WASHINGTON STATE
DEPARTMENT OF
ECOLOGY

Guidance for Conducting Water Quality Assessments and Watershed Characterizations Under the Nonpoint Rule (Chapter 400-12 WAC)

Publication No. 95-307
February 1995

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Guidance for Conducting Water Quality Assessments and Watershed Characterizations Under the Nonpoint Rule (Chapter 400-12 WAC)

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I. Introduction

This guidance was originally written by the Washington State Department of Ecology (Ecology) in 1989 for use by watershed management committees that were developing watershed action plans pursuant to the Nonpoint Rule (Chapter 400-12 of the Washington Administrative Code). The principal author of the original document was Joy Michaud of the Environmental Investigations and Laboratory Services Program (EILS). The Riparian Corridor Assessment section was written by Kenneth Stone and the Land Use Assessment section was written and updated by Bob Duffy, both of the Water Quality Program. The Riparian Corridor Assessment was recently revised by Ed Rashin of EILS. The Watershed Characterization and Data Management sections were largely excerpted from an EILS document by Robert Cusimano entitled, *Technical Guidance for Assessing the Quality of Aquatic Environments*, written for those interested in conducting monitoring under the Centennial Clean Water Fund grant program. Both documents contain useful guidance for water quality assessment and should be used together since not all information is contained in each, and grant funding is likely to be pursued in many watersheds subject to the nonpoint rule. Revisions to this guidance document were necessary because of changes in Chapter 400-12 in 1991, and the need to clarify some issues brought forward since the document's initial publication. The revisions were written and compiled by Randy Coots of EILS.

Background

In February 1988, the Puget Sound Water Quality Authority adopted the Nonpoint Rule for the ranking of watersheds and development of action plans for priority watersheds in the Puget Sound basin (Chapter 400-12 WAC). Action plans for prevention and control of nonpoint sources of pollution are developed and implemented at the local level, with assistance from the Department of Ecology, other state agencies, and the Puget Sound Cooperative River Basin Team. The Nonpoint Rule was revised in November 1991 to clarify and streamline the watershed action plan process, and leave more flexibility with local watershed committees.

Water quality assessments are an integral part of the watershed action plan process. Watershed management committees need to use assessments during the characterization and implementation strategy phases of developing a watershed action plan.

The process for developing a watershed action plan involves four phases. They are:

Phase 1 -- Watershed characterization and goals/objectives;
Phase 2 -- Action plan nonpoint pollution control strategy;
Phase 3 -- Action plan implementation strategy; and
Phase 4 -- Action plan review and approval.

Purpose of Guidance

This guidance is based on the procedures and requirements of Chapter 400-12 WAC. It provides watershed management committees with information on the water quality assessment components of the action plans (Chapter 400-12-515(2)(c)(iv)). It makes recommendations for using water quality monitoring as a tool to meet immediate and long-term watershed management objectives. This guidance manual will enable development of sound monitoring programs by directing water quality managers to resources for data collection and recording.

II. Watershed Characterization

Developing a watershed characterization is the first phase in the preparation of a watershed action plan under Chapter 400-12 WAC. A watershed characterization is an examination and summarization of existing information to define problems so that action plan goals and objectives can be developed. Specifically, beneficial use impairments, types and levels of pollutants, and probable nonpoint sources of pollution are identified. Preparation of the watershed characterization is conducted under the direction of the lead agency, and the watershed management committee as appropriate. At a minimum the characterization includes (Chapter 400-12-515(2)(c)):

(i) a description of the biological conditions and physical characteristics of the environment;
(ii) information on land use and population, including existing and probable trends;
(iii) a description of habitats;
(iv) an assessment of existing water quality and anticipated trends;
(v) a map showing the action plan boundaries. Where a plan is being jointly prepared with a ground water management program, the boundaries of the ground water management planning area shall be included;
(vi) a map showing jurisdictional boundaries of the local, state, federal, and tribal governments, participating special purpose districts, and implementing entities in the watershed;
(vii) a map showing all waterways, water bodies, and known wetlands;

(viii) a discussion of existing federal, state, local, and other water quality programs ongoing in the watershed; and
(ix) a description of information that is desirable but unavailable.

