other agency data.

Enable a Soundwide Approach to Information Analysis

In developing PSAMP, the Authority has recognized the need for an integrated monitoring program. The data management system for PSAMP will allow data to be integrated to assess long-range trends, the overall condition of the Sound, and the success of the Puget Sound plan.

Data from different PSAMP tasks will be integrated, analyzed and presented in reports including the State of the Sound report. Special reports which address specific questions or problem areas in depth will be prepared as needed. Integrated data will also be available to researchers and decision-makers.

In order to produce integrated reporting of Puget Sound data, the PSAMP data management system must have a wide range of data retrieval and analytical capabilities, including the capability to produce graphs and tables, perform statistical analyses, perform mass-loading calculations for Puget Sound, and provide input to numerical models of the Sound.

Enable Data to be Used in a Variety of Forms

PSAMP data will be used and analyzed in a variety of ways (see Appendix B). Surveys designed to determine present and future use of Puget Sound data in general (Tetra Tech, 1985c; Tetra Tech, 1986b) also show varying needs for data presentation and analysis. For example, DNR aquatic land resource managers need mapped information on Puget Sound habitats to identify natural resources within areas of potential development. Ecology staff concerned with water quality need the ability to compare dissolved oxygen values with state standards. Fisheries staff must be able to trace changes in the relative abundance of different species over time.

In addition, water quality managers need data on differing time-scales, and with differing ease of access. For example, while Ecology staff occasionally need maps or statistical analyses, their most frequent needs are for listings of data selected by area and sampling date. DNR staff are more frequent users of maps and do not have a strong need for statistical analyses.

Many computer users expect to have direct access to information stored in computerized databases, including the ability to retrieve tables of information, perform simple analyses and produce graphics. Most users recognized that certain types of retrievals and analyses require the assistance of expert programming staff.

Present Geographic Data in a Usable Format

Production of the Puget Sound Environmental Atlas (Evans-Hamilton and D.R. Systems, 1986) was sponsored by the EPA, COE, and the Authority. The atlas is designed to present up-to-date environmental information on Puget Sound in a readily accessible format. Forty-five types of data are presented on maps of Puget Sound (Table 3-2). To date, about 350 copies of the atlas have been distributed.

The Puget Sound Environmental Atlas will need to be updated regularly to incorporate changing information on resources and human activities, and to reflect the increasing availability of data. Locations of kelp and eelgrass beds identified during

surveys of nearshore habitat will be presented on maps, and water and sediment quality data will be displayed at their respective sampling points.

Resource managers need better resolution than was provided in the original edition of the Puget Sound Environmental Atlas in order to identify resources and human uses in shoreline areas. In addition, they may need more detail about the types and nature of resources than is provided on the maps, and may need to do very intensive and detailed analyses of geographic data that would require use of a computerized geographic information system.

TABLE 3-2: TOPICS CONTAINED IN THE PUGET SOUND ENVIRONMENTAL ATLAS

Shorelines

Political Boundaries (international, county, city, Indian reservations), watershed boundaries

Navigation lanes, precautionary areas, ferry routes

Utilities (pipelines and cables)

Shoreline master plans

Population forecasts (1980, 1990, 2000)

Fishing Piers, artificial reefs

Parks and recreational areas, beaches

Bathymetry

Water currents (net near-surface and near-bottom)

Usual and accustomed tribal fishing areas

Natural Resources:

- Coastal wetlands
- Eelgrass and kelp Beds
- Waterfowl and seabirds
- Wildlife refuges, estuarine sanctuaries, nature preserves
- Major marine mammal use areas
- Areas containing species of special concern
- Major salmon fishing areas (commercial and recreational)
- Major groundfish areas (flatfish, rockfish, etc.)
- Herring and surf smelt spawning areas
- Herring holding areas
- Clam, oyster and geoduck beds (commercial and recreational)
- Shrimp and crab resource areas
- Aquaculture facilities and designated aquaculture areas

Pollution Data and Sources:

Point Source Discharge locations (waste treatment plant outfalls, industrial and municipal discharges, combined sewer overflows, storm drains)

- Dredged material disposal sites
- Organics concentrations in the sediment (low molecular weight polycyclic aromatic hydrocarbons, high molecular weight polycyclic aromatic hydrocarbons, chlorinated phenols, total PCBs)
- Metals concentrations in the sediment (arsenic, cadmium, copper, mercury, lead, zinc)

Areas of Concern:

- Red Tide Prone Areas (paralytic shellfish poisoning)
- Approved and prohibited commercial shellfish beds
- Areas of where sediments have chemical concentrations significantly different from background levels
- Sediment bioassays
- Bioaccumulation of metals and organics
- Areas with abnormal benthic communities
- Areas with diseased bottomfish, sport fishing advisories

Rivers and streams will need to be added to the atlas to enable mapping of results of freshwater monitoring.

Ensure Data Quality

Consistency of data collection, reporting, and formatting over time will be essential to analyzing trends in conditions in the Sound. Consistency among different types of data (i.e., in defining sampling locations and conditions) will be essential to creating a complete and integrated picture of the Sound.

All PSAMP data will be collected and managed according to a rigorous set of quality assurance standards. These standards will address sample collection and analysis, documentation, data management, and data reporting formats.

All data collected in the past, or collected outside of PSAMP, will have to be evaluated before they can be used with PSAMP data. Other data will be evaluated to ensure that they are pertinent and adequately documented, and that collection techniques and analytical methods allow data to be compared. In addition, the costs and potential benefits of adding these other data to the PSAMP database in a usable format will be considered.

Encourage Data Sharing Among Agencies and Programs

Ongoing Puget Sound programs which collect data that may be used in conjunction with PSAMP include NOAA's National Status and Trends Program, the Puget Sound Dredged Disposal Analysis, and the EPA urban bay program (see Chapter 1). Many of these programs utilize sampling strategies which are similar to PSAMP, and analyze samples using existing Puget Sound protocols. The PSAMP data management system should be able to use data from other programs and provide data to other programs as appropriate.

APPROACH

Develop a Distributed System

A single computerized database or geographic information system for Puget Sound will probably not be able to meet all resource agency needs while providing an adequate integrative function for Sound-wide analysis. The system recommended for PSAMP distributes data and data management capabilities and allows parts of the system to be tailored to specific agency needs.

Use Computer Technology

Many agencies are encouraging their staff to take advantage of computer technology to access resource information and data on environmental quality. The costs of using computer power have decreased by orders of magnitude in the past 10 years and promise to decrease still further. Individuals who are not expert in computer programming can use personal computers as powerful tools in their everyday work.

The PSAMP data management system will take advantage of these changes in technology.

Develop an Information-Centered Approach

Many key resource agencies are moving towards an information-centered approach to environmental data management. An information-centered approach (Martin, 1983) treats information as a resource to be managed, rather than as an appendage of a single project. Since data that describes conditions in the environment is usable for a variety of purposes, an information-centered approach is appropriate.

Computerized databases that use the information-centered approach are developed to fit the inherent logical structure of the information collected. Information-centered databases allow the data to be used for a wide variety of purposes. Storing PSAMP data in information-centered databases will support a wide variety of agency needs and will support the overall integration and utilization of information collected by the agency.

Encourage Data Users to be Computer Users

The PSAMP data management system will be designed to allow technical and managerial staff to use computers directly in performing their every-day tasks. Direct and rapid access to environmental data will help water quality managers make decisions with the best available information. This access can be achieved through use of software that allows computer users to retrieve and analyze data without the help of a programmer.

Staff training on general computer operation, computer information organization, and computer uses should accompany the development of information-centered data management systems.

Improve Data Transfer Capabilities

Sharing of data among agencies and among different programs within the same agency will improve the ability of those agencies to carry out their mandates in a cost-effective manner. Data sharing will be facilitated by increasing information about what data are available and how they can be obtained, increasing the availability of well-organized and documented digital data, and developing standard formats for data exchange.

Many state agencies are in the process of assessing their needs and developing data management systems. With careful design and coordination, the PSAMP data management system and systems developed to handle other agency needs will be able to readily share data.

RECOMMENDED COMPONENTS

The PSAMP data management system will consist of 3 components:

* Monitoring Databases - Implementing agencies will create and maintain computerized databases of PSAMP data. These databases will support agency monitoring efforts and meet agency needs for day-to-day management of data and access to information.

* A Central Puget Sound Database - The Puget Sound monitoring staff will create and maintain an integrated central database containing selected monitoring data and other Puget Sound data.

* A Geographic Information System - The Puget Sound monitoring staff will create a Puget Sound geographic information system (GIS) to support the need for updating maps and integrating geographic data.

These components will be coordinated by the use of standardized quality assurance requirements and the regular transfer of data among components. The flow of information among system components is shown in Figure 3-1.

Monitoring Databases

Each implementing agency will have primary responsibility for collecting, managing, and assuring the quality of data from its portion of the program. In order to meet these responsibilities, each agency will need:

* A project archive or document management system.
* A computerized database of monitoring data.
* Quality control procedures.
* Procedures for data transfer to the central Puget Sound Database, and to other agency databases.

Project archive

Field forms, laboratory data reports, and all quality assurance information collected as part of PSAMP will be stored and maintained by each implementing agency in a permanent project library or archive. There must be clear cross-references between any computerized database storing monitoring data and the project library. This will enable an interested user to locate additional information and documentation for computerized data.

Computerized database

Data - All data collected in the field will not necessarily be entered into a computerized database; certain specific information needed to support data uses will be stored. Appendix C is a list of the minimum information to be stored for each type of monitoring data.

In certain situations, additional information from other sources may be needed for PSAMP data analysis and interpretation. The need to link ambient monitoring data to data from other programs, including compliance monitoring and intensive surveys, should be carefully considered in designing the computerized database.

Functions - The computerized database used to store monitoring data will perform the following functions:

* Allow entry and editing of different types of information (e.g., station locations, sample descriptions, and analytical data).
* Check entered data to ensure that valid codes are used.
* Allow searches to find specific pieces of information in the computerized database.
* Link computerized data to information stored in the project library or archives.
* Produce standard tables of data for monitoring program reports.

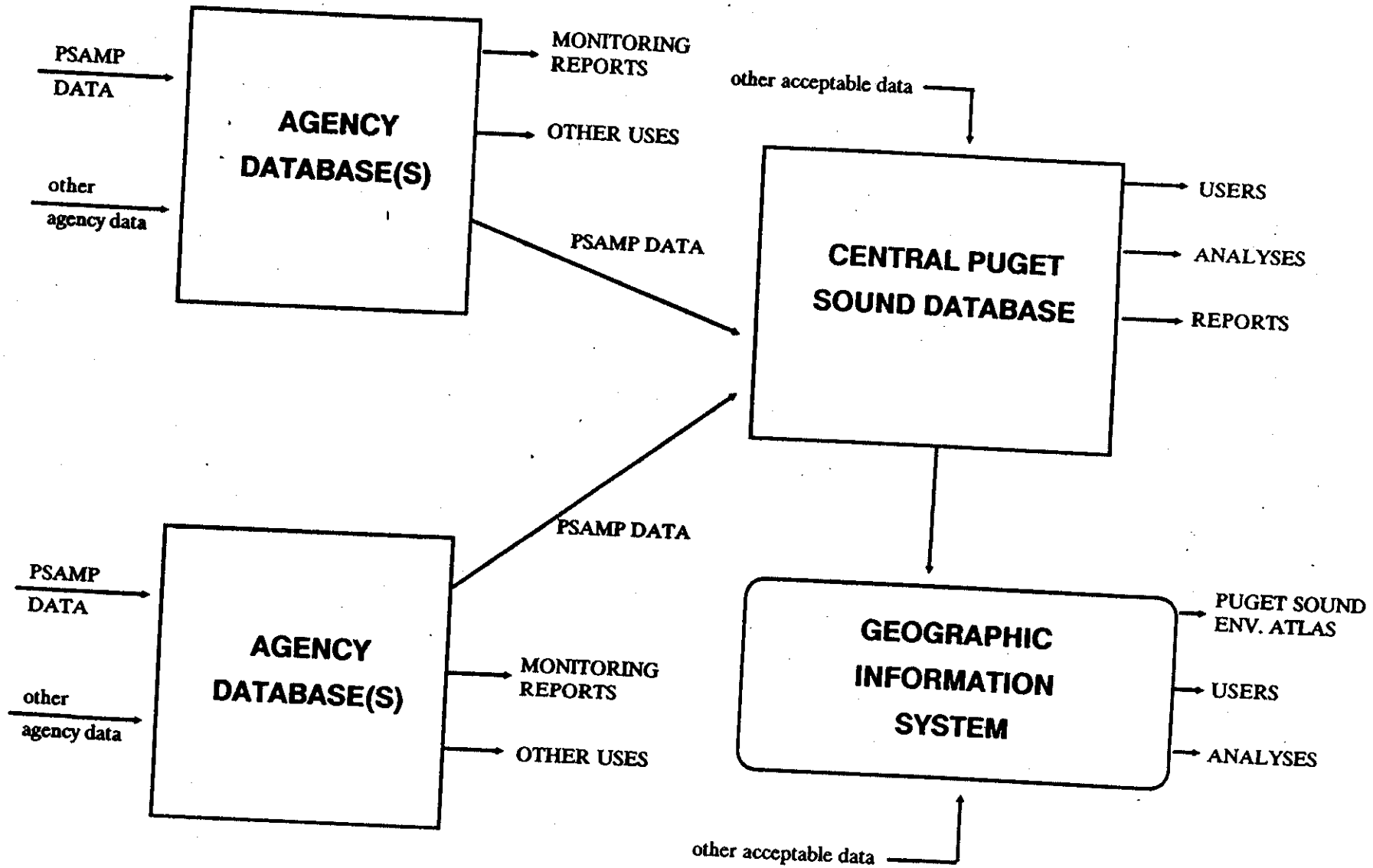

FIGURE 3-1. FLOW OF INFORMATION IN THE PSAMP DATA MANAGEMENT SYSTEM

* Output data in a standard format for transfer to the central Puget Sound database.

Other functions that may also be needed include tracking the location and destination of monitoring samples, performing quality assurance checks on analytical replicates, and transferring data to other software packages for analysis and presentation.

Recommended Tools - Each implementing agency should assess its needs and decide whether an existing computerized database can be used to store PSAMP data, or whether a new database should be designed. The computerized database chosen should provide access and answers to users' needs on an appropriate time-scale and in an appropriate format. The computerized database selected should be compatible with the agency's efforts to develop integrated information-centered systems for managing environmental data.

If a new computerized database is to be developed, commercially available database management systems (e.g., Focus, Info, dBase III, and Rbase System V) should be considered. Relational databases are recommended because they can store many different types of information in a logical manner that enables data to be combined and manipulated. Agencies that are collecting habitat data should consider developing a GIS that includes both a relational database and a geographic database.

Database management systems provide many built-in capabilities for organizing and retrieving data, and for building data entry screens, menus, and user-friendly programs. These capabilities can substantially reduce the costs of system development and system maintenance. Use of these systems can encourage increased use of data by agency staff, rather than by trained computer personnel. If user-friendly screens and menus are not developed as an initial part of the system, the system selected should have the flexibility to allow their later addition.

It may be necessary to use several different software packages to develop a computerized database to meet all agency needs. It is usually more efficient to develop programs that transfer selected data from databases to commercially available statistics and graphics packages than to try to program these capabilities into a database.

Microcomputers are recommended to house the computerized database because of their accessibility and ease of use. Microcomputers can provide substantial computer capacity at a low cost, and can be linked together in a network to allow several users simultaneous access to the computerized database.

Quality control procedures

Each implementing agency will prepare a data management plan that specifies how data quality assurance goals will be met. Quality control procedures (i.e., instructions for collecting, entering, verifying, and analyzing data) will be set up to ensure that the data entered into the database are of high quality. Certain information will be stored in the computerized database to enable data users to judge the quality of data stored.

Quality assurance is discussed further in Chapter 4. The key components of a quality assurance program are outlined in detail in Appendix A.