The scoping outline in Appendix I can be useful for identifying and gathering existing watershed characterization data. The sections in this guidance on riparian corridor assessment (V) and land use (VI) can be used to help complete portions (i), (ii), (iii), (vi), and (vii) of the characterization.

Existing water quality data gathered to address elements (i) and (iv) of the characterization need to be detailed enough to define the extent of problems created by nonpoint sources. The data need to be evaluated for long-term and seasonal trends, frequency of water quality criteria violations, correlations among parameters, natural concentration variability, and associations of water quality to upstream land use types. These types of evaluations help focus action plan goals and strategies. They also provide a base from which to build a long-term water quality monitoring design.

If water quality data are absent or very sparse, it is appropriate to undertake a limited monitoring program or conduct a set of intensive water quality surveys. These activities can be funded from local sources and are also eligible for funding under the Centennial Clean Water Fund grant program. The goal of such efforts is to collect water quality baseline data necessary to complete the watershed characterization and determine the general location and magnitude of nonpoint source problems. The monitoring is often of short duration since watershed management committee deadlines must be met. Land use and subjective water quality information from local citizens and agencies, state regulatory agencies, and other people familiar with the watershed can be helpful for focusing the parameters to measure and sampling locations of the monitoring effort (see the Appendix I resource list). If this information is combined with knowledge of general pollutant sources, transport, and deposition mechanisms, a better monitoring design will be created. A "shot-gun" or random approach is usually not an effective monitoring design, even in cases where few water quality data exist.

Any monitoring design needs to address the following:

1. What beneficial uses are being impaired, and what are the best measurement(s) to document the degree of impairment? For example, fecal coliform sampling would be appropriate to measure the impairment of swimming beaches, but not for the loss of fish habitat by poor construction practices. In the case of lost fish habitat, physical measurements may be better than water sample data.

2. When are the pollutants most likely present in the system, and in what form (*i.e.*, are they more likely to be found in the water column, sediment, or biota)? Is the problem related to a particular land use practice, a hydrologic or climatic event, or a combination of both? For example, NPS problems from agricultural areas often peak during wet season storm events even though application of animal wastes or agricultural chemicals may have occurred during the dry season. The wash-off driven nature of NPS pollution requires careful planning.

Water Quality Monitoring Plan and Design

Planning A Water Quality Assessment Program

Data can be collected to monitor or to characterize ambient conditions in aquatic systems. The purpose for collecting data may be to identify pollutant types and sources for control actions, assess the impact of controls on the containment of pollutants, to detect long-term trends, to measure compliance with ambient standards, to provide a summary of average or extreme conditions, or to establish baseline data for future reference.

The following is a list of steps, modified from those presented by Gilbert (1987), that should be addressed when undertaking any monitoring program:

1) Develop a problem statement for the general area of concern. Example:

   Statement of Problem
   High levels of fecal coliform and nutrients are routinely found in streams draining the Anywhere Creek watershed. The major contributor to the elevated concentrations is suspected to be poor dairy farming practices.

   Note: Information on the background or history of the problem is also helpful in providing focus for a project. For this example, what are the traditional farming practices, what health issues have been raised, what other pollution sources are suspect, etc.

2) Clearly define objectives, including all assumptions and hypotheses. Example:

   Specific Objectives of the Project
   a) Determine fecal coliform, nutrients, TSS, temperature, and conductivity values on stream reaches above and below the major impact areas.

   b) Determine loads to the stream for each parameter and statistically analyze for relationships between variables.

c) Determine the number of water quality criteria exceedances for each variable from impact areas.

d) Relate the exceedances to impairment of water usage under state water quality standards.

3) Define areas of interest, (*e.g.*, stream reach, lake, estuary, watershed).

4) Collect available background information on the physical characteristics of the study area, weather patterns, groundwater influences, and any other information that might help in the monitoring design or interpretation of collected data.

5) Conduct a reconnaissance trip through the watershed. Bring a USGS topographic (topo) map of the area and note major features and practices that may influence water quality (*e.g.*, manure spreading, construction areas, hobby farms, etc.). The 7.5 minute maps (1:24,000 scale) are recommended. Topo's are available at most outdoor sporting goods stores.

6) Examine existing data or conduct a pilot study to obtain information on possible concentration ranges and variability to be encountered.

7) Develop a sampling design that will provide representative data from the study area. Define (1) the types and number of samples to be collected, (2) the sampling frequency and station locations, and (3) the field measurements and collection procedures needed to meet objectives and hypotheses of the monitoring program.

8) Develop a quality assurance and quality control program for all aspects of the project including: field sample collection, sample processing, laboratory analysis, data validation, data entry and management, statistical analyses, and data interpretation and reporting (reference Section II - QA/QC).

9) Develop a data management plan, including field and laboratory data forms and a data management system (reference Section IV. - Data Management).

10) Conduct the monitoring according to established protocols and the quality assurance/quality control plan.

11) Summarize relevant information and evaluate hypotheses.

12) Prepare a report summarizing steps 1 through 11 above, including an evaluation of whether objectives have been met.

Whether a consultant is contracted or county water quality staff are selected to develop and implement the monitoring plan, the following criteria should be considered before assigning tasks to any candidate: experience in conducting water quality monitoring programs; expertise in the areas of environmental science (environmental engineering, limnology, biology, hydrology, statistics); and management and logistic capabilities.

Quality Assurance/Quality Control (QA/QC)

A quality assurance/quality control program is the only means of assurance that the data and information produced by monitoring are accurate. Data used for making decisions that may affect individuals, communities, industry, or governments must be of sufficient accuracy and precision to minimize the possibility of misinterpretation. Although measurement data are only estimates of true values, QA/QC procedures can be incorporated into the sampling, analysis, and reporting elements of a project to provide an estimate of the accuracy of the data.

Quality control activities are designed to ensure that the measurement process is capable of meeting data quality objectives for accuracy. Quality control procedures are applied to maintain statistical control of the measurement process, which includes sample collection and instrument calibration and analysis. Quality control procedures include the use of blanks, replicates, spikes, and check standards (*e.g.*, standard reference materials).

Whereas QC is specific to the measurement process, QA is the overall integrated program for assuring the reliability of data. Quality assurance involves all aspects of sample collection, analysis, data management, and reporting. Quality assurance is achieved by developing a specific QA project plan. Other QA activities include:

- Selection of an accredited analytical laboratory
- Developing Standard Operating Procedures (SOPs)
- Training field sampling crews
- Establishing a communication scheme between management, sampling, and analytical personnel
- Conducting on-site field inspections
- Collecting and analyzing different types of QC samples to quantify data quality (*i.e.*, blanks, for detecting the potential for sampling, transport, or laboratory contamination; replicates, for determining the reproducibility of the analytical procedure; spikes, for determination of the recovery of an analyte; and check standards or standard reference materials, for the accuracy of the analysis)
- Defining data management procedures (reference Section IV - Data Management)

A QA plan must be completed before sampling begins. Anyone interested in developing an appropriate QA plan should contact the QA/QC Section of Ecology at (360) 895-4649 for laboratory QA questions or the Watershed Assessments Section at (360) 407-6698 for field QA questions, and read Ecology (1991) *Guidelines and Specifications for Preparing Quality Assurance Project Plans*. This document discusses the following major plan elements:

- *Title Page
- Table of Contents
- *Project Description
- *Project Organization and Responsibility
- *Data Quality Objectives
- *Sampling Procedures
- *Analytical Procedures
- Data Reduction, Review, and Reporting
- *Quality Control Procedures
- Performance and Systems Audits
- Preventive Maintenance
- *Data Assessment Procedures
- Corrective Action
- Quality Assurance Reports

After considering each of these elements, the project manager may decide to omit some for a particular project. Eight elements are necessary for even the most basic of projects. These eight elements, identified by an asterisk (*) in the list above, must be included in every QA plan.