Procedures for data transfer

Information in each monitoring database will be transferred to the central Puget Sound database as soon as data from a monitoring event have been entered and verified. The MMC will recommend formats for the transfer of data from agency databases into the Puget Sound database. These formats will specify the order and contents of files created to transfer the information for each data type that is listed

in Appendix C, and will be based on existing formats (i.e., EPA Storet and ODES formats and NOAA National Oceanographic Data Center data archive formats). These same transfer formats will enable data to be transferred among implementing agency databases.

Integrated Database

The Puget Sound monitoring staff (to be housed in the Puget Sound Water Quality Authority until 1991) will create and maintain a central computerized database designed to integrate information on Puget Sound. Data from PSAMP will form the core of this Puget Sound database. This database will support the needs of decision-makers, planners, researchers, and the general public by making up-to-date comprehensive information on Puget Sound available. The Puget Sound database will support the Puget Sound Water Quality Management Plan by making information available for problem identification and for assessing the plan's success.

The Puget Sound Database will have the following components:

* A Puget Sound data inventory.
* A computerized database.
* A program management system for PSAMP.
* Quality control procedures.

Puget Sound data inventory

The Puget Sound database will not store all available data on Puget Sound, but will serve as a source of information on what data are available and how they may be obtained. This information will be compiled from monitoring program reports and other existing sources of information (e.g., Chapman et al., 1985; Metro, 1987), and will be updated regularly.

Computerized database

Data - The Puget Sound database will store environmental data from PSAMP tasks. Individual data points stored in agency monitoring databases will generally not be stored on the Puget Sound database, but summarized data will be transferred to the central database for further analysis. For example, an agency monitoring database will record the abundance of every benthic invertebrate species found in a sample, while the Puget Sound database will store a diversity index, or a figure for total abundance in the sample. Details of what data will be transferred to the Puget Sound database, and how it will be summarized, will be determined during detailed design of the Puget Sound database.

Other data which are necessary to meeting monitoring program goals (e.g., data summarized in the Puget Sound Environmental Atlas) will be added to the Puget Sound database. Historical data and data collected by other programs will be evaluated to ensure that they are pertinent and adequately documented, and that collection techniques and analytical methods allow data to be used for PSAMP analysis. Costs of obtaining these data in a usable format will also be considered.

Functions - The Puget Sound computerized database will perform the following functions:

* Load monitoring data transferred from implementing agencies.
* Check data to ensure that they were properly transferred.

* Enable editing of data if necessary.

* Search for specific pieces of information in the computerized database.

* Produce standard tables of data for monitoring program reports.

* Perform data analyses to summarize or process information.

* Transfer data to a variety of software packages for statistical analyses, graphics, modeling, or mapping.

* Provide data to water quality managers, planners, researchers and other users.

Recommended Tools - The Puget Sound database will be developed on an IBM compatible microcomputer using a relational database management system. Available products (e.g., Oracle, dBase III, Focus, and RBase 5000, Knowledge Manager) will be evaluated during detailed system design. The Puget Sound database will use other software to provide additional capabilities for data presentation and analysis: a word-processing package (e.g., Word-Perfect), a spreadsheet (e.g., LOTUS 1-2-3), and a statistical package (e.g., SPSS, or SAS).

The quantity of data to be stored in a Puget Sound database (five to 10 megabytes per year) can be managed for several years using existing microcomputer technology. Within that time period, laser disks that will store hundreds of megabytes of information will become available. New software will substantially increase the speed and processing power of microcomputers as well. The Puget Sound database will be designed to take advantage of new technology as it becomes available.

Initially, the Puget Sound database will be developed on a local area network (i.e., a network linking users in the same office or building). As technology and budgets allow, the network will be expanded to allow users to access the system via telephone lines. Copies of the database may be made available on portable disks (e.g., CD-ROMs) for use directly by users on their own computers. These alternatives and their costs will be explored during detailed system design.

If it proves feasible to develop a full-scale GIS for Puget Sound (see discussion below), the Puget Sound database and the GIS may be integrated into a single system, which will run on a large multi-user computer system. The microcomputer Puget Sound database will serve as a prototype system for three to five years, until an integrated system can be developed. Many of the models, programs, screens, and procedures developed for the microcomputer database will be usable in the integrated version of the system.

Program management system

The Puget Sound database will serve as an overall management tool for tracking the status and success of the individual tasks of the ambient monitoring program. It will be used to assess the success of the monitoring program, and to determine whether changes are needed in monitoring program design.

Quality control procedures

Maintaining data quality in the integrated Puget Sound database is essential if it is to be a reliable source of information. A data management plan will be developed for the Puget Sound database that will specify how quality assurance goals will be met. Procedures for loading, verifying, and securing PSAMP data will be specified. Criteria for evaluating historical data and data from other programs will also be developed.

Geographic Information System

A geographic information system is a computerized tool for managing geographic information (information that defines or describes physical locations on the earth). For environmental data, geographic data can consist of discrete points (e.g., sampling station locations and point source outfalls), lines (e.g., sampling transects and shorelines), or areas (e.g., kelp beds, wildlife refuges, and areas of similar grain size).

A geographic information system manages geographic data so that it can be digitized, manipulated, analyzed, and presented in a variety of scales and formats. Using a GIS, geographic data can be linked to tabular data that describes and qualifies the geographic information. For example, the boundaries of a kelp bed can be linked and related to information about species composition and percent cover.

GIS systems are expensive to develop and maintain, due to the costs of system design and development, mini- or mainframe computer hardware and software, and effort required to create, digitize, and update accurate maps from field data.

Updating the Puget Sound atlas

The digital files created for the Puget Sound Environmental Atlas will form the basis of a Puget Sound GIS. The geographic data in these files will be maintained at the resolution at which they were originally digitized. The boundaries of the geographic segments will be adjusted to USGS quad map boundaries, and other changes will be made to improve mapping capabilities.

The Puget Sound GIS will be stored at an appropriate computer facility. DNR, the Department of Wildlife, the USGS, and the University of Washington all have the capability to store the GIS. ARC/INFO has been chosen for GIS software because it is the system most widely used by local, state, and federal agencies in the Northwest to manage resource and land-use information.

The Puget Sound Environmental Atlas will be updated every two to three years. Maps or digital files of atlas data will be provided to appropriate agencies for use in updating information. Updated maps, or new digital data, will be incorporated into the Puget Sound GIS. Monitoring data will be summarized and transferred to the GIS for mapping.

Managing Puget Sound resources using GIS

The Puget Sound GIS could become the central location for storing geographic data on Puget Sound. This could be achieved by:

* Obtaining existing digital data from agencies that are maintaining Puget Sound data on their own GISs; or

* Developing cooperative agreements with agencies in order to expand the types of information and level of detail stored in the Puget Sound GIS.

Efforts are currently underway among federal agencies, state agencies, and tribal organizations to reduce the costs of developing GIS systems by sharing digital data. Puget Sound GIS files will be distributed to agencies so that they can incorporate this information into their own GISs. Updates of data from agency GISs systems will be used to update the Puget Sound atlas.

Certain agencies or programs may wish to use the Puget Sound GIS to meet their needs, in lieu of developing their own GISs. PSAMP would support the collection and maintenance of the information needed to update the Puget Sound Environmental Atlas; agencies would contribute funds for storage of additional information, map production, and geographic analysis to meet their specific needs.

Quality control procedures

The quality of geographic data can be ensured by careful digitizing and data verification, and by accurate transfer of information. A data management plan will be developed for the GIS that will specify how quality assurance goals will be met, especially in the transfer of digital information among GISs.

IMPLEMENTATION

Development of the Puget Sound database and Puget Sound GIS will involve the following steps:

* Develop a detailed system design.
* Prepare detailed cost estimates for hardware, software, and system development.
* Obtain appropriate computer equipment and software.
* Design and implement data formats and file structures for encoding and storing data in computerized form.
* Write computer programs for managing data (i.e., entering, sorting, editing, deleting).
* Write computer programs for retrieving and analyzing data.
* Develop menus, messages, and forms that guide the user through the process of working with data.
* Develop procedures for the transfer, receipt, entry, and quality control of data.
* Test the system in a real operating environment.
* Train users at various levels to understand the system's purpose and uses.
* Refine the system to better meet user needs.

Chapter 4.
Quality Assurance/ Quality Control (QA/QC)

CRITERIA FOR ENSURING DATA QUALITY

Coordination among agencies and organizations is essential to ensure that all necessary portions of the monitoring design are carried out and that the quality of the data are consistently high. In addition, careful planning during the design phase of the monitoring program will lead to a technically defensible program which can be implemented as funding becomes available. The following criteria will be applied throughout the entire planning and implementation process.

* Unambiguous and scientifically valid sampling parameters will be selected.
* Sampling and analytical protocols will be chosen that are scientifically valid and allow comparisons over time, as well as among sample locations. The Puget Sound protocols will be used, where applicable.
* Sample locations will be chosen and sample replicates collected in order to differentiate between natural (normal) variability and human-caused variability, using statistically valid methods, whenever possible.
* Measurements made throughout the monitoring program will be consistent and will be compatible with other monitoring programs.
* Complete QA/QC programs will be designed along with each task of the monitoring program for field sampling, laboratory analysis, and data management.
* Sampling information including station locations, sampling methods, analytical results, and QA/QC information will be kept in a safe permanent storage facility, on a computerized database. Duplicate copies of all computerized data files will be maintained at a separate location for security.
* Complete technical data reports, including summary QA/QC information, will be prepared in a timely fashion and made available to a broad audience.
* The results of the monitoring program will be analyzed and interpreted in a consistent manner, and periodic reports will be prepared for a broad audience.

These reports will cover specific monitoring components as well as the overall monitoring program.

* Results of the monitoring program will be placed on databases which are readily accessible to all program participants, other water quality managers, and researchers.

PURPOSE OF A QA/QC PROGRAM

A QA/QC program ensures that data exhibit an acceptable level of quality and that the level of quality is properly documented. Following a well-organized, rigorous set of guidelines will result in a data set which will produce defensible answers to management questions and will be accepted by scientific researchers.

It is essential that data quality be maintained throughout the process of field collection, lab analysis, data entry, and data retrieval. Consistency of collection, reporting, and formatting of similar data over time is essential to analyzing trends in conditions in the Sound. Careful attention to consistency among different types of data is essential to creating a complete and integrated picture of the Sound.

NECESSARY COMPONENTS OF A QA/QC PLAN

A QA/QC plan requires that a detailed work plan be written which includes a sampling plan, laboratory analytical requirements, and a data management plan. A outline of these elements is listed here. A more detailed account appears in Appendix A.

Field Sampling Plan

The field sampling plan should identify:

* The objectives and priorities of the field survey.
* All necessary field personnel and their duties.
* The number and location of all variables to be sampled.
* Field sampling methods and protocols.
* All necessary equipment and supplies.
* Cruise schedules.
* The information to be recorded on field logs.
* Sample storage and shipping procedures.
* The location of laboratories to which samples will be shipped.

Further details in the sampling plan should include preparation techniques for field gear and sample bottles, equipment maintenance and calibration, station positioning, and data recording.

Laboratory Analytical Requirements

Quality control measures which should be included in the sample analysis phase of PSAMP include:

* Laboratory protocols and handling procedures;

* Precision and accuracy measurements; and
* Procedures for review of laboratory data.

Data Management Plan

The data management plan should describe:

* The computerized database for data storage;
* Analysis and interpretation techniques to be used on the data; and
* All quality assurance procedures for data management.

Chapter 5.
Program Costs and Financing

PROGRAM COSTS

The recommended PSAMP design will cost approximately $3.3 million a year to implement. This cost was developed program task by program task, during the course of PSAMP design.

In order to prepare a detailed cost for the program, each task was divided into 11 subtasks and costs assigned for personnel, equipment, supplies and travel. In an attempt to provide an objective and uniform estimate, the subtasks were applied to all tasks, even though some are not entirely appropriate for all PSAMP tasks. The 11 subtasks are:

* Management.
* Quality assurance.
* Shore mobilization.
* Vessel (or aircraft) mobilization.
* Sea operations navigation.
* Sea (or airborne) operations.
* Vessel demobilization.
* Sample analyses.
* Data management.
* Data entry, verification, and analysis.
* Data interpretation and reporting.

Details of the cost estimate are extremely lengthy. A summary of annual costs and startup costs for each task are shown in Table 5-1. Footnotes to the table explain some of the major expenditures in each task.

Data Management Costs

Monitoring databases

The costs to enter and manage data from each task of the monitoring program have been included in the cost estimate for that task. It is estimated that data management, including data entry, analysis, interpretation, and reporting, will cost $155,000 per year for the entire program.

The cost estimates included in each monitoring task do not include the cost for setting up each agency's computerized database. System development costs for all of the 5 implementing agencies are estimated at $270,000.

Puget Sound database

The total estimated cost for development and operation of the Puget Sound database over the next 3 years is $250,000. Costs will include evaluation and phased purchase of hardware and table 5-1 heresoftware, development of the computerized database, and loading of monitoring program data and other information. It will cost about $75,000-$100,000 per year to maintain the system.

Geographic information system

A GIS designed solely to update the Puget Sound Environmental Atlas will cost about $50,000 in startup costs, and from $5,000 to $25,000 per year to maintain depending on the computer system chosen. Costs to update the atlas depend on what recent data are readily available. Assuming that data are easily obtainable, it will cost from $100,000 to $125,000 to produce an updated atlas.

Development of the atlas files into a full Puget Sound GIS will cost approximately $125,000 to $150,000. GIS maintenance costs may be higher since data would need to be readily accessible to users. Costs of updating the atlas will be less than above.

Some startup costs for developing a Puget Sound GIS have been included in the budget shown in Table 5-1, but further funding will be needed if a full GIS is to be developed.

FUNDING PSAMP

A long-term monitoring program like PSAMP can only be maintained if a stable funding base is found. Large annual fluctuations in resource levels would make it difficult to sustain well-trained personnel and to generate comparable data over a period of time. Government funding of monitoring at both the state and federal level will be sought to provide a stable funding base.

Funds for implementation of PSAMP were not included in the budget request to the Washington State Legislature with other 1987 Puget Sound plan elements for the 1987-1988 biennium, as the monitoring program had not yet been designed.

The Puget Sound Water Quality Authority submitted a supplemental appropriations request to the state Legislature for the 1988 legislative session, for the purpose of implementing the PSAMP. Due to financial constraints facing the State, the request was not granted. Funds for PSAMP implementation will be included in the 1989 plan request. Passage by the Legislature of the Discharge Permit Fee Law (SB 6085) freed some state resources within Ecology for plan-related activities in 1988, including some funding for monitoring.

Federal funding is also being sought for the PSAMP, through the National Estuary Program and as line item funding in the federal budget, in the same manner in which Chesapeake Bay and the Great Lakes are funded. All federal funding alterna-

TABLE 5-1.
PUGET SOUND AMBIENT MONITORING PROGRAM
COST ESTIMATE BY PROGRAM TASK

TASK	IMPLEMENTING AGENCY	ONGOING ANNUAL PROGRAM COST	FTE's (ONGOING)[a]	STARTUP COSTS	FTE's FOR STARTUP[b]	EQUIPMENT FOR STARTUP[c]
SEDIMENT	Ecology	590,000[d]	0.5[d]	43,000[e]	0.5	8,000
WATER COLUMN	Ecology	565,000	6.4	211,000	1.2	128,000[f]
FISH	Fisheries	350,000	2.0	87,000	1.0	16,000[g]
SHELLFISH	DSHS	315,000	2.3	40,000	0.5	12,000[g]
BIRDS & MAMMALS	Wildlife	175,000	1.9	34,000	0.5	8,000[g]
NEARSHORE HABITAT	DNR	220,000	2.0	0[h]	0.0	0
FRESHWATER	Ecology	339,000	1.3	77,000	0.0	77,000[i]
RIVER MOUTHS	Ecology	382,000	0.4[d]	12,000	0.0	2,000
CITIZEN MONITORING	PSWQA	110,000	0.5[j]	50,000[k]	0.0	50,000[k]
PROGRAM MANAGEMENT	PSWQA	233,000	4.2	127,000[l]	0.0[m]	30,000
TOTAL		3,329,000	21.5	681,000	3.7	331,000

a. Cost of FTE's included in annual program cost
b. Cost of FTE's included in startup costs
c. Cost of Equipment included in startup costs
d. Costs represent consulting contract; FTE is for contract management
e. Most Sediment startup costs covered in 1988
f. Equipment includes purchase of CTD system, boat & trailer, vehicle
g. Purchase of computer equipment plus miscellaneous equipment
h. Start-up costs for nearshore habitat covered in 1988
i. Purchase of flow metering equipment, vehicle
j. Citizen Monitoring coordinator
k. Purchase of analytical equipment
l. Includes $100,000 for GIS development contract
m. Start-up costs for 1988 paid by EPA

tives are unlikely to be fulfilled in the next two to four years, however. In the short-term, funding of PSAMP will probably be at the state level.