Designing a Water Quality Assessment Project

Numerous challenges are faced when developing an appropriate water quality monitoring design. The major problem is to define the environmental "population" of interest. The first four steps listed in Section II under "Planning a Water Quality Assessment Program" must be completed before committing to the monitoring aspects of the program (*i.e.*, developing a problem statement, defining objectives, defining areas of interest, and collecting available background information). Completion of these steps will assist in defining the population of interest. Unless the population is clearly defined and related to the project objectives, the collected data may not be useful in addressing the issues of concern.

The identification of any existing water quality problems is the first task in developing a sampling design. Once problems are identified, a set of explicit objectives should be developed for the sampling program. These objectives can then be prioritized based on the resources available. Afterwards, the sampling design can be developed.

According to Gaugush (1987) a sampling design must provide answers to four fundamental questions:

- What to sample?
- How many samples?
- Where to sample?
- When to sample?

The answer to the first question, "What to sample?" is the list of parameters to be measured based on the problem statement and specific objectives (Table 1). If the problem statement and objectives are properly developed, then the parameters of interest will be fairly obvious. Ideally, the temporal and spatial allocation of samples would only be based on the desire to meet the stated program objectives. However, the number, area, and frequency of sampling are often affected by the size of budget, personnel availability, and other logistic considerations.

In order to determine the best allocation of samples, it is advisable to seek the technical services of someone who understands complex water quality assessment issues. There are a number of points that must be considered in this aspect of a program: spatial and temporal variability of the parameters of interest, hydrologic conditions, and other physical variables that might affect the results. An in-depth discussion of these issues is beyond the scope of this document, however, the following subsections list some of the major considerations for designing a water quality monitoring project.

Field Survey Design

Once the goals and objectives of the program have been set, designing an appropriate monitoring scheme can begin. The goal of any monitoring project is to efficiently use resources to get the necessary data at the lowest cost and effort. The more information gathered, and greater level of understanding obtained about the parameters and survey area during the proposal phase, the more efficient the monitoring design will be.

General guidelines for designing a monitoring program are as follows:

1) Establish what limits you have on resources.

   - Budget
   - Equipment
   - Staff (Who can help? What are their levels of experience? When are they available?)

- Field time (This ranges from the length of a survey day that allows timely delivery of samples to labs, to length of daylight hours, to the seasonal period of critical conditions.)
- Data evaluation deadlines

(2) Set the physical boundaries of the study area, and try to clearly isolate as many sources as possible. Try to keep the residual, or "unknown source," category as small as possible.

- Define the upstream limit of the study area or a control station. Establish a site with homogenous (*i.e.*, fully mixed) water quality outside the influence of any of the target sources.

- Define the limits on source identification depending on the objectives. For tributaries either put a site at the mouth, or one at the mouth and one upstream at a control station above the area of concern. For point sources, establish a site at the final effluent discharge point unless efficiency data or data on a source of contaminants within the point source collection system are needed. Nonpoint sources can be defined by careful station placement. Ground water inputs can be estimated by difference, measured by well sampling, or included in a residual term. Precipitation inputs can be estimated from local weather station data, measured on site, or included in a residual term. Instream or autochthonous inputs (like sediments, algae, macrophytes, bacteria, and aquatic biota) which cause changes in water quality can be measured, estimated, or included in a residual term.

- Define the downstream limit where your measurements and data analyses/evaluations end.

3) Establish data capabilities:

- Previous studies in similar systems provide an excellent means of estimating variance and should be used whenever possible. Given the resources at hand and required resolution, what is the probability that the proposed sampling design will detect a change in water quality? Will an estimate based on a few samples meet the long term objectives and be defensible? Do power analysis (Cohen, 1988) to:

  a) Calculate the number of samples needed to detect the magnitude of change (or difference, or confidence interval about your estimate) you need to detect; and/or
  b) Calculate the magnitude of change that you can likely (based on the confidence needed in not missing something) detect with the resources available.

- What level of confidence in the data and your interpretation of the conditions will be gained from adding stations, samples, parameters, or better detection limits?

- Which element of your analysis has the greatest degree of error? Does the level of precision you want for other elements make sense relative to this margin of error? For example, if you are determining mean monthly phosphorus loading, it doesn't make sense to measure discharge by timing a stick floating downstream, and then require high precision in the analytical phosphorus data.

4) Mass balance calculations are an important tool for evaluating contaminant sources, transport mechanisms, and sinks (*e.g.*, a water balance equation):

$$Q_{inflow} + Q_{tributary} - Q_{evaporation} - Q_{diversion} \pm Q_{groundwater} = Q_{outflow}$$

The design of a survey should ensure mass balance data are available and are collected where they will accurately represent the element of the equation. Sometimes lateral or vertically stratified sampling will be necessary to achieve the desired accuracy (see #7, below). Other situations call for temporal stratification at a single site, or good understanding of time of travel within a survey area (see #6, below).

Usually mass balance calculations are set up for several parameters. Calculation proceeds from doing the water balance, to a conservative parameter balance (*e.g.*, chlorides or solids), to a more complex parameter (*e.g.*, metals or nutrients) balance. The investigator must take these interactions into consideration during the design phase, and account for each higher level of complexity in the calculation.

5) The investigator must have a clear understanding of probable transport mechanisms and sinks for a particular contaminant to place sampling stations, make parameter lists, decide which media to collect, and arrange proper collection schedules. For example, for several toxic substances it is important to sample suspended sediment and organic carbon concentrations to accurately estimate the fate of the toxic material. In addition, sediments are often the only medium where some toxicants can be detected; if so, the sediments should be sampled.

The investigator must also be knowledgeable about ancillary parameters necessary to evaluate a contaminant of interest against a criterion or standard. For example, to evaluate ammonia concentrations against water quality criteria, temperature and pH values are needed; hardness values are required for evaluation of some metals; and sediment analyses need grain size, total organic carbon (TOC), and percent solids.

There are several general references, case studies, and journal articles that can be used as examples of successful design strategies. These are listed in the Annotated Bibliography/References sections.

6) The general schedule of the field work and the specific spatial and temporal layout of sampling stations within the study area are important elements to address. The reader can consult texts discussing sampling design if he/she is unfamiliar with the concepts outlined below (Gilbert, 1987; Reckhow and Capra, 1983; Hammer and MacKichan, 1981; Sanders *et al.*, 1983, and Ward *et al.*, 1990).

The timing of sample collection should be scheduled to best characterize the water quality problem. Specifically, the critical period needs to be defined. Nonpoint source impacts are generally more sporadic, and may be related to: wet weather, storm events, or certain activities like irrigation, fertilizing, harvest seasons, construction schedules, or the manure spreading/storing period. Water quality impacts from municipal point sources are often most severe while the receiving water is at low flow. Some industrial point sources or municipal point sources with a large industrial input may have a greater impact on receiving waters at another time of the year. For instance, food processors discharge at harvest time when flows are slightly higher. Seasonally stratified sampling designs are useful when a study area has a mix of point and nonpoint source impacts. With seasonal designs, samples collected during different periods within the year can address different types of problems.

There are several sampling designs to choose from once the general sampling period is established. A routine sampling schedule (same site at same time of day, at set intervals) may be appropriate for basic water quality characterization or long-term trends. Changes between sample runs can be compared, but the diel variability in parameter concentrations at a specific site may be missed. A random sampling schedule can address station variability, but may not be effective in describing critical events, or follow qualitative changes as a block of water moves downstream, or seaward. Specific event (rainstorm) monitoring is important in many nonpoint situations. It can also be difficult because sometimes the investigator cannot predict when the events will occur. Usually a communication link with local weather stations has to be created, and a high level of organization, readiness, and coordination must be maintained.

The investigator needs to decide how samples will be collected over the survey period. Grab, continuous, composite, and sequential sampling methods have been used by Ecology.

Grab samples are the most common method used. They are normally hand dipped and can usually be collected quickly, with minimal equipment and processing needs. However, they may be less representative of the station, and require careful planning and forethought before collection.