PSAMP COST EFFICIENCIES

If monitoring data are collected in a systematic and coordinated manner, the available funding resources will be most efficiently used and the resulting description of the Sound, its resources, and associated pollution problems will be technically accurate.

The $3.3 million annual PSAMP cost estimate has been reduced by the elimination of duplicative efforts among existing agency programs, redirection of state agency monitoring efforts, and through the commitment of resources by federal, state and local jurisdictions. Cost savings (as well as educational benefits) are also proposed through the involvement of the public in collecting samples at many locations around the Sound.

The annual $3.3 million cost estimate for PSAMP can be reduced by $295,000 in current state program money, as detailed below:

* Ecology: $140,000 to Water Column Task; $105,000 to Rivers & Streams.
* Puget Sound Water Quality Authority (Authority): $50,000 to Citizens' Monitoring (through the public involvement and education fund).
* Total: $295,000

In addition, 1987-1989 funding from EPA will reduce planning and startup costs for PSAMP, specifically in the development of the central Puget Sound database, in coordination of the program, and in protocol development and characterization of nearshore habitat. $500,000 in state general fund money, made available due to the passage of the discharge permit fee bill in 1987, will be directed towards startup and baseline monitoring of sediments during 1988-1989.

Central coordination and management of PSAMP by Authority staff will ensure that the funds are used efficiently, that data are available to all water quality management agencies and the public, and that the accepted monitoring design is followed. Oversight and quality control by Authority staff will also ensure that the results of the program are acceptable to the scientific community.

The division of responsibility among state agencies for implementing the entire monitoring program is shown below:

* 57 percent to Ecology ($1.88 million).
* 10 percent to WDF ($350,000).
* 10 percent to DSHS ($315,000).
* Seven percent to DNR ($220,000).
* Five percent to Wildlife ($175,000).
* 10 percent to the Authority ($343,000).
* Total: $3.33 million.

COMPARISON WITH OTHER MONITORING PROGRAMS

The approximate $3.3 million a year cost estimate for PSAMP is less than estimates for similar monitoring programs elsewhere in the country. The two major programs already in existence are Chesapeake Bay and the Great Lakes.

Estimates of money spent on the Chesapeake Bay Monitoring Program, made by the Bay Liaison Office in Annapolis, Maryland, are approximately $10 million a year spent from federal sources (EPA and NOAA) and states (largely Maryland and Virginia, with some contribution by Pennsylvania). Additional moneys come from local jurisdictions, notably Washington, D.C. The state of Maryland alone spends between $3 and $4 million a year on monitoring its major tributaries to the Bay, with a comparable amount spent by Virginia. The states of Maryland and Virginia both appropriate funds for monitoring through special state legislation.

The Great Lakes International Surveillance Plan (GLISP) is a monitoring program which covers all five lakes and involves two federal governments, eight states and one province. According to an estimate by the International Joint Commission Great Lakes Institute, the U.S. Government spends $7 million a year. Each state provides funds to local jurisdictions to assist in monitoring activities. The cost of Great Lakes fisheries monitoring is not covered in this figure. Fisheries monitoring is coordinated by another international commission and funded separately by the federal, state and provincial governments.

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Appendix A. Quality Assurance/ Quality Control Plan

INTRODUCTION

The cornerstone of a well-run monitoring program is a reliable quality assurance/quality control (QA/QC) program. A QA/QC program ensures that data exhibit an acceptable level of quality and that the level of quality is properly documented. Following a well-organized, rigorous set of guidelines results in a data set which will produce defensible answers to management questions and will be accepted by scientific researchers.

It is essential that data quality be maintained throughout the process of field collection, lab analysis, data entry, and data retrieval. Consistency of collection, reporting, and formatting of similar data over time will be essential to analyzing trends in conditions in the Sound. Careful attention to consistency among different types of data will be essential to creating a complete and integrated picture of the Sound.

The purpose of this QA/QC document is to provide a framework for developing the QA/QC element of each monitoring task of PSAMP. It outlines the necessary components of a quality assurance program: sampling design and detailed work plan, responsible personnel, project archive, and computerized database.

Water column data are then used as an example to illustrate quality control procedures. This portion of the document outlines procedures that should be followed when samples are collected in the field, shipped to laboratories, and stored or analyzed within laboratories, and when data are received, reviewed, entered into a computer database, analyzed, and interpreted. This document is not intended to be exhaustive and leaves ample scope for detail particular to each monitoring task.

NECESSARY COMPONENTS OF A QUALITY ASSURANCE PROGRAM

Sampling Design and Detailed Work Plan

The first step in sampling design is to identify the question or questions to be answered by the study. Statistical analysis is used to determine how many samples must be taken in order to answer that question (or questions) with a stated level of certainty. By making certain assumptions about the nature of the environment, the required frequency and geographic extent of sampling can be determined. A text book on experimental design (e.g., Zar, 1984) will help in determining sampling design.

A detailed sampling plan should be developed from the sampling design. This sampling plan should describe the sampling design and should state study objectives in order of priority. It should also contain a field sampling plan, list of laboratory analytical requirements, and a data management plan.

Field sampling plan

The field sampling plan should include the following:

* Listing of the scientific party and the responsibilities of each member.
* Description of survey area, including background information and station locations.
* Vessel requirements (e.g., size, laboratory needs, sample storage needs).
* Location and availability of an alternate survey vessel.
* All special equipment needed for the cruise (e.g., camera, nets, walkie-talkies, radios).
* Listing of the variables to be measured in the field.
* Listing of information to be recorded in sampling logs and on field forms.
* Listing of the number of samples to be taken, variables to be measured, and the containers and preservatives needed for these samples.
* Location and number of all sample splits or QA/QC samples to be submitted with the field samples.
* Brief description of sampling methods, including station positioning technique, sampling devices, replication, and any special instructions.
* Procedures for automated data acquisition.
* Detailed cruise schedule.
* Sample storage and shipping procedures.
* Listing of laboratories to which samples should be shipped after cruise completion.

Laboratory analytical requirements

Laboratory analytical requirements should specify:

* Required analytical protocols, detection limits, and standard recoveries for each type of sample analysis.
* Planned procedures for data review.

Data management plan

The data management plan should contain the following:

* Description of the computerized database that will be used to store data.
* Listing of planned data analyses and statistical tests.
* Description of quality assurance procedures for data management.

Responsible Personnel

Chief scientist

A chief scientist should be appointed for each field program or cruise. He or she should thoroughly review the field sampling plan (including QA/QC criteria) before each cruise.

Each member of the scientific party should be aware of the study objectives and priorities in order to understand the impact that changes to the sampling plan, dictated by field conditions, may have on the overall goals of the cruise. After the sampling plan has been reviewed, contingency plans should be outlined. These plans should include potential problems and their solutions.

The captain of the survey vessel should be provided with a copy of the cruise plan to ensure that it is consistent with the equipment and capabilities of the vessel and to maximize communication between the vessel crew and the scientific party.

Data manager

Monitoring program data management will require several types of personnel, including computer systems analysts, computer programmers, data entry technicians, and a data manager. The data manager should have overall responsibility for ensuring data quality, and will work with scientific staff to ensure that high quality data are obtained and stored.

The data manager should:

* Work with technical staff and analytical laboratories to ensure that high quality data are available in proper formats.
* Act as the project quality assurance officer to ensure that data stored in the computerized database adequately reflect the results of technical evaluation.
* Ensure that those preparing or entering data into the computerized database understand and follow established procedures.
* Work with computer programmers to ensure that the computerized database performs as desired.
* Train and assist users of the computerized database.
* Maintain the security and integrity of paper and computer files.

Project Archive and Documentation

Field forms, laboratory data reports, and all quality assurance information collected as part of PSAMP should be stored and maintained by the responsible agency in a permanent project archive or library. All information collected during the monitoring program will not necessarily be stored in a computerized database. Any information not stored electronically should be available in the project archive and should be readily found from references in the monitoring database.

Computerized Database

Choice of system

Each participating agency should assess its needs and decide whether an existing computerized database can be used to store PSAMP data, or whether a new

database should be designed. The computerized database chosen should have the capability to provide answers to user's needs on an appropriate time-scale, and in an appropriate format.

If a new computerized database is to be developed, commercially available database management software (e.g., dBase III, and Rbase System V) should be considered. These systems provide many built-in data management capabilities. Relational databases provide the capability to store many different types of information in a logical format that enables information to be linked and joined in an infinite variety of ways for data analyses. A well-structured system will provide a means of asking different types of questions of the database using flexible, logical statements.

It may be necessary to use several different software packages to develop a computerized database to meet all agency needs. While database management software can perform certain types of data analysis, it is more efficient to develop programs that transfer selected data from databases to commercially available statistics and graphics packages than to try to program all of these capabilities into a database.

Each agency should also assess the availability of equipment to store the monitoring database and accommodate users. Consideration should be given to the amount of data to be stored, the number of expected users, the expected frequency of use, and the number of simultaneous users the system should be able to accommodate.

A data dictionary will provide minimum documentation for the computerized database. The data dictionary should list all the information that the system is designed to store.

Data model

A data model is a specific representation of how information will be organized on a computer.

Computerized databases should be designed so that data are logically organized into files of related information. For example, metals data, bioassay results, and benthic invertebrate abundances should be stored in separate files and linked by common station and sample identifiers.

In order to enable PSAMP data collected by different agencies to be used together in a central database, data should be organized and identified by certain common elements such as monitoring program tasks, stations, and samples.

Monitoring Task - Specific field efforts for a monitoring task will have a unique identifier, composed of a task ID and a date. All sampling that takes place under this task, and all resulting data, should be labeled by this identifier.

Station - Each station where sampling occurs or environmental observations are made should be given a unique station identifier. All resulting data should be labeled with this station identifier.

A standard coordinate system should be used in identifying station locations. The use of the state plane coordinate system (SPC) is recommended as it is the state mapping standard, and because several state geographic information systems use SPC. Coordinates should be stored with sufficient accuracy to allow reoccupation of stations.

Sample - Each sample should be given a sample identifier. Each sample identifier should be unique within a monitoring task and at a monitoring station. The com-

bination of monitoring task ID, station ID, and sample ID will uniquely label a monitoring program sample. All resulting data should be labeled accordingly.

When observations are made at a station rather than a sample collected, use of a sample identifier is inappropriate. Data resulting from observations should be identified by the task ID, station ID, and date and time at which the observations are made.

The use of consistent sample and observation identifiers will allow different information from the same monitoring task to be combined for analytical purposes. For example, alkalinity values and metals concentrations could be combined for assessing compliance with water quality criteria, or benthic diversity could be correlated with phenol concentrations at a given station. Consistent and careful reporting of station locations and geographic identifiers for Puget Sound will enable data from different monitoring program components to be combined and analyzed.

QUALITY CONTROL PLAN FOR WATER COLUMN DATA

Introduction

Quality assurance/quality control procedures outlined in th Puget Sound Estuary Program (PSEP) protocols should be followed during PSAMP, whenever they are available. As there is no PSEP protocol for water column sampling, this document uses the PSAMP water column program as a case study.

The examples cited for types of sample collection, storage, transport, and analysis are often peculiar to water column studies, although there are analogues in other field studies. Sample tracking, data entry, verification, security, and computer system requirements are more generally applicable to all aspects of PSAMP. There has been no attempt made here to cover most of the data analysis and interpretation techniques likely to be used on PSAMP data; these will vary greatly among different portions of the program.

Field Sampling Preparation (or Laboratory Preparation)

For single day cruises, sampling preparation should be carried out early on the day before scheduled sampling. For cruises of longer duration, preparation should start several days before the planned embarkation. This allows time for maintenance, minor repairs and the purchase of missing or spare parts without changing the proposed sampling schedule. Sampling preparation should include the following:

Checklists

A detailed list of all equipment, gear, and supplies should be made for each task or type of sampling. Copies of the list should be available so that a new one can be used before each sampling date. Individual items should be checked off as they are packed or readied.

Sample bottle preparation and cleaning of gear

All sample bottles must be cleaned or prepared in a manner consistent with the type of sample to be collected. For example, preserved phytoplankton, dissolved oxygen, and conductivity (salinity) bottles need only be rinsed, while bottles for chlorophyll and nutrient analyses should be acid washed to cut down on bacterial action. New plastic bottles used for live analyses (like chlorophyll) should be seasoned to decrease plastic leaching. Any preservatives may be added to the bottles at this

point. All bottles should be permanently labelled, with additional information to be added in the field.

All sampling gear should be cleaned each time it is used, preferably rinsed with tap water after sampling is completed (in marine waters this is an absolute must). Hydrographic bottles should be acid washed periodically. Electrodes should always be rinsed with distilled water before and after use. Intermediate sampling vessels (between hydro bottle and sample bottle) should be washed or rinsed before each field sampling.

Laboratory vessels should be rigorously cleaned with acid and/or soap and water. Hydrochloric (muriatic) acid diluted to 20 to 50 percent is sufficient to clean most lab and field glassware and sample bottles. If contamination by toxic organics is suspected, chromic acid washing may be necessary. Alternately, the vessels (particularly plastics) should be thrown out. Plastic sample bottles are cheap compared to field sampling and analysis costs. Sample quality can be jeopardized in order to save a few cents.

Equipment and maintenance

Before each sampling date electronic equipment must be checked against external standards and any internal standardization procedures (red-lining, etc.) followed. Any carry-along standard solutions must be fresh (and the renewal date recorded on the container) and clean-looking. Batteries and/or charge levels must be checked and replaced or charged as needed. It is not a good idea to charge an instrument to full capacity unless it needs it, as rechargeable battery packs lose their "memory" for a full charge if never allowed to drain. Extra batteries, replacement battery packs, and chargers should always be carried along on sampling trips. Any routine instrument maintenance should be done (as indicated by the equipment log) and any damage repaired (if possible) at once, before it gets worse.

Periodically instruments will have to be sent to the manufacturer for repair or calibration; spares must be located for purchase or rent. Spare instruments and/or supplies for more laborious hand analysis or sampling must always be available on the vessel unless samples can be returned to shore for analysis without compromising sample quality.

Data recording

Log forms should be prepared for recording information in the field. A separate station identification form should be used to identify, number, and locate each station occupied. Other forms should be used to record required information about samples and different types of data. Example forms include:

* A hydrographic log form for water column sampling, detailing station number, date, time, and depth of observations, with columns to record values for each variable measured.

* A sampling log form detailing station number, date, time, and depth of samples taken with columns to record bottle numbers for each sample.

* Streamflow log with station number, date, time, flow, etc.

Header information on each log form must include date, time, station number, weather, and observer. A field notebook should be prepared for use as a "diary" or recording of non-standardized, unusual, or interesting data, as further discussed in the section on field sampling (below). Plenty of copies of each log form as well as clipboards, pencils, and erasers should be available. Staff should be trained in the proper use of the field forms prior to the actual sampling event.

Equipment log

A log book should be kept for all electronic equipment and should be handy for field sampling preparation. The book should have a separate section (page) for each instrument and should detail the manufacturer, model, and serial number of the instrument and any associated sensors. Suggested maintenance and recalibration intervals should also be noted. Columns are needed for date, damage/problem noted, repairs performed (including batteries replaced, solutions renewed), the observer's name, and miscellaneous information such as returns to the manufacturer for repair and calibration, calibration problems, suspected problems, etc.