Continuous monitoring using data-logging and probe devices is usually limited (by the technology available) to a few parameters, (*e.g.*, discharge, temperature, pH, dissolved oxygen (D.O.), and conductivity). Monitoring in this manner can yield valuable information on diel cycles. Equipment security, cost, maintenance, and calibration are the major difficulties with using data-loggers for unattended monitoring.

Automatic composite and sequential samplers can be used to monitor parameters that once collected, are stable over the sampling/storage period. Both types of samplers can be set to collect on a time interval or flow-paced basis. Compositor samples provide good average concentration. Sequential samples can be analyzed individually, or groups of samples can be composited. Sequential samples can provide excellent information on changes in concentration, especially over a storm event or industrial waste process cycle. Manual sequential sample collection over a 24-hour period is also performed. More personnel are required for manual compositing than for most surveys, but a larger variety of samples can be collected and analyzed. Sequential samplers generate more samples per event and therefore increase costs.

7) Obtaining a representative sample from a waterbody requires that the investigator understand the interaction of physical factors existing at the station with the source being monitored. A station located where complete mixing or homogeneous water quality exists will require fewer samples than one located at the intersection of several sources. In most cases, maps and an on-site visit can be used to determine how many samples should be taken to characterize a station, but preliminary sampling may be necessary in other cases. For example, conductivity or temperature measurements can be quickly performed as a depth profile and/or transect across a waterbody at a preliminary station location. The depth profile may indicate stratification, so that upper and lower layer sampling may be necessary. The transect may suggest an influence from an unknown upstream source, so that the station must be moved farther downstream, or samples must be taken across the waterbody and averaged together.

The longitudinal and lateral mixing of a tributary with a mainstem, or an effluent with the receiving water, requires some calculation or testing to evaluate station placement. Alternatively, conductivity or other tracer measurements can be taken to establish whether well-mixed conditions are present.

8) Quality assurance and quality control (QA/QC) procedures must be designed into each survey. The number of QC samples taken is directly related to the level of confidence an investigator wants in the results. The level of QC is also dependent upon the parameters analyzed, media sampled, and project budget.

The two important concepts for accuracy are bias and precision. Bias is a measure of systematic error due to the analytical method and the laboratory's use of the method or any other source (*e.g.*, hour of collection etc.), whereas precision refers to the reproducibility of a test under repeated trials. Bias may be estimated through tests on standard reference materials, matrix spikes, and method spikes. Precision may be assessed through analysis of field replicates, lab duplicates, and duplicate spikes (note: a replicate is a repeated sample collected immediately following the first, where a duplicate is one sample volume divided into two samples). Other useful QA/QC approaches include inter-laboratory comparisons and analysis of blank samples (transport, transfer, and filtration blanks in the field; method blanks in the lab). The laboratory (and ultimately, the project leader) must decide if QC results indicate the need for data flagging, correction, and/or elimination.

There are no hard and fast rules for how many QC samples are enough. One general "rule of thumb" is: 10% to 20%, or a minimum of one blank, one field replicate, and one lab duplicate per sampling day. Certified standard reference materials for internal spike sampling and inter-laboratory comparisons are also available through most commercial laboratories. Recommendations for frequency of spiked sampling are generally included in the method description.

Lab and Equipment Scheduling and Budget

It is important to schedule equipment and laboratory needs as soon as possible. Lab capacity may be limited for some parameters. The following are a few "tips" which may make your lab and equipment scheduling smoother and more successful:

- Determine type of sample transport to lab and rough schedule (sometimes air, bus, or ferry transport is necessary, so you need to know where the terminal is located and the departure/arrival schedule). Check these against sample holding times to determine if there will be a conflict. Also, travel time from project site to terminal should be considered if they're separated by long distances.

- Know what to sample to meet the project objectives: are the type and number of samples adequate?

- What QC samples are needed? Which QC samples need to be included in the lab budget and which will the lab pay for?

- Check with the lab to see what analyses they can do and detection limits they can achieve, and compare that to what you need.

- If the lab can't perform a particular analysis or develop an appropriate procedure, contact a lab that can perform the analyses.

- Ask the lab for the QC data generated for the project to back up detection limits, resolution, etc...