Field Sampling

Sampling protocols

Field sampling should be carried out in as consistent a manner as possible between sampling dates and between observers. In order to achieve this, field training courses for all field personnel must be held. In addition, a step by step protocol should be available for each type of sampling, protected in a plastic envelope. Well-trained observers will rarely refer to the field protocol sheet, while less experienced observers will find it helpful. When a member of the scientific party has any doubts about a particular procedure, referring to the protocol should clarify the situation.

Positioning

Accurate navigation is essential to ensuring that stations can be located and reoccupied with confidence. The station positioning system selected for a field program should meet all accuracy requirements for the program and should provide highly repeatable measurements.

Information on positioning water column stations should be printed and available along with the sampling protocol, including methods and fixes for visual sightings as well as navigational equipment fixes.

Calibration samples

Electronic instruments produce consistent but relative readings and must be calibrated to real-life samples in order to accurately measure water quality or other parameters. When a new instrument is purchased, and periodically thereafter, a complete calibration must be carried out, which includes:

* Linearity of scale (i.e., does tripling the concentration triple the reading? If an instrument is linear on the coarsest scale, it will be linear on all others.)
* Scale factor (i.e., is the 10X scale exactly 10 times the 1X?).
* Calibration constant (i.e., the constant by which the meter reading is to be multiplied should be verified with samples over the entire detection range).

Additionally, at least one field calibration sample should be collected for each electronic sensor each time field sampling takes place. Table A-1 outlines the types of samples to be collected.

Calibration of a highly specialized electronic instrument, such as a CTD, requires that calibration samples be collected regularly, as for any other instrument. In addition, the actual calibration of the electronic signal should be carried out by a trained electronics technician and/or someone familiar with CTD output.

Replicates

In order to measure the precision of an analytical technique, replicate samples must be collected and analyzed and a range of values calculated.

Replicate samples may be collected on each sampling trip or concentrated in a small number of trips, provided the collection is spread over the year and five to 10 percent of the total samples collected are replicates. The number of replicates necessary to determine the precision of a technique varies with the natural variability of the parameter and must be tempered by time and money available for analysis. For example, biological variability is far greater (in general) than chemical or physical variability, so more replicates are required for chlorophyll than for nutrients or temperature. It is preferred that three or more replicates be collected, in order to calculate confidence intervals. If this is not practical, two will suffice. Table A-2 gives a theoretical replicate sampling design for a water column study.

TABLE A-1: PARAMETERS AND TYPES OF CALIBRATION SAMPLES

Dissolved Oxygen: Winkler O_2, drawn first from sample bottle using proper technique, pickled in field, analyzed by titration in lab

Conductivity: Collected in glass bottle with tight stopper, analyzed by conductivity bridge in lab

Temperature: Verified in field with reversing thermometer on sample bottles

pH: Check against CO_2 and alkalinity measurements made in field

Turbidity: Very difficult sample to calibrate - rely on good periodic lab calibration and secondary (carry along) standard

Streamflow: Manufacturer calibrated

Field notebook

Field forms (as discussed in the section on field preparation) should be kept religiously as they are the only clue as to what actually happened. A diary or notebook should also be used in the field to record observations about weather, unusual sightings, and other comments. At a minimum, the field notebook should document:

* Date and time of starting work.
* Names of field team members.
* Purpose of proposed sampling effort.
* Description of sampling site, including information on any photographs taken.
* Location of sampling site.
* Details of actual sampling effort, particularly deviations from standard operating procedures.
* Field observations.
* Type and number of sample bottles collected.

A hand-held tape recorder can take the place of the field notebook (but not the field forms!) and is helpful in recording further information the observer hasn't time to write down.

Automated data acquisition

Data that are acquired through the use of automated devices or through remote sensing will be received in digital form. These data may need to be subject to initial processing in the field to ensure that information is correctly labeled and identified, and to link the digital information with information noted on field forms or in the field notebook.

Sample labels

Sample labels must be waterproof and securely fastened to the outside and/or placed inside each sample container. Labels must contain the station number, sample number, preservation technique, date and time of collection, location of collection, and signature of the collector.

A consistent numbering system should be used for each sample throughout the sampling, analysis, quality assurance, and data entry process, so that information can be easily tracked back to original field logs or lab reports. The sample numbering scheme should identify the monitoring program component, the station, and the sample number.

Sample transport and holding

Samples must be transported to the laboratory as soon as possible after the end of sampling, under conditions which will not contribute to the breakdown of the samples, or allow for mistakes in sample identification. Similarly, if the samples are to be held for any appreciable time, they must be stored correctly. Table A-3 outlines the correct methods for the transport and the holding of samples. Documentation ensures that sample handling has been proper and serves as proof if questions arise later.

TABLE A-2: NUMBER AND SAMPLING FREQUENCY OF REPLICATE SAMPLES PER SAMPLING DEPTH (NUMBERS BASED ON 4 SAMPLING STATIONS)

PARAMETER	NO. OF REPLICATES	FREQUENCY
Chlorophyll	6	twice a year
Phaeopigments	3	quarterly
Nutrients	3	quarterly
Dissolved Oxygen	3	quarterly
Conductivity	3	twice a year
Temperature	3	twice a year
pH	3	quarterly
CO_2	3	quarterly
Alkalinity	3	quarterly
Secchi Disk Readings	3	twice a year
Chloride	3	twice a year

Cleanliness

Cleanliness is right next to consistency in importance. Sampling gear and sampling bottles must always be sparkling clean. Also, rinsing gear and bottles is necessary to ensure the removal of any previous sample or washing media. It has been shown scientifically that three rinses removes and replaces almost all (95 percent) of the previous liquid contaminant. Bottle caps should be rinsed as well.

Sample Follow-Up and Analysis

Preservation and storage of samples

All samples should be processed as soon as possible after sampling, not to exceed the time limits in Table A-4.

Transport to laboratory

Samples must be transported to the lab as soon as possible in the same manner as they have been held. That is, on ice for nutrients and chlorophyll and in the dark for dissolved oxygens and chlorophyll, etc.

Information archive

A proper flow of paper is essential to tracking data from the field, through lab analysis to their entry into the database. Field logs and notes should be copied immediately upon return from the field and stored in the project archive.

Sample tracking

A means of tracking the location and status of samples taken during each monitoring cruise should be developed, in order to determine when a data set is complete, or to resolve questions about missing or incomplete information. The tracking system should consist of paper logs, or should be part of the computerized database. A computerized tracking system could produce reports detailing the status of various samples and would be able to identify overdue or missing results.

A designated custodian should be responsible for all incoming samples at the laboratory including the following duties:

* Reception of samples.
* Sample tracking.
* Distribution of samples to different laboratories for analyses.
* Supervision of labeling, record keeping, data reduction, and data transcription.
* Storage and security of all samples, data, and documents.

The condition of all samples should be noted. All irregularities indicating that sample security or quality may have been jeopardized (e.g., evidence of tampering, loose lids, cracked jars) should be noted on the sample analysis request form and returned with other QA/QC information.

"Blind" replicates to laboratory

Replicates of each type of sample should be forwarded periodically to the laboratory without being identified as replicates. For this reason all sample bottles should be identified by a code number, not a distinguishing name. It is helpful to the lab, however, to indicate the approximate range of concentrations in the sample (i.e., high or low). Good replication by the commercial or in-house lab will instil further confidence in the validity of the data set.

Calibration of laboratory instruments

Laboratory instruments used by either a commercial or in-house lab must be fully calibrated when purchased and at least once a year thereafter, as outlined for field instruments above.

TABLE A-3
TRANSPORTATION & HOLDING OF FIELD SAMPLES

SAMPLE	TRANSPORTATION	HOLDING	REMARKS
Chlorophyll & Phaeopigments	Filter samples ASAP, dessicate filters and keep cool and dark OR transport water in dark, on ice and filter ASAP	Freeze filters in dessicator	Pigments are very light (and heat) labile. Also, subject to micro-zooplankton grazing
Nutrients	Carry on ice with preservative OR filter and freeze	Chill (or freeze)	Subject to bacterial action
Dissolved Oxygen	Keep in dark, especially until acidified	Keep in dark	Stable for about 2 weeks if acidified
Conductivity	No special precautions ---------->		
Chloride	No special precautions ---------->		
Phytoplankton Samples	Preserve with Lugol's or formalin to ~4%, keep in dark	Keep in dark	Some cells (diatoms) start to degrade in a few weeks
Zooplankton Samples	Preserve with buffered formalin to 4%	Keep in dark (not as critical as for phytoplankton)	Chitin dissolves eventually

Laboratory standardization and accuracy

Blanks and standards must be run with each batch of samples, when practical. Table A-5 summarizes the number of blanks and standards to be run with each type of water column sample, the detection limits, and the accuracy (the maximum percentage which acceptable standards can deviate from the actual value).

Laboratory replicates and blanks

Laboratory replicates should be run on at least five percent of all samples, and distilled water as well as reagent blanks should be run with each batch. If the blank exceeds twice the detection limit, additional blanks should be run until this level is reached.

Timetable for renewing standard solutions, reagents

Fresh chemicals must always be used for all laboratory analyses. Chemicals have varying lifetimes; the timetable on which they should be renewed must be ascertained from Standard Methods (1980), Strickland and Parsons (1980) or other appropriate sources. As a general rule, reactive agents should be replaced often (once a day to once a week), while standards and catalysts have longer shelflives (one week to one year). Appropriate storage (in the dark, refrigerated, or frozen) will extend the life of many chemicals.

Timely return of data from the laboratory

An ongoing monitoring program requires a quick turnaround of samples and data reports from the lab. The rapid return of data to the observer will allow him or her to make adjustments or corrections to the sampling program. Two weeks it not an unreasonable time for data from most lab analyses, although exceptions may occur. Contractual arrangements with both commercial and in-house laboratories should specify this timeframe.

Shipboard laboratory analysis

Depending upon the size and capabilities of the survey vessel, many environmental variables can be analyzed on board. In general, the laboratory procedures described in this document are applicable to both shipboard and land-based laboratories. Consistency is important in assuring that analytical results will be comparable regardless of where samples are analyzed.

TABLE A-4: TIME LIMITS ON STORAGE OF SAMPLES BEFORE ANALYSIS

SAMPLE	MAXIMUM STORAGE TIME
Chlorophyll	filter within 8 hours, filters can be held
Phaeopigments	for at least 2-4 weeks
Nutrients	preserved with acid - 1 week
	frozen - 1 month
Conductivity	stable indefinitely
Salinity	stable indefinitely
Chloride	stable indefinitely
Dissolved Oxygen	after acidification - 2 weeks
Phytoplankton	in dark, with preservative - at least 1 month
Zooplankton	with preservative - 3 months

Data Review

Review of laboratory procedures

Either a commercial or an in-house lab must be supervised to ensure that correct analytical procedures are followed and that proper calibration, standardization and renewal of chemicals is carried out. Once procedures have been set up the lab should run without difficulty and the supervisor need only check if problems arise (such as questionable data) or if new personnel take over the analyses. Standard curves for each analysis should be obtained from the lab periodically. Performance checks of the lab may reveal problems with poor technique or outdated chemicals. Accepted techniques for laboratory and field analysis are shown in Table A-6.

Precision

The precision of a technique is a measure of the agreement among individual measurements of the same property, or the reproducibility of the method. Replicates are run on each type of measurement to determine the precision. Table A-7 outlines the necessary precision which must be obtained for each type of water column measure. Data should be reviewed to determine if precision requirements were met.

Calculation of accuracy and precision

The accuracy of each analysis should be calculated following each standardization, and questionable data points dropped from the database. (For most types of analysis, this will already have been done by the lab.) Accuracy statistics are calcu-

TABLE A-5
LABORATORY STANDARDIZATION
PROCEDURES & MEASURES OF ACCURACY

TYPE OF SAMPLE	BLANKS	STANDARDS	DETECTION LIMIT	ACCURACY
Chlorophyll & Phaeopigments	1 Acetone blank per 10 samples (min) also, filter blank	No true* standards exist	.05 ug/l	± 10%
Total Phosporous & Ortho Phosporous	1 each per run of samples: - distilled water - w/reagents	2,5,10,50,100 & 200 ug/lP => using at least 4 at appropriate conc.	2.0 ug/l	± 5% => ≥ 10 ug/l ± 10% => ≥ 10 ug/ ± 5% => ≥ 5 ug/l
Nitrate	Same	10,20,50,100,500 & 1000 ug/lN => at least 4	10 ug/l	± 10%
Nitrite	Same	5,10,20,50 & 100 ug/l => at least 4	5 ug/l	± 20%
Kjeldahl Nitrogen	Same	150,300,1000,3000 & 5000 ug/lN => at least 4	150 ug/l	± 35%
Conductivity Salinity Chloride	1 blank per sample run		.01%	± 8%
Dissolved Oxygen	4 blanks per **	.1,1,5,10,20,30		
pH		2-4 commercially available standards	.05 pH units	± .1 pH unit
Secchi Depth	-		.1m	
Temperature		Test thermometer with 0°C, 100°C water OR have thermometers calibrated	.1°C	± 5%

*EPA sells a "calibration standard" for chlorophyll which can be a useful check, but is not practical to use regularly

**A good mean blank must be obtained before sample analysis, with less than 1% spread in values.

lated as percent recovery of multiple concentrations of a spike for each standardization period as follows:

$$P_i = \frac{A_i - B_i}{T_i}$$

where P_i = Percent Recovery

A_i = Analytical results of spiked sample

B_i = Background level determined by separate analysis of unspiked sample

T_i = known True value of the spike

The mean and standard deviation of percent recovery can be calculated as a measure of accuracy over a time period:

$$\overline{P_i} = 1/n \sum_{i=1}^{n} P_i \qquad \text{and} \qquad S(P_i) = \sqrt{\frac{\sum_{i=1}^{n} (P_i - \overline{P_i})^2}{n-1}}$$

Similarly, the precision of each replicate sample run should be calculated and outlying data discarded. In most cases, only the mean of the replicates will be entered into the database.

Basic precision statistics are calculated for each set of three or more replicates as mean and standard deviation:

$$\overline{X} = \frac{\sum_{i=1}^{n} X_i}{n} \qquad S_i = \sqrt{\frac{\sum X_i^2 - \frac{(\sum X_i)^2}{n}}{n-1}}$$

If only two replicates are available, the mean is calculated along with the range:

$$R = \overline{X_1} - \overline{X_2}$$

Summary precision statistics become considerably more complicated to calculate, because the method is dependent on the relationship between the precision and the concentration range of the replicates. Should the need arise to calculate summary precision statistics, a statistical textbook or EPA's document on calculation of data quality indicators (EPA, 1983) should be consulted.

Checks on plankton identification and plant biomass analyses

Samples which cannot be checked for accuracy, such as phytoplankton, zooplankton identification, and aquatic plant biomass, can be checked for precision (i.e., variability in repeated estimates). Replicate samples will aid in determining a precision estimate, but error estimates for subsampling and difference between observers must also be accounted for. Subsampling error should be estimated periodically by subsampling replicates. Between observer error is estimated by having each observer count the same field (dish) of plankton or estimate the same area of plant cover. Essentially, a nested-ANOVA design is followed.

Identification errors can be reduced by holding mini-workshops where knowledgeable individuals verify the identification of plants and animals. Museum samples can greatly aid in the identification of aquatic macrophytes and macrozooplankton. Taxonomic keys should be available to aid in identification as well. Precision of benthic invertebrate identification should be reviewed in the same manner.

Computerizing QA/QC information

Even though all quality assurance information need not be entered into the computerized database, the database should provide sufficient information to judge the general quality of the data. Information stored should include:

* The units in which data are stored.
* A description of methods used to collect, process, and analyze samples. (Codes can be used instead of descriptors.)
* Standard data qualifiers to indicate the quality of the data value reported.
* Adequate references to enable a user to locate original sources of data in the project library.