- Talk with the lab person in charge of scheduling: know exactly what you want run (special detection limits or analyses, mixed media, etc.), roughly when and how samples will arrive, and how many. If the lab can't do the analyses because of lab load capacity, can you reschedule your sampling dates and still meet objectives?

- Ask the lab for advice if you need it, and check the estimate of lab cost against the budget.

- Familiarize yourself with the proper operation of field equipment and check to see that it is operable. If it's not operable, either schedule repair or find an alternative.

- If possible, bring back-up equipment.

- Check to ensure that field reagents (*e.g.*, pH buffer) are fresh and adequate.

Reconnaissance Trip

The complexity of a monitoring scheme or unfamiliarity with sampling locations should determine whether a reconnaissance trip through the project area is warranted. A recon trip, if practical, is useful for meeting local contacts, verifying map and field conditions, locating boat launch sites, and dealing with other details. Some other tasks may include:

- Getting permission to cross private property to access a sampling site.

- Observing if chosen sites are representative and safely accessible.

- Collecting field data in locations where information is limited (*e.g.*, dissolved oxygen, conductivity, pH, and discharge) to run in preliminary models or calculations.

- Talking to dairy managers about manure application and spreading schedules, or Wastewater Treatment Plant (WTP) operators about discharge routines, problems, cycles, production volumes, and upsets.

Field Survey

Anything that could have been done to plan ahead should have been done. Once in the field, your options to obtain bottles and replacement parts, or time to establish survey stations, becomes limited. A few field considerations:

- Keep a detailed and legible notebook. Entries should include: project name, sampler's names, weather conditions, sampling date and time, site descriptions, and water quality or other data.

- Keep a sense of order. Establish your sampling scheme prior to going into the field. Sample upstream to downstream (or reverse) to best meet program objectives. The upstream to downstream order on a small stream can sometimes create contamination problems downstream after upstream sites are sampled. The reverse order does not allow plug flow sampling (*i.e.*, sampling of a specific block of water as it moves down the drainage). Estuarine or tidal river areas also can have difficult station sampling orders depending on the tide changes.

- Collect water quality samples so as not to disturb benthic invertebrate or sediment sampling areas. Also, do not collect water samples downstream of where you are walking, wading, or have recently disturbed the sediment.

- Watch and be prepared for unexpected sources of contamination, while being flexible enough to deal with them. Take notes on land uses adjacent to and upstream of sampling sites.

- Call the lab when samples are coming/not coming on schedule, or if there have been major changes in the number or kind of samples.

- Pack samples in coolers in a way which prevents breakage and intrusion of ice water into sample containers. It is sometimes helpful to put sample bottles into plastic bags within the cooler. Also, "blue ice" is recommended when shipping samples via air freight to prevent water leakage from the cooler into the cargo area.

- Make sure sample labels are clearly marked with appropriate information on sample data and analysis requested. A waterproof pencil or indelible ink pen should be used.

- Protect field meters against excessive exposure to water, shock, heat, or cold. Secure meters in vehicles and boats against jolting and falling.

- Long-term monitoring devices should be secured by chain and lock, and camouflaged when located in unsecured areas.

Specific protocols on sample collection and handling can be found in the following publications: Mills *et al.* (1986), PSEP (1986), Striplin (1988), EILS (1992), Plafkin *et al.* (1989), APHA *et al.* (1992), and EPA/PSEP (1990). Other guidance can be found in the References/Annotated Bibliography sections.

Special Studies

There may be situations where special studies are necessary to augment or verify existing information. During plan development, special studies may be used to define specific problems. For example, a more detailed study of stormwater characteristics and testing for cross-connections may be necessary in an urban area. A pesticide screening in agricultural runoff may be the aim of another study in a rural area. During watershed plan implementation, special studies will take on many different forms. The expected diversity of special studies precludes development of general guidelines, however two particularly important types of special studies are worthy of brief mention.

A special study for priority pollutants should be considered for initial watershed characterization if such data do not exist. Priority pollutants are a list of 137 organic compounds and metals considered potentially toxic or carcinogenic. These compounds require careful collection procedures and are expensive to analyze in the laboratory.