TABLE A-6: ACCEPTABLE METHODS FOR LABORATORY ANALYSIS OF FRESHWATER SAMPLES

PARAMETER	METHOD
Chlorophyll	Strickland & Parsons (1968)
Phaeopigments	(spectrophotometric method)
Total phosphorus	Standard Methods (1980) (ascorbic acid or stannous chloride method)
Soluble reactive phosphorus	Standard Methods (1980) (ascorbic acid or stannous chloride method)
Nitrate	Standard Methods (1980)
Nitrite	Standard Methods (1980)
Ammonia	Standard Methods (1980) (Phenate method)
Organic Nitrogen (Kjeldahl)	Standard Methods (1980)
Dissolved Oxygen	Winkler method, or standard methods (1980) electrode method
pH	Standard Methods (1980) (membrane electrode method)
Chloride	Standard Methods (1980)
Conductivity	Standard Methods

Data Entry and Verification

Data entry

Data from field forms and analytical laboratories can be entered directly from field forms and lab reports into the computerized database, provided that they have been reviewed for completeness by the technical staff and the data manager. During this review, questionable values, data qualifiers, or incorrectly reported data can be adjusted or removed from the data set.

Data entry forms can be designed to match the field forms and laboratory reporting forms. Otherwise, data will need to be transferred to new forms that match the entry screens.

All data entry and verification should be carried out by trained operators.

TABLE A-7
PRECISION LIMITS

TYPE OF SAMPLE	PRECISION	TYPE OF SAMPLE	PRECISION
Chlorophyll & Phaeopigment	± 10%	pH	± .1 pH unit
Total Phosphorus & Orthophosphorus	± 5% => ≥ 10 ug/l ± 10% => ≥ 10 ug/l ± 20% => ≥ 5 ug/l	Secchi disc depth Temperature	± 10% ± 5%
Nitrate	± 20%	Phytoplankton species identification	± 20%
Ammonia	± 10%	Zooplankton species identification	± 25%
Kjeldahl Nitrogen	± 35%	Aquatic plant cover	± 20%
Conductivity Chloride	± 8%	Streamflow	± 15%
Dissolved Oxygen	± 8%	Fecal Coliforms	± 25%

Data verification

All information entered into the computerized database should be verified to ensure that data are complete and accurate, that valid codes are used and that data are labeled with correct program component, station, and sample numbers. Computer programs may be employed to conduct these checks.

Data should be printed out and visually verified by someone other than the entry operator. Alternative methods of verification include double entry and identification of values outside acceptable ranges. Inaccurate entries should be noted and corrected as soon as possible. Incorrect printouts of information should be destroyed, and should not be used for data analysis.

Digital data

Data may also be received in digital form (e.g., the data from CTD measurements). These data will need to be reduced and reformatted to be included in the computerized database. Some laboratories may have the capability to transmit data in electronic form to agencies. Such transmissions should not take the place of the laboratory providing formal paper data reports, but can save the substantial time and money required to reenter the data into the agency system.

Electronic data may be received from the laboratory on floppy disk or by modem over telephone lines. If electronic transmission is used, software that contains means of checking the accuracy and completeness of such transmission should be used (e.g., Crosstalk XVI). Agencies will need to define acceptable data transfer formats, ensure that adequate data verification is performed when data are first entered, and develop procedures to load data into the computerized database and check the accuracy and completeness of data received.

Availability of data

Any data entered into the computerized system should not be available for use until all errors or discrepancies found have been corrected. Such a restriction can be implemented in a variety of ways: for example, by entering data into temporary files that are later loaded into a permanent database for use, or by labeling data that have been verified, and permitting only those data to be included in reports.

Data security

The database management system and procedures set up to manage monitoring data should provide adequate capabilities for ensuring data security, recording changes to information, and preventing accidental loss of information. Security procedures are necessary for users to feel comfortable with the quality and completeness of information stored in the computer.

The computerized database should be set up so that access to certain kinds of functions can be controlled. Some users should be authorized only to retrieve data from the system, while others should be able to add, edit, or delete data. Changes made to data should be recorded, along with the identity of the editor, and the date that changes were made.

The database should be protected against unauthorized or accidental deletion with regularly-made backup copies. These copies will enable recovery of information accidentally damaged or destroyed by human error or equipment failure. Copies of files should be made as often as the contents of files change.

Copies of all data files should be maintained offsite from the main storage facility to guard against loss of the database through fire or other disaster. These files should also be updated on a regular basis.

Data Transfer

Information in each agency's monitoring program database should be transferred to the central PSAMP database as soon as data from a monitoring event have been entered and verified.

The MMC will develop and recommend formats for the transfer of data from agency databases into the central PSAMP database. This format will specify the order and contents of files created to transfer the information for each data type that is listed in Appendix B. These formats will be designed as convenient transfer formats and not primarily as formats for the storage and use of data. Agencies should develop programs to translate data from their databases into this format. A translation program will be used to load data into the central database as well.

The data transfer format will specify that particular data identifiers (monitoring task, station, and sample), codes, data qualifiers, and units be used. Agencies developing new systems to accommodate monitoring data may wish to consider the use of these codes in their systems. Otherwise, programs will be needed to translate one set of codes into another, which may potentially create problems.

Codes

The standard format for transferring data from monitoring databases to the central database will require data to be reported using certain codes. National Oceanographic Data Center (NODC) codes will be used whenever possible in the development of the data transfer format.

Units

Data should be transferred to the central database in standard units. These units are presented in Table A-8. Agencies should consider storing data in these standard

units in their data systems, to facilitate comparisons of environmental data collected from many different programs.

Methods

The MMC will develop a set of codes used to describe methods of sample collection, preparation, and analysis for all pertinent types of data.

Qualifiers

Standard data qualifiers should be used with all data to indicate the quality of the data value reported. A list of qualifiers to be used in the transfer of data to the central database will be developed and maintained by the MMC. Agencies should consider the compatibility of their qualifier systems with the recommended system to avoid confusion in interpreting data from different databases. Data reports that present data qualifiers should always provide a key to the meaning of the qualifiers.

Data quality levels

The MMC may develop criteria for levels of data quality to be used to label data from the program. These levels will broadly categorize data quality and will be designed to provide guidance on appropriate data uses. For example, a data quality level of "three" might mean that certain key information about the data (e.g., sampling gear or analysis method) is not available. A data quality level of "two" might indicate that the information is available but that the accuracy, precision or reliability of the data do not meet certain criteria. A data quality level of "one" would identify data that meet the highest data quality standards.

Data Analysis and Reporting

Control of data quality should continue through data analysis, interpretation, and reporting. Information should be packaged and displayed in as correct and representative a manner as possible. Ideally, a report should answer the statistical questions that prompted the study design, characterize the ecosystem in terms of the parameters measured and their variability and trends over time, and note correlations or interactions between parameters.

Sources of information

Since the computerized database will be the source of accurate, quality-assured information, all data used for reports and analyses should be retrieved directly from the database. All data retrievals should be dated and clearly labeled and identified. Tables of information from the database can be incorporated directly into project reports by transferring files into word-processing software.

Any individual using data for analysis should understand what information is available and what level of data quality is appropriate for his or her analysis.

Standard data manipulations

Certain types of data analysis should be performed on all data. Exceptions occur, of course, when there are insufficient data to calculate measures of variability. These analyses include the calculation of mean ($\bar{x}$), standard deviation (s) and the range of values.

Parameters should be plotted over time in order to spot unlikely trends in data, questionable spikes, and so on. This form of trend analysis, and calculated means and variances, constitute a vital check on the data quality and can, by careful review, point out electronic instrument drift, data entry errors, and systematic errors. This form of overview provides the best system audit possible.

Timely data tabulation and analysis will aid in evaluating monitoring effectiveness, and may lead to redesign or redirection of monitoring efforts.

Reporting formats

Tables of data should always indicate the units in which data are reported, and the meaning of any codes or qualifiers used with the data. Consistent and correct units should be used throughout all data tabulation, analysis, and reporting. The cgs system is the internationally accepted one, and should be followed at all times. Table A-8 details the units used for many monitoring program parameters.

TABLE A-8: UNITS TO BE USED IN ALL DATA REPORTING

PARAMETER	UNITS REPORTED
WATER QUALITY	
Chlorophyll/Phaeopigments	ug/l or mg/m^3
Nitrogen and Phosphorus (various forms)	ug/l or mg/m^{3*}
Dissolved Oxygen	mg/l**
pH	pH units
Conductivity	millimhos
Salinity/Chloride	‰
Biomass (Plankton or Macrophyte)	ug/l or g/m^3
Streamflow	m^3/sec
Nutrient Load	kg/time
Temperature	oC
Fecal coliform bacteria	MPN
Enterococci	MPN
Metals	ug/l
Organics	ug/l
SEDIMENT	
Metals	mg/kg dry weight
Organics	ug/kg dry weight
Grain size	% by phi class
Total Organic Carbon	% dry weight
Nitrogen	% dry weight
Free sulfide	mg/kg dry weight
FISH TISSUE	
Metals	mg/kg wet weight
Organics	ug/kg wet weight
Lipid	mg/kg wet weight

* In marine waters, usually reported as ug-at/l

**In marine waters, often reported as ml/l

Documentation of analyses

The appropriate tests, computer programs, assumptions, or constants used for an analysis should be documented and stored in the project archive so that it can be consulted should any question about analysis arise.

QA/QC Audits

Overall quality assurance and quality control can be summarized as the results of performance and systems audits.

Performance audits take place at the level of field collection, lab analysis, keypunching, and data analysis. The results of the audits qualitatively documents the level of confidence of each part of the procedure.

Systems audits qualitatively measure the overall reliability of the system, as the various parts interact, and is measured at the time of standard data analysis.

Responsible agencies will provide quality assurance audits of monitoring data in accordance with appropriate PSEP protocols.

Appendix B. Analyses to be Conducted on Data Collected under PSAMP

ANALYSES TO BE CONDUCTED ON DATA COLLECTED UNDER
THE PUGET SOUND AMBIENT MONITORING PROGRAM (PSAMP)

ANALYSES	TO BE INCLUDED IN: ANNUAL MONITORING REPORTS	SPECIAL REPORTS
MONITORING TASK: SEDIMENT TRIAD		
Sediment Chemistry/Conventionals/Grain Size		
Effect of QA results on data quality	A	
Listings of chemical concentrations grouped by station, area (e.g., embayment)	A	
Listing of results combined into major groups (e.g., Total Low MW PAH, % sand)	A	
Calculation of concentrations normalized to total organic carbon or % fines	A	
Calculation of appropriate summary statistics	A	
Graphic presentations of data and summary statistics (e.g., bar charts)	D	G
Statistical comparisons of differences in concentrations among areas	A	S,G
Identification of values exceeding Puget Sound AETs	A	S
Display of elevation of concentrations above appropriate reference station concentrations	D	S
Special graphic presentation of grain size results (e.g. Shepard diagrams)	D	S
Correlations among selected chemicals/variables (e.g., lead vs. copper)	D	S
Display of temporal changes in concentrations at stations	T	S,G
Statistical analysis of temporal changes in concentrations	T	S,G
Creation of maps of sediment texture and toc		G
Factor analysis	D	S
Bioassay		
Listings of individual results for samples and controls by bioassay type, area	A	
Comparisons of test mortality with positive and negative control sample results	A	
Effect of QA results on data quality	A	
Calculation of appropriate summary statistics	A	
Graphic presentations of data and summary statistics	D	G
Statistical comparison with appropriate reference area	A	S,G
Statistical comparisons of bioassay results among stations, areas	A	S,G
Statistical analysis of temporal changes in bioassay results	T	S,G
Correlation among results of different bioassays	D	S,M

ANALYSES TO BE CONDUCTED ON DATA COLLECTED UNDER
THE PUGET SOUND AMBIENT MONITORING PROGRAM (PSAMP)

ANALYSES	TO BE INCLUDED IN: ANNUAL MONITORING REPORTS	SPECIAL REPORTS
Benthic Invertebrates		
Effect of QA results on data quality	A	
Listings of abundance for each taxon in each replicate sample	D	
Calculation of summary statistics for each replicate sample (total abundance, total taxa, numbers in each major taxonomic group, selected species, diversity, abundances of pollutant tolerant, pollutant sensitive, and opportunistic species)	A	
Calculation of summary statistics by station	A	S,G
Calculation of summary statistics on a per square meter basis	A	
Graphic presentations of data and summary statistics	A	G
Statistical comparison with appropriate reference area	D	S
Statistical comparisons of results among stations, areas	A	S,G
Cluster analysis to characterize Puget Sound communities	D	S
Statistical analysis of temporal changes in results	T	S,G
Overall Analyses		
Correlation of bioassay results at a station with selected sediment concentrations	D	S,G
Correlations of benthic summary statistics with selected sediment concentrations	D	S,G
Calculation of new AETs for Puget Sound		S*
Identification of problem areas/need for intensive study	D	G
Creation of maps displaying monitoring results		G
Correlation among results of different bioassays		M
Analysis of monitoring effectiveness		M

ANALYSES TO BE CONDUCTED ON DATA COLLECTED UNDER
THE PUGET SOUND AMBIENT MONITORING PROGRAM (PSAMP)

ANALYSES	TO BE INCLUDED IN: ANNUAL MONITORING REPORTS	SPECIAL REPORTS
MONITORING TASK:WATER COLUMN		
CTD data		
Effect of QA results on data quality	A	
Listings of data by depth (in 1 meter intervals) by area	D	
Listing of CTD data integrated over same intervals as nutrient data	A	
Vertical plots: data vs. depth	A	
Horizontal plots of data across areas and with depth	D	S
Plots of changes in values over the year	A	S,G
Plots of changes in values from year to year	T	S,G
Other graphic presentations of data and summary statistics	D	S,G
Solstice sampling		
Effect of QA results on data quality	A	
Listings of results at each of 2 integrated depth intervals by area	A	
Calculation of mean and variation in variables (e.g., moving average)	A	
Graphic display of values across areas and with depth	A	S,G
Statistical comparison of grouped values among areas	D	S
Plots of changes in values over sampling period	A	S,G
Analysis of trends in grouped values within a year	A	
Plots of changes in values from year to year	T	S,G
Analysis of trends in grouped values from year to year	T	S,G
Other graphic presentations of data and summary statistics	D	S,G
Other water column (nutrient, chlorophyll)		
Effect of QA results on data quality	A	
Listings of results at each of 2 integrated depth intervals by area	A	
Vertical plots: data vs. depth	A	
Horizontal plots of data across areas and with depth	A	
Plots of changes in values over a year	A	
Plots of changes in values from year to year	T	S,G

ANALYSES TO BE CONDUCTED ON DATA COLLECTED UNDER
THE PUGET SOUND AMBIENT MONITORING PROGRAM (PSAMP)

ANALYSES	TO BE INCLUDED IN: ANNUAL MONITORING REPORTS	SPECIAL REPORTS
Comparison of data to classifications or standards	D	G
Other graphic presentations of data and summary statistics	D	S,G
Integrated analysis		
Correlation among selected variables (e.g., nutrient concentrations and phytoplankton)	D	S
Time-series analysis		S
Identification of problem areas/ need for intensive survey	D	G
Relationship of results to demography, compliance data, sources	D	G
Creation of maps of monitoring results		G

ANALYSES TO BE CONDUCTED ON DATA COLLECTED UNDER
THE PUGET SOUND AMBIENT MONITORING PROGRAM (PSAMP)

ANALYSES	TO BE INCLUDED IN: ANNUAL MONITORING REPORTS	SPECIAL REPORTS
MONITORING TASK: FISH		
Bioaccumulation		
Listings of characteristics of fish examined by station, area	D	
Summaries of characteristics of fish examined	A	
Effect of QA results on data quality	A	
Listings of chemical concentrations by station, area	A	
Listing of results combined into major groups (e.g., Total Low MW PAH)	A	
Calculation of concentrations normalized to total lipid content	A	
Calculation of appropriate summary statistics	A	
Statistical comparisons of differences in concentrations among stations	A	S,G
Statistical comparison with appropriate reference areas	A	S,G
Statistical comparisons of differences in concentrations among areas	A	S,G
Display of temporal changes in concentrations at stations	T	G
Statistical analysis of temporal changes in concentrations	T	S,G
Graphic presentations of data and summary statistics	D	G
Correlations among selected chemical concentrations	D	S
Comparison with FDA consumption guidelines	D	G
Comparison of differences among species	D	S,G,M
Pathology		
Listings of characteristics of fish examined (including external pathology) by station, area	D	
Summaries of characteristics of fish examined	A	
Effect of QA results on data quality	A	
Listings of number and frequency of occurrence of various lesions and conditions	A	
Listings of number and frequency of occurrence of lesions combined into major groups	A	
Listings of numbers of fish with one or more lesion by station	D	
Graphic presentations of data and summary statistics	D	G
Relationship of incidence of lesions to age, sex, length, weight	A	S
Relationship of external gross pathology to lesion occurrence	D	S
Comparisons of differences in frequency of major lesion types with reference stations	A	S,G
Display of temporal changes in lesion occurrence	T	G

ANALYSES TO BE CONDUCTED ON DATA COLLECTED UNDER
THE PUGET SOUND AMBIENT MONITORING PROGRAM (PSAMP)

ANALYSES	TO BE INCLUDED IN: ANNUAL MONITORING REPORTS	SPECIAL REPORTS
Statistical analysis of temporal changes in frequency of major lesion types	T	S,G
Fisheries Harvest and Stock Assessment		
Presentation of statistics for recreational and commercial catch for selected species	D	G
Presentation of statistics for population abundances of selected species	D	G
Analysis of temporal changes in CPUE	D	G
Graphic presentations of data and summary statistics (e.g., bar charts)	D	G
Integrated analyses		
Creation of maps displaying monitoring results		G
Identification of problem areas/ need for intensive survey	D	G
Human health risk assessment		S
Analysis of differences in chemical concentrations in fish with and without lesions	D	S
Correlations of lesion frequency and chemical concentrations	D	S
Discussion of relationship of lesion occurrence to fish harvest	D	G
Discussion of relationship of chemical contamination with fisheries harvest data	D	G

ANALYSES TO BE CONDUCTED ON DATA COLLECTED UNDER
THE PUGET SOUND AMBIENT MONITORING PROGRAM (PSAMP)

ANALYSES	TO BE INCLUDED IN: ANNUAL MONITORING REPORTS	SPECIAL REPORTS
MONITORING TASK: SHELLFISH		
Abundance		
Listings of the abundance of each species in cores	D	
Summaries of population characteristics of each species	A	
Graphic presentations of data and summary statistics	D	G
Statistical comparisons of species abundance and characteristics by station and area	A	S,G
Statistical analysis of temporal changes in abundance, age, and size	T	S,G
Cluster analysis to characterize communities		S
Pathogen indicators in water		
Effect of QA results on data quality	A	
Listings of pathogen concentrations by station, area	A	
Graphic presentations of data and summary statistics	D	G
Statistical comparisons of difference in pathogen concentrations among areas	A	S,G
Statistical analysis of temporal changes in pathogen concentrations	T	S,G
Correlations with PSP or pathogens found in shellfish	A	S
Identification of problem areas	D	G
Bioaccumulation		
Listings of characteristics of class composited	D	
Summaries of characteristics of class composited	A	
Effect of QA results on data quality	A	
Listings of chemical concentrations grouped by station, area	A	
Listing of results combined into major groups (e.g., Total Low MW PAH)	A	
Calculation of concentrations normalized to total lipid content	A	
Calculation of appropriate summary statistics	A	
Graphic presentations of data and summary statistics	D	G
Statistical comparisons of differences in concentrations among areas	A	S,G
Statistical comparison with appropriate reference area	A	S,G
Analysis of temporal changes in concentrations	T	S,G

ANALYSES TO BE CONDUCTED ON DATA COLLECTED UNDER
THE PUGET SOUND AMBIENT MONITORING PROGRAM (PSAMP)

ANALYSES	TO BE INCLUDED IN: ANNUAL MONITORING REPORTS	SPECIAL REPORTS
Correlations among selected chemicals/variables	D	S
Correlations with PSP concentrations	A	S
Comparison with FDA consumption guidelines	A	G
PSP		
Listings of characteristics of class composited	D	
Summaries of characteristics of class composited	A	
Effect of QA results on data quality	A	
Listings of concentration of PSP	A	
Graphic presentations of data and summary statistics	D	G
Comparison of occurrence or concentration of PSP with characteristics of class	D	S
Statistical comparisons of differences in concentrations among areas	A	S,G
Display of temporal changes in PSP concentration at a station	T	G
Statistical analysis of temporal changes in concentrations	T	S,G
Pathogens		
Listings of characteristics of class composited	D	
Summaries of characteristics of class composited	A	
Effect of QA results on data quality	A	
Listings of concentrations of pathogens	A	
Calculation of appropriate summary statistics	A	
Graphic presentations of data and summary statistics	D	
Correlation of pathogen concentration with characteristics of class	D	S
Statistical comparisons of differences in concentrations among areas	A	S,G
Display of temporal changes in pathogen concentration at a station	T	G
Statistical analysis of temporal changes in concentrations	T	S,G

ANALYSES TO BE CONDUCTED ON DATA COLLECTED UNDER
THE PUGET SOUND AMBIENT MONITORING PROGRAM (PSAMP)

ANALYSES	TO BE INCLUDED IN: ANNUAL MONITORING REPORTS	SPECIAL REPORTS
Integrated analysis		
Correlations among PSP and pathogens	A	S
Identification of problem areas	D	G
Creation of maps of monitoring results		G
Creation of map of areas (e.g., shellfish beds, closure areas)		G
Relationship of closure areas, sources to pathogens, PSP		S,G
Health risk assessment		S

ANALYSES TO BE CONDUCTED ON DATA COLLECTED UNDER
THE PUGET SOUND AMBIENT MONITORING PROGRAM (PSAMP)

ANALYSES	TO BE INCLUDED IN: ANNUAL MONITORING REPORTS	SPECIAL REPORTS
MONITORING TASK: MAMMALS		
Listings of abundances of seals by area	D	
Estimates of yearly abundance, reproductive success by area	A	
Graphic presentations of data and summary statistics	D	G
Comparisons of differences in abundance, reproduction among areas	A	S,G
Display of temporal changes in population characteristics in an area	T	G
Analysis of temporal changes in population characteristics	T	S,G
Toxics in dead seals		
Summary of characteristics of individual sampled	D	S
Effect of QA results on data quality	D	S
Listings of chemical concentrations, PSP (if available)	D	S
Listing of results combined into major groups (e.g., Total Low MW PAH)	D	S
Graphic presentations of data and summary statistics (e.g., bar charts)	D	S,G
Analyses of concentrations normalized to total lipid content	D	S
Comparison with levels known to cause harm to marine seals	D	S,G
MONITORING TASK: BIRDS		
Listing of occurence and abundance of selected species	A	
Presentation of statistics for wildfowl harvest	A	
Graphic presentations of data and summary statistics	D	G
Analysis of temporal changes in abundance, harvest	T	S,G
Identification of temporal and spatial trends in habitat use	T	S,G
Relationship to habitat changes	D	G

ANALYSES TO BE CONDUCTED ON DATA COLLECTED UNDER
THE PUGET SOUND AMBIENT MONITORING PROGRAM (PSAMP)

ANALYSES	TO BE INCLUDED IN: ANNUAL MONITORING REPORTS	SPECIAL REPORTS
MONITORING TASK: FRESHWATER		
Water Column - conventionals		
Effect of QA results on data quality	A	
Graphs of monthly flows at each station	A	
Summaries of wet and dry season flows at each station	A	G
Listing of data with depth by station, basin	D	
Vertical plots: data vs. depth	A	
Horizontal plots of data across areas and with depth	D	
Display of changes in values of variables with distance upstream in a basin	D	S,G
Display of temporal changes in values at stations	T	G
Metals		
Effect of QA results on data quality	A	
Listing of metals concentrations	D	
Calculation of appropriate summary statistics	A	
Graphic presentations of data and summary statistics	D	G
Comparisons of differences in concentrations among basins	A	S,G
Display of temporal changes in concentrations at stations	T	S,G
Analysis of temporal changes in concentrations	T	S,G
Correlations among selected chemicals/variables	D	S
Fish bioaccumulation		
Listings of characteristics of fish examined (including gross pathology) by station, area	D	
Summaries of characteristics of fish examined	A	
Effect of QA results on data quality	A	
Listings of chemical concentrations by station, basin	A	
Listing of results combined into major groups (e.g., Total Low MW PAH)	A	
Calculation of concentrations normalized to total lipid content	A	
Calculation of appropriate summary statistics	A	
Graphic presentations of data and summary statistics	D	G

ANALYSES TO BE CONDUCTED ON DATA COLLECTED UNDER
THE PUGET SOUND AMBIENT MONITORING PROGRAM (PSAMP)

ANALYSES	TO BE INCLUDED IN: ANNUAL MONITORING REPORTS	SPECIAL REPORTS
Statistical comparisons of differences in concentrations among stations, basins	A	S,G
Analysis of temporal changes in concentrations	T	S,G
Analysis of relationship between upstream and downstream concentrations	A	S,G
Correlations among selected chemicals/variables	D	S
Comparison with FDA consumption guidelines	A	G
Comparison of differences among species		S,M
Analysis of relationship of fish characteristics to chemical concentrations	D	S
Freshwater - Integrated Analyses		
Compliance with water quality standards	D	G
Identification of problem areas/ need for intensive survey	D	G
Correlation among selected variables (e.g., nutrient concentrations and phytoplankton)	D	S
Calculation of contaminant contributions for specific rivers, and total to Puget Sound		S
Time-series analysis		S
Relationship of results to demography, compliance data, sources		G
Creation of maps of monitoring results		G

ANALYSES TO BE CONDUCTED ON DATA COLLECTED UNDER
THE PUGET SOUND AMBIENT MONITORING PROGRAM (PSAMP)

ANALYSES	TO BE INCLUDED IN: ANNUAL MONITORING REPORTS	SPECIAL REPORTS
MONITORING TASK: RIVER MOUTHS		
River Mouths - Chemistry		
Effect of QA results on data quality	A	
Listings of chemical concentrations grouped by station, basin	A	
Listing of results combined into major groups (e.g., Total Low MW PAH, Z sand)	A	
Calculation of concentrations normalized to total organic carbon or Z fines	A	
Calculation of appropriate summary statistics	A	
Graphic presentations of data and summary statistics	D	G
Statistical comparisons of differences in concentrations among areas	A	S,G
Identification of values exceeding Puget Sound AETs	A	S
Display of elevation of concentrations above appropriate reference station concentrations	D	S
Special graphic presentation of grain size results (e.g. Shepard diagrams)	D	S
Correlations among selected chemicals/variables	D	S
Display of temporal changes in concentrations at stations	T	S,G
Analysis of temporal changes in concentrations	T	S,G
Creation of maps of sediment texture and toc		G
Factor analysis	D	S
River Mouths - Benthic Invertebrates		
Effect of QA results on data quality	A	
Listings of abundance for each taxon in each replicate sample	D	
Calculation of summary statistics for each replicate sample	A	
Calculation of summary statistics by station	A	
Calculation of summary statistics on a per square meter basis	A	S,G
Graphic presentations of data and summary statistics	D	G
Statistical comparison with appropriate reference area	D	S
Statistical comparisons of results among stations, areas	A	S,G
Cluster analysis to characterize Puget Sound communities	D	S
Statistical analysis of temporal changes in results	T	S,G

ANALYSES TO BE CONDUCTED ON DATA COLLECTED UNDER
THE PUGET SOUND AMBIENT MONITORING PROGRAM (PSAMP)

ANALYSES	TO BE INCLUDED IN: ANNUAL MONITORING REPORTS	SPECIAL REPORTS
River Mouths - Integrated Analyses		
Correlations of benthic summary statistics with selected sediment concentrations	D	S,G
Relationship of results in nearshore areas to results in main basin and embayments	D	G
Identification of problem areas/need for intensive study	D	G
Creation of maps displaying monitoring results		G
Analysis of monitoring effectiveness		M

ANALYSES TO BE CONDUCTED ON DATA COLLECTED UNDER
THE PUGET SOUND AMBIENT MONITORING PROGRAM (PSAMP)

ANALYSES	TO BE INCLUDED IN: ANNUAL MONITORING REPORTS	SPECIAL REPORTS
MONITORING TASK: NEARSHORE HABITAT		
Presentation of maps of aquatic habitat		G
Identification and discussion of changes in areal extent and nature of habitats	T	G
Calculation of total area in each habitat type grouped by area, county		G
Graphic presentations of data and summary statistics (e.g., bar charts)	A	S,G
MONITORING TASK: ADDITIONAL DATA		
Climate/Weather		
Analyses of short-term climatic changes on resources (e.g., fish abundance, river flow)		G
Analyses of long-term climatic changes on resources (e.g., fish abundance, river flow)		G
Graphic presentations of data and summary statistics (e.g., bar charts)		G
Aquaculture Sites and Yields		
Listing of types and extent of various aquaculture activities		G
Demographic and Socioeconomic Conditions		
Analysis of relationship between population growth and habitat changes		G
Analysis of relationship between population growth and contamination, biological effects		G

APPENDIX C.
DATA DICTIONARY

A list of the minimum data items to be stored in a computerized database for each component of the monitoring program is presented in this Appendix. The list is generally organized by the Puget Sound Ambient Monitoring Program Summary presented in the Executive Summary of this document. NOTE: This is not an exhaustive list of the data that should be collected, reported or analyzed, merely a list of items to be computerized.

For each monitoring program component, the appendix contains a list of data items by subject area and data type. The organization of data items into these types represents a first attempt at rationalizing the data using a relational data model. For some program components, data items are listed that will be the same for most or all types of data that will be collected within that component. For example, any of the fish data that is collected for PSAMP will need the data items represented under data types: STATIONS, and TRAWLS. The SUBJECT AREA line indicated the scope of the data items.

MONITORING PROGRAM TASK: **SEDIMENT**
SUBJECT AREA: **FOR ALL SEDIMENT SAMPLING**
DATA TYPE: **STATIONS**

MONITORING PROGRAM TASK
STATION NAME
RIVER OR EMBAYMENT WHERE STATION IS LOCATED
LOCATION (COORDINATES)
STATION TYPE
WATER DEPTH AT STATION
REFERENCE

MONITORING PROGRAM TASK: **SEDIMENT**
SUBJECT AREA: **FOR ALL SEDIMENT SAMPLING**
DATA TYPE: **SAMPLES**

MONITORING PROGRAM TASK
STATION NAME
SAMPLE NUMBER
DATE
TIME
GEAR USED TO TAKE SAMPLE (TYPE AND SIZE)
PENETRATION DEPTH
SAMPLE UPPER DEPTH IN SEDIMENTS
SAMPLE LOWER DEPTH IN SEDIMENTS
SAMPLE COLOR
SAMPLE ODOR
SAMPLE TEXTURE
PURPOSE OF SAMPLE

REFERENCE

MONITORING PROGRAM TASK: **SEDIMENT**
SUBJECT AREA: **SEDIMENT CHEMISTRY**
DATA TYPE: **METALS**

MONITORING PROGRAM TASK
STATION
SAMPLE NUMBER
METHOD USED TO PREPARE SAMPLE IN LAB
INSTRUMENTATION USED TO ANALYZE SAMPLE
METHOD USED TO PREPARE SAMPLE IN FIELD
ALUMINUM
ANTIMONY
ARSENIC
CADMIUM
CHROMIUM
COPPER
IRON
LEAD
MANGANESE
MERCURY
NICKEL
SILVER
ZINC
REFERENCE

MONITORING PROGRAM TASK: **SEDIMENT**
SUBJECT AREA: **SEDIMENT CHEMISTRY**
DATA TYPE: **ORGANICS**

MONITORING PROGRAM TASK
STATION
SAMPLE NUMBER
METHOD USED TO PREPARE SAMPLE IN LAB
INSTRUMENTATION USED TO ANALYZE SAMPLE
METHOD USED TO PREPARE SAMPLE IN FIELD
ACID EXTRACTABLE ORGANICS CONCENTRATIONS
BASE/NEUTRAL ORGANICS CONCENTRATIONS
PESTICIDE AND PCB CONCENTRATIONS
VOLATILES CONCENTRATIONS
REFERENCE