Concentrations of many priority pollutant compounds are usually below detection limits in the water column, even when there is a known source affecting water quality. Because these pollutants are typically associated with particulate matter, they are often most effectively evaluated by analyzing sediment samples. Sediment samples may show the impact of long-term, chronic pollutant doses that cannot be detected in the water column. Therefore, sediment samples should be analyzed as a screen to check for the presence of priority pollutants. Sediment samples for priority pollutant screening should be collected from depositional areas (*e.g.*, pools) below potential sources or at the base of catchment areas.

Sediment collection procedures are described in Appendix III. An analysis of the sediment sample for priority pollutant screening should include the following groups of compounds:

Acid Extractable Compounds
Base-Neutral Extractable Compounds
Pesticides
Herbicides
Polychlorinated biphenyls (PCBs)
Priority Pollutant Metals

Grain size, total organic carbon (TOC), and percent solids should be measured in each sediment sample to aid in data interpretation. The cost of a full priority pollutant scan at detection limits applicable to water quality standards can be very high. It may be appropriate to do a screening for compound groups initially, based on the watershed characteristics and known pollutant sources. Results can then be used to target analyses at lower detection limits for pollutants that were identified but unquantified in the initial screen. Assuming concentrations are acceptable (*i.e.*, below detection, or similar to published concentrations measured at unimpacted sites), sediments need only be sampled occasionally. If sediments or previous work done in the watershed indicate there may be a problem, further sampling should be initiated.

Another type of special study, biological assessment, examines the biological component of freshwater ecosystems. Biological assessments may be of value in evaluating habitat condition, trends, and cumulative impacts of pollutants.

Freshwater communities are comprised of various groups of organisms (*e.g.*, fish, benthic macroinvertebrates, plankton, etc.). Each group may provide specific types of environmental information based on habitat requirements and the suitability of existing habitat. The use of biological information in an environmental assessment integrates water quality over time and provides an evaluation of existing beneficial uses, while water samples provide information for a more discrete time interval. Guidance on sampling procedures for biological assessments can be found in Section VII (Annotated Bibliography) and Ecology (1994).

Data Summaries and Interpretation

Data should be presented in summary form in the text of assessment reports, with an appendix containing all survey data. Laboratory and field QA/QC techniques and results should also be summarized. Precipitation information and some discussion, or calculated value, for estimating watershed saturation conditions should be provided for each sampling event. Figures showing sampling sites for routine and runoff-event surveys should be included, in addition to other appropriate figures (*e.g.*, land use patterns or septic system distribution). More information on this topic is provided in Section IV, Data Management.

Loading calculations for important sources or tributaries and a discussion of how each compares to the total pollutant load of the system (percent load) should be included in the text and tables (see Appendix II). The loading assessment should also include a comparison of how the major sources are related to each other in terms of total stream volume (percent total load versus percent total volume). Concentrations and/or loads should be compared with water quality standards and other streams or stream segments. The text should include discussion of how important sources vary with season and flow conditions. Comparisons of historical and current data should be included where possible.

III. Long-Term Monitoring

Purpose

Long-term monitoring should be designed to provide watershed management committees and lead agencies with information on trends relating to land use, water quality, habitat, and biological conditions (Chapter 400-12-515(2)(c)(i-iv)). Long-term monitoring should enable a determination of whether implementation of source control programs in the action plan have been effective in protecting water quality, beneficial uses, and achieving other action plan goals. Design of long-term monitoring networks are site specific in nature and require information from references included in the Annotated Bibliography (see Section VII). The monitoring design should be statistically sound. It should be designed to detect impacts caused by human activities; it should also measure resource improvement or degradation following changes in those activities. Long-term monitoring can be used to increase public awareness and knowledge of water quality problems, needs, and potential solutions. The lead implementing entity or agency responsible for sampling must make a commitment up front to long-term monitoring because of the need to budget resources. Results of long-term monitoring should be described in a written report that will guide activities and can be updated periodically.

General Approach

Water quality problems