MONITORING PROGRAM TASK: **SEDIMENT**
SUBJECT AREA: **SEDIMENT CHEMISTRY**
DATA TYPE: **CONVENTIONALS**

MONITORING PROGRAM TASK
STATION
SAMPLE NUMBER
METHOD USED TO PREPARE SAMPLE IN FIELD
METHOD USED TO ANALYZE SAMPLE

PERCENT TOTAL ORGANIC CARBON
PERCENT SOLIDS
PERCENT TOTAL VOLATILE SOLIDS
PERCENT ROCKS
PERCENT SILT
PERCENT SAND
PERCENT CLAY
PERCENT FINES
SEDIMENT COMPOSITION (PERCENT BY PHI CLASS)
FREE SULFIDE CONCENTRATION
REDOX INTERFACE DEPTH
PORE WATER SALINITY
REFERENCE

MONITORING PROGRAM TASK: **SEDIMENT**
SUBJECT AREA: **BIOASSAYS**
DATA TYPE: **AMPHIPOD BIOASSAYS**

MONITORING PROGRAM TASK
STATION
SAMPLE NUMBER
REPLICATE NUMBER
METHODS
BIOASSAY DURATION
MORTALITY IN ASSOCIATED POSITIVE AND NEGATIVE CONTROL SAMPLES
SPECIES USED IN BIOASSAY
STATION WHERE SUBJECT SPECIMENS OBTAINED
CONCENTRATION OF ORIGINAL SAMPLE SUPERNATANT USED
PERCENT MORTALITY
REFERENCE
DATE ANALYSIS COMMENCED

MONITORING PROGRAM TASK: **SEDIMENT**
SUBJECT AREA: **BIOASSAYS**
DATA TYPE: **BIVALVE BIOASSAY**

MONITORING PROGRAM TASK
STATION
SAMPLE NUMBER
REPLICATE NUMBER
METHODS
SPECIES USED IN BIOASSAY
STATION NAME WHERE BIVALVES OBTAINED
BIOASSAY DURATION
CONCENTRATION OF ORIGINAL SAMPLE SUPERNATANT USED
MORTALITY IN ASSOCIATED POSITIVE AND NEGATIVE CONTROL SAMPLES
ABNORMALITY IN ASSOCIATED POSITIVE AND NEGATIVE CONTROL SAMPLES
PERCENT MORTALITY
PERCENT ABNORMALITY
REFERENCE

MONITORING PROGRAM TASK: **SEDIMENT**
SUBJECT AREA: **BIOASSAYS**
DATA TYPE: **MICROTOX BIOASSAY**

MONITORING PROGRAM TASK
STATION
SAMPLE NUMBER
REPLICATE NUMBER
BIOASSAY DURATION
CONCENTRATION OF ORIGINAL SAMPLE SUPERNATANT USED
PERCENT CHANGE IN ASSOCIATED POSITIVE AND NEGATIVE CONTROLS PERCENT
CHANGE IN LUMINESCENCE
DATE ANALYSIS COMMENCED
REFERENCE

SUBJECT AREA: **BENTHIC INVERTEBRATES**
DATA TYPE: **SAMPLE PREPARATION**

MONITORING PROGRAM TASK
STATION
SAMPLE NUMBER
SEIVE MESH SIZE
RELAXANTS USED
STAIN USED
WHEN SEIVED

MONITORING PROGRAM TASK: **SEDIMENT**
SUBJECT AREA: **BENTHIC INVERTEBRATES**
DATA TYPE: **ABUNDANCE**

MONITORING PROGRAM TASK
STATION
SAMPLE NUMBER
TAXA NAME
ABUNDANCE IN SAMPLE
REFERENCE

MONITORING PROGRAM TASK: **WATER COLUMN**
SUBJECT AREA: **ALL WATER COLUMN SAMPLING**
DATA TYPE: **STATIONS**

MONITORING PROGRAM TASK
STATION NAME
STATION TYPE
EXACT LOCATION
RIVER OR EMBAYMENT WHERE STATION IS LOCATED
REFERENCE
WATER DEPTH AT STATION

MONITORING PROGRAM TASK: **WATER COLUMN**
SUBJECT AREA: **WATER QUALITY OBSERVATIONS**
DATA TYPE: **FIELD OBSERVATIONS**

MONITORING PROGRAM TASK
STATION NAME
OBSERVATION NUMBER
DATE
TIME
TIDE STAGE
UPPER DEPTH AT WHICH MEASUREMENT WAS TAKEN
LOWER DEPTH AT WHICH MEASUREMENT WAS TAKEN
OBSERVER
TEMPERATURE
DISSOLVED OXYGEN
SALINITY
TURBIDITY
AMBIENT LIGHT LEVEL
DEPTH OF 1% LIGHT LEVEL
SECCHI DISK DEPTH
WIND DIRECTION
WIND SPEED
REFERENCE

MONITORING PROGRAM TASK: **WATER COLUMN**
SUBJECT AREA: **NUTRIENTS AND CHLOROPHYLL**
DATA TYPE: **SAMPLES**

MONITORING PROGRAM TASK
STATION NAME
SAMPLE NUMBER
DATE
TIME
TIDE STAGE
WEATHER
UPPER DEPTH AT WHICH SAMPLE WAS TAKEN
LOWER DEPTH AT WHICH SAMPLE WAS TAKEN
GEAR USED TO TAKE SAMPLE
PURPOSE OF SAMPLE
REFERENCE

MONITORING PROGRAM TASK: **WATER COLUMN**
SUBJECT AREA: **NUTRIENTS AND CHLOROPHYLL**
DATA TYPE: **NUTRIENTS AND CHLOROPHYLL**

MONITORING PROGRAM TASK
STATION NAME
SAMPLE NUMBER
SILICA
AMMONIA
TOTAL CHLOROPHYLL A
PHOSPHATE
NITRATE
METHOD
REFERENCE

MONITORING PROGRAM TASK: **WATER COLUMN**
SUBJECT AREA: **ODORS, FLOATABLES, SPILLS**
DATA TYPE: **INCIDENT OBSERVATIONS**

DATE
TIME
OBSERVATION NUMBER
LOCATION
RIVER OR EMBAYMENT
TIDE STAGE
OBSERVER
ODOR OBSERVED?
FLOATABLES OBSERVED?
COLOR OBSERVED?
SEVERITY OF ODOR
SEVERITY OF FLOATABLE
SEVERITY OF COLOR
SIZE OF AREA AFFECTED BY ODOR
INCIDENT REPORTED TO
REPORT NUMBER
REFERENCE

MONITORING PROGRAM TASK: **FISH**
SUBJECT AREA: **ALL FISH SAMPLING**
DATA TYPE: **STATIONS**

MONITORING PROGRAM TASK
STATION NAME
RIVER OR EMBAYMENT WHERE STATION IS LOCATED
LOCATION (COORDINATES)
STATION TYPE
REFERENCE

MONITORING PROGRAM TASK: **FISH**
SUBJECT AREA: **ALL FISH SAMPLING**
DATA TYPE: **TRAWLS**

MONITORING PROGRAM TASK
SURVEY NAME
STATION NAME
TRAWL NUMBER
TRAWL DATE
TRAWL START TIME
TRAWL END TIME
TRAWL START LOCATION
TRAWL END LOCATION
TRAWL LENGTH
TIDE STAGE
WEATHER
GEAR USED
MINIMUM WATER DEPTH
MAXIMUM WATER DEPTH
REFERENCE

MONITORING PROGRAM TASK: **FISH**
SUBJECT AREA: **TOXIC CHEMICALS AND FISH DISEASE**
DATA TYPE: **INDIVIDUAL MEASUREMENTS**

MONITORING PROGRAM TASK
STATION NAME
TRAWL NUMBER
FISH NUMBER
SAMPLE NUMBER
SPECIES
FISH SEX
FISH AGE
FISH REPRODUCTIVE STATUS
FISH WEIGHT
FISH MAXIMUM TOTAL LENGTH
FISH LENGTH MEASUREMENT METHOD
GENERAL APPEARANCE
REFERENCE

MONITORING PROGRAM TASK: **FISH**
SUBJECT AREA: **TOXIC CHEMICALS AND FISH DISEASE**
DATA TYPE: **SAMPLES**

MONITORING PROGRAM TASK
STATION NAME
TRAWL NUMBER
SAMPLE NUMBER
NUMBER OF INDIVIDUALS IN SAMPLE
FISH NUMBER(S)
ORGAN USED FOR ANALYSIS
PERCENT MOISTURE
REFERENCE

MONITORING PROGRAM TASK: **FISH**
SUBJECT AREA: **TOXIC CHEMICALS IN FISH**
DATA TYPE: **METALS**

MONITORING PROGRAM TASK
STATION NAME
TRAWL
SAMPLE NUMBER
MERCURY CONCENTRATION
LEAD CONCENTRATION
CADMIUM CONCENTRATION
ZINC CONCENTRATION
COPPER CONCENTRATION
ARSENIC CONCENTRATION
METHOD USED TO PREPARE SAMPLE IN LAB
INSTRUMENTATION USED TO ANALYZE SAMPLE
METHOD USED TO PREPARE SAMPLE IN FIELD
REFERENCE

MONITORING PROGRAM TASK: **FISH**
SUBJECT AREA: **TOXIC CHEMICALS IN FISH**
DATA TYPE: **ORGANICS**

MONITORING PROGRAM TASK
STATION NAME
TRAWL
SAMPLE NUMBER
LIPID CONTENT
ACID EXTRACTABLE ORGANICS CONCENTRATIONS
BASE/NEUTRAL ORGANICS CONCENTRATIONS
PESTICIDE CONCENTRATIONS
TOTAL PCBS
METHOD USED TO PREPARE SAMPLE IN LAB
INSTRUMENTATION USED TO ANALYZE SAMPLE
METHOD USED TO PREPARE SAMPLE IN FIELD
REFERENCE

MONITORING PROGRAM TASK: **FISH**
SUBJECT AREA: **FISH DISEASE**
DATA TYPE: **PATHOLOGY (INTERNAL AND EXTERNAL)**

MONITORING PROGRAM TASK
STATION NAME
TRAWL
FISH NUMBER
ORGAN
LESION CODE
SEVERITY
DISTRIBUTION
REFERENCE

MONITORING PROGRAM TASK: **FISH**
SUBJECT AREA: **FISHERIES HARVESTS AND STOCK ASSESSMENTS**
DATA TYPE: **HARVEST**

YEAR
LOCATION OR AREA
SPECIES or group
ABUNDANCE ESTIMATE
FISHING EFFORT ESTIMATE?
CATCH (pounds)
CATCH (numbers)
VALUE
VALUE OF COMMERCIAL CATCH
VALUE OF SPORTS CATCH
REFERENCE

MONITORING PROGRAM TASK: **SHELLFISH**
SUBJECT AREA: **ALL SHELLFISH SAMPLING**
DATA TYPE: **STATIONS**

MONITORING PROGRAM TASK
STATION NAME
STATION TYPE
EXACT LOCATION
RIVER OR EMBAYMENT WHERE STATION IS LOCATED
REFERENCE
WATER DEPTH AT STATION

MONITORING PROGRAM TASK: **SHELLFISH**
SUBJECT AREA: **ALL SHELLFISH SAMPLING**
DATA TYPE: **CORES**

MONITORING PROGRAM TASK
STATION NAME
CORE NUMBER
DATE
TIME
CORE DEPTH
CORE AREA
GEAR USED
REFERENCE

MONITORING PROGRAM TASK: **SHELLFISH**
SUBJECT AREA: **SHELLFISH ABUNDANCE**
DATA TYPE: **ABUNDANCES**

MONITORING PROGRAM TASK
STATION NAME
CORE NUMBER
SPECIES
ABUNDANCE

MONITORING PROGRAM TASK: **SHELLFISH**
SUBJECT AREA: **SHELLFISH ABUNDANCES**
DATA TYPE: **HARVEST**

YEAR
LOCATION OR AREA
TYPE OF SHELLFISH
ABUNDANCE ESTIMATE
FISHING EFFORT ESTIMATE?
CATCH (pounds)
CATCH (numbers)
VALUE
VALUE OF COMMERCIAL CATCH
VALUE OF SPORTS CATCH
REFERENCE

MONITORING PROGRAM TASK: **SHELLFISH**
SUBJECT AREA: **ALL SHELLFISH SAMPLING**
DATA TYPE: **INDIVIDUAL MEASUREMENTS**

MONITORING PROGRAM TASK
STATION NAME
CORE NUMBER
BIVALVE NUMBER
SAMPLE NUMBER
SPECIES
LENGTH OF INDIVIDUAL
AGE OF INDIVIDUAL
REFERENCE

MONITORING PROGRAM TASK: **SHELLFISH**
SUBJECT AREA: **TOXIC CHEMICALS, PSP AND BACTERIA IN SHELLFISH**
DATA TYPE: **SAMPLES**

MONITORING PROGRAM TASK
STATION
CORE NUMBER
SAMPLE NUMBER
ORGAN ANALYZED
NUMBER OF INDIVIDUALS
WET WEIGHT
METHOD USED TO PREPARE SAMPLE IN FIELD
REFERENCE

MONITORING PROGRAM TASK: **SHELLFISH**
SUBJECT AREA: **TOXIC CHEMICALS IN SHELLFISH**
DATA TYPE: **METALS**

MONITORING PROGRAM TASK
STATION
SAMPLE NUMBER
METALS CONCENTRATIONS
METHOD USED TO PREPARE SAMPLE IN LAB
INSTRUMENTATION USED TO ANALYZE SAMPLE
REFERENCE

MONITORING PROGRAM TASK: **SHELLFISH**
SUBJECT AREA: **TOXIC CHEMICALS IN SHELLFISH**
DATA TYPE: **ORGANICS**

MONITORING PROGRAM TASK
STATION
SAMPLE NUMBER
INDIVIDUAL
LIPID CONTENT
ACID EXTRACTABLE ORGANICS CONCENTRATIONS

BASE/NEUTRAL ORGANICS CONCENTRATIONS
PESTICIDE CONCENTRATIONS
METHOD USED TO PREPARE SAMPLE IN LAB
INSTRUMENTATION USED TO ANALYZE SAMPLE
REFERENCE

MONITORING PROGRAM TASK: **SHELLFISH**
SUBJECT AREA: **PSP AND BACTERIA IN SHELLFISH**
DATA TYPE: **MICROBIAL CONCENTRATIONS**

MONITORING PROGRAM TASK
STATION
SAMPLE NUMBER
METHOD USED TO PREPARE SAMPLE
FECAL COLIFORMS
METHOD USED TO MEASURE FECAL COLIFORMS
PSP CONCENTRATION
METHOD USED TO MEASURE PSP
REFERENCE

MONITORING PROGRAM TASK: **SHELLFISH**
SUBJECT AREA: **ALL WATER QUALITY SAMPLING**
DATA TYPE: **STATIONS**

MONITORING PROGRAM TASK
STATION NAME
STATION TYPE
EXACT LOCATION
RIVER OR EMBAYMENT WHERE STATION IS LOCATED
REFERENCE
WATER DEPTH AT STATION

MONITORING PROGRAM TASK: **SHELLFISH**
SUBJECT AREA: **WATER QUALITY OBSERVATIONS**
DATA TYPE: **FIELD OBSERVATIONS**

MONITORING PROGRAM TASK
STATION NAME
OBSERVATION NUMBER
DATE
TIME
TIDE STAGE
UPPER DEPTH AT WHICH MEASUREMENT WAS TAKEN
LOWER DEPTH AT WHICH MEASUREMENT WAS TAKEN
OBSERVER
TEMPERATURE
DISSOLVED OXYGEN
SALINITY
TURBIDITY
AMBIENT LIGHT LEVEL
DEPTH OF 1% LIGHT LEVEL
SECCHI DISK DEPTH

WIND DIRECTION
WIND SPEED
REFERENCE

MONITORING PROGRAM TASK: **SHELLFISH**
SUBJECT AREA: **ODORS, FLOATABLES, SPILLS**
DATA TYPE: **INCIDENT OBSERVATIONS**

DATE
TIME
OBSERVATION NUMBER
LOCATION
RIVER OR EMBAYMENT
TIDE STAGE
OBSERVER
ODOR OBSERVED?
FLOATABLES OBSERVED?
COLOR OBSERVED?
SEVERITY OF ODOR
SEVERITY OF FLOATABLE
SEVERITY OF COLOR
SIZE OF AREA AFFECTED BY ODOR
INCIDENT REPORTED TO
REPORT NUMBER
REFERENCE

MONITORING PROGRAM TASK: **SHELLFISH**
SUBJECT AREA: **PATHOGEN INDICATORS IN THE WATER COLUMN**
DATA TYPE: **SAMPLES**

MONITORING PROGRAM TASK
STATION NAME
SAMPLE NUMBER
DATE
TIME
TIDE STAGE
WEATHER
UPPER DEPTH AT WHICH SAMPLE WAS TAKEN
LOWER DEPTH AT WHICH SAMPLE WAS TAKEN
GEAR USED TO TAKE SAMPLE
PURPOSE OF SAMPLE
REFERENCE

MONITORING PROGRAM TASK: **SHELLFISH**
SUBJECT AREA: **PATHOGEN INDICATORS IN THE WATER COLUMN**
DATA TYPE: **PATHOGEN INDICATORS**

MONITORING PROGRAM TASK
STATION NAME
SAMPLE NUMBER
METHOD USED TO PREPARE SAMPLE

FECAL COLIFORMS
METHOD USED TO MEASURE FECAL COLIFORMS
REFERENCE

MONITORING PROGRAM TASK: **SHELLFISH**
SUBJECT AREA: **AQUACULTURE SITES AND YIELDS**
DATA TYPE: **ACTIVITIES**

ACTIVITY NAME
TYPE OF CROP
RIVER OR EMBAYMENT
LOCATION
START YEAR
END YEAR
AREA COVERED BY OPERATION
OWNER
METHOD
REFERENCE

MONITORING PROGRAM TASK: **SHELLFISH**
SUBJECT AREA: **AQUACULTURE SITES AND YIELDS**
DATA TYPE: **SPECIES GROWN**

ACTIVITY NAME
YEAR
SPECIES
YIELD
VALUE OF YIELD
REFERENCE

MONITORING PROGRAM TASK: **BIRDS**
SUBJECT AREA: **AVIAN ABUNDANCES/REPRODUCTIVE SUCCESS**
DATA TYPE: **SURVEYS**

MONITORING PROGRAM TASK
SURVEY NAME
SURVEY DATE
STATION NAME
TIME OF SURVEY
TIDE STAGE AT TIME OF SURVEY
WEATHER AT TIME OF SURVEY
SURVEY METHODS
NUMBER OF SURVEYORS
HABITAT TYPE
AREA SURVEYED
REFERENCE

MONITORING PROGRAM TASK: **BIRDS**
SUBJECT AREA: **AVIAN ABUNDANCES/REPRODUCTIVE SUCCESS**
DATA TYPE: **STATIONS**

MONITORING PROGRAM TASK
STATION NAME
STATION TYPE
LOCATION (COORDINATES)
RIVER OR EMBAYMENT WHERE STATION IS LOCATED
REFERENCE

MONITORING PROGRAM TASK: **BIRDS**
SUBJECT AREA: **AVIAN ABUNDANCES/REPRODUCTIVE SUCCESS**
DATA TYPE: **ABUNDANCES**

SURVEY NAME
STATION NAME
SPECIES
ABUNDANCE
ABUNDANCE OF ADULTS
ABUNDANCE OF YOUNG
REFERENCE

MONITORING PROGRAM TASK: **BIRDS**
SUBJECT AREA: **WATERFOWL HARVESTS**
DATA TYPE: **HARVESTS**

LOCATION OR AREA
YEAR
SEASON
SPECIES
NUMBER HARVESTED
ABUNDANCE ESTIMATE
REFERENCE

MONITORING PROGRAM TASK: **MARINE MAMMALS**
SUBJECT AREA: **ABUNDANCE AND REPRODUCTIVE SUCCESS**
DATA TYPE: **SEAL SURVEYS**

MONITORING PROGRAM TASK
STATION NAME
SURVEY NUMBER
SURVEY START DATE
SURVEY END DATE
SURVEY START TIME
SURVEY END TIME
TIDE STAGE
WEATHER
AREA SURVEYED
SURVEYOR
SURVEY METHOD
REFERENCE

MONITORING PROGRAM TASK: **MARINE MAMMALS**
SUBJECT AREA: **ABUNDANCE AND REPRODUCTIVE SUCCESS**
DATA TYPE: **SEAL SITES**

MONITORING PROGRAM TASK
SITE NAME
SITE LOCATION
RIVER OR EMBAYMENT WHERE SITE IS LOCATED
SITE TYPE
REFERENCE

MONITORING PROGRAM TASK: **MARINE MAMMALS**
SUBJECT AREA: **ABUNDANCE AND REPRODUCTIVE SUCCESS**
DATA TYPE: **SEAL SITE USE**

MONITORING PROGRAM TASK
SITE NAME
YEAR
SITE USE (e.g., nursery, haul-out)
REFERENCE

MONITORING PROGRAM TASK: **MARINE MAMMALS**
SUBJECT AREA: **ABUNDANCE AND REPRODUCTIVE SUCCESS**
DATA TYPE: **ABUNDANCES AND REPRODUCTIVE SUCCESS**

MONITORING PROGRAM TASK
STATION NAME
SURVEY NUMBER
SPECIES
NUMBER OF FEMALES
NUMBER OF PUPS
REFERENCE

MONITORING PROGRAM TASK: **MARINE MAMMALS**
SUBJECT AREA: **TOXIC CHEMICALS IN MARINE MAMMALS**
DATA TYPE: **STATIONS**

MONITORING PROGRAM TASK
STATION NAME WHERE MAMMAL FOUND
EMBAYMENT IN WHICH INDIVIDUAL WAS FOUND
EXACT LOCATION FOUND
REFERENCE

MONITORING PROGRAM TASK: **MARINE MAMMALS**
SUBJECT AREA: **TOXIC CHEMICALS IN MARINE MAMMALS**
DATA TYPE: **INDIVIDUALS**

MONITORING PROGRAM TASK
STATION
INDIVIDUAL NUMBER
SPECIES
DATE FOUND
DATE OF DEATH
WEIGHT
AGE
LENGTH
FOUND FLOATING? BEACHED?
CONDITION FOUND
REFERENCE

MONITORING PROGRAM TASK: **MARINE MAMMALS**
SUBJECT AREA: **TOXIC CHEMICALS IN MARINE MAMMALS**
DATA TYPE: **SAMPLES**

MONITORING PROGRAM TASK
STATION
INDIVIDUAL
SAMPLE NUMBER
ORGAN ANALYZED
WET WEIGHT
METHOD USED TO PREPARE SAMPLE IN FIELD
REFERENCE

MONITORING PROGRAM TASK: **MARINE MAMMALS**
SUBJECT AREA: **TOXIC CHEMICALS IN MARINE MAMMALS**
DATA TYPE: **METALS**

MONITORING PROGRAM TASK
STATION
INDIVIDUAL
SAMPLE NUMBER
MERCURY CONCENTRATION
METHOD USED TO PREPARE SAMPLE IN LAB
INSTRUMENTATION USED TO ANALYZE SAMPLE
REFERENCE

MONITORING PROGRAM TASK: **MARINE MAMMALS**
SUBJECT AREA: **TOXIC CHEMICALS IN MARINE MAMMALS**
DATA TYPE: **ORGANICS**

MONITORING PROGRAM TASK
STATION
INDIVIDUAL
SAMPLE NUMBER
LIPID CONTENT
ACID EXTRACTABLE ORGANICS CONCENTRATIONS
BASE/NEUTRAL ORGANICS CONCENTRATIONS
PESTICIDE CONCENTRATIONS
METHOD USED TO PREPARE SAMPLE IN LAB
METHOD USED TO PREPARE SAMPLE IN FIELD
INSTRUMENTATION USED TO ANALYZE SAMPLE
REFERENCE

MONITORING PROGRAM TASK: **NEARSHORE HABITAT**
SUBJECT AREA: **HABITAT INVENTORY**
DATA TYPE: **PHOTOGRAPHS**

PHOTOGRAPH NUMBER
PHOTOGRAPH SOURCE
DATE OF PHOTOGRAPH
REFERENCE
METHOD

MONITORING PROGRAM TASK: **NEARSHORE HABITAT**
SUBJECT AREA: **HABITAT INVENTORY**
DATA TYPE: **HABITAT ID**

PHOTOGRAPH NUMBER
HABITAT NUMBER
RIVER OR EMBAYMENT
HABITAT TYPE
SIZE OF HABITAT (AREA)
REFERENCE

MONITORING PROGRAM TASK: **NEARSHORE HABITAT**
SUBJECT AREA: **HABITAT INVENTORY**
DATA TYPE: **SPECIES ID**

PHOTOGRAPH NUMBER
HABITAT NUMBER
REPLICATE QUADRAT NUMBER
SPECIES OBSERVED
DENSITY OF SPECIES
STANDING STOCK OF SPECIES
PERCENT COVER OF SPECIES
REFERENCE

MONITORING PROGRAM TASK: **NEARSHORE HABITAT**
SUBJECT AREA: **HABITAT INVENTORY**
DATA TYPE: **HABITAT USES**

PHOTOGRAPH NUMBER
HABITAT NUMBER
DATE
SPECIES
TYPE OF USE
OBSERVER
REFERENCE

MONITORING PROGRAM TASK: **FRESHWATER**
SUBJECT AREA: **FLOW IN RIVERS AND STREAMS**
DATA TYPE: **MONTHLY FLOW**

REFERENCE
RIVER
MONTH
AVERAGE MONTHLY FLOWS (cfs)
REFERENCE

MONITORING PROGRAM TASK: **FRESHWATER**
SUBJECT AREA: **FLOW IN RIVERS AND STREAMS**
DATA TYPE: **WATERSHEDS**

NUMBER OF STREAMS
NUMBER OF MILES OF STREAMS
WATERSHED NAME

MONITORING PROGRAM TASK: **FRESHWATER**
SUBJECT AREA: **ALL FRESHWATER SAMPLING**
DATA TYPE: **STATIONS**

MONITORING PROGRAM TASK
STATION NAME
STATION TYPE
RIVER OR EMBAYMENT WHERE STATION IS LOCATED
EXACT LOCATION
WATER DEPTH AT STATION
TIDAL NATURE OF STATION
REFERENCE

MONITORING PROGRAM TASK: **FRESHWATER**
SUBJECT AREA: **CONVENTIONAL PARAMETERS**
DATA TYPE: **FIELD OBSERVATIONS**

MONITORING PROGRAM TASK
STATION NAME
DATE
TIME
TIDE STAGE
WEATHER
UPPER DEPTH AT WHICH MEASUREMENT WAS TAKEN
LOWER DEPTH AT WHICH MEASUREMENT WAS TAKEN
OBSERVER
DISSOLVED OXYGEN
SECCHI DISK DEPTH
AMBIENT LIGHT LEVEL
TURBIDITY
WIND DIRECTION
WIND SPEED
TEMPERATURE
REFERENCE

MONITORING PROGRAM TASK: **FRESHWATER**
SUBJECT AREA: **METALS**
DATA TYPE: **SAMPLES**

MONITORING PROGRAM TASK
STATION NAME
SAMPLE NUMBER
DATE
TIME
TIDE STAGE
GEAR USED TO TAKE SAMPLE
UPPER DEPTH AT WHICH SAMPLE WAS TAKEN
LOWER DEPTH AT WHICH SAMPLE WAS TAKEN
PURPOSE OF SAMPLE
REFERENCE

MONITORING PROGRAM TASK: **FRESHWATER**
SUBJECT AREA: **METALS**
DATA TYPE: **METALS**

MONITORING PROGRAM TASK
STATION NAME
SAMPLE NUMBER
CONCENTRATIONS OF REQUIRED METALS
METHOD USED TO PREPARE SAMPLE IN LAB
INSTRUMENTATION USED TO ANALYZE SAMPLE
METHOD USED TO PREPARE SAMPLE IN FIELD
REFERENCE

MONITORING PROGRAM TASK: **FRESHWATER**
SUBJECT AREA: **FISH TISSUE TOXICANTS**
DATA TYPE: **TRAWLS**

MONITORING PROGRAM TASK
SURVEY NAME
STATION NAME
TRAWL NUMBER
TRAWL DATE
TRAWL START TIME
TRAWL END TIME
TRAWL START LOCATION
TRAWL END LOCATION
TRAWL LENGTH
TIDE STAGE
WEATHER
GEAR USED
MINIMUM WATER DEPTH
MAXIMUM WATER DEPTH
REFERENCE

MONITORING PROGRAM TASK: **FRESHWATER**
SUBJECT AREA: **TOXIC CHEMICALS AND FISH DISEASE**
DATA TYPE: **SAMPLES**

MONITORING PROGRAM TASK
STATION NAME
TRAWL NUMBER
SAMPLE NUMBER
SPECIES
NUMBER OF INDIVIDUALS IN SAMPLE
ORGAN USED FOR ANALYSIS
REFERENCE

MONITORING PROGRAM TASK: **FRESHWATER**
SUBJECT AREA: **TOXIC CHEMICALS AND FISH DISEASE**
DATA TYPE: **INDIVIDUAL MEASUREMENTS**

MONITORING PROGRAM TASK
STATION NAME
TRAWL NUMBER
FISH NUMBER
SAMPLE NUMBER
SPECIES
FISH SEX
FISH REPRODUCTIVE STATUS
FISH WEIGHT
FISH TOTAL LENGTH
FISH LENGTH MEASUREMENT METHOD
REFERENCE

MONITORING PROGRAM TASK: **FRESHWATER**
SUBJECT AREA: **TOXIC CHEMICALS IN FISH**
DATA TYPE: **METALS**

MONITORING PROGRAM TASK
STATION NAME
TRAWL
SAMPLE NUMBER
MERCURY CONCENTRATION
LEAD CONCENTRATION
CADMIUM CONCENTRATION
ZINC CONCENTRATION
COPPER CONCENTRATION
ARSENIC CONCENTRATION
METHOD USED TO PREPARE SAMPLE IN LAB
INSTRUMENTATION USED TO ANALYZE SAMPLE
METHOD USED TO PREPARE SAMPLE IN FIELD
REFERENCE

MONITORING PROGRAM TASK: **FRESHWATER**
SUBJECT AREA: **TOXIC CHEMICALS IN FISH**
DATA TYPE: **ORGANICS**

MONITORING PROGRAM TASK
STATION NAME
TRAWL
SAMPLE NUMBER
LIPID CONTENT
ACID EXTRACTABLE ORGANICS CONCENTRATIONS
BASE/NEUTRAL ORGANICS CONCENTRATIONS
PESTICIDE CONCENTRATIONS
TOTAL PCBS
METHOD USED TO PREPARE SAMPLE IN LAB
INSTRUMENTATION USED TO ANALYZE SAMPLE
METHOD USED TO PREPARE SAMPLE IN FIELD
REFERENCE

MONITORING PROGRAM TASK: **FRESHWATER**
SUBJECT AREA: **FISH DISEASE**
DATA TYPE: **EXTERNAL PATHOLOGY OBSERVATIONS**

MONITORING PROGRAM TASK
STATION NAME
TRAWL
FISH NUMBER
ORGAN
LESION CODE
SEVERITY
DISTRIBUTION
REFERENCE

MONITORING PROGRAM TASK: **RIVER MOUTHS**
SUBJECT AREA: **NEARSHORE ESTUARINE SEDIMENTS**
DATA TYPE: **ALL DATA TYPES ARE THE SAME AS THOSE FOR SEDIMENT CHEMISTRY EXCEPT THAT AMPHIPOD BIOASSAY DATA ARE NOT COLLECTED**

MONITORING PROGRAM TASK: **RIVER MOUTHS**
SUBJECT AREA: **NEARSHORE WATER COLUMN**
DATA TYPE: **ALL DATA TYPES ARE THE SAME AS THOSE FOR WATER COLUMN WITH THE ADDITION OF PATHOGEN DATA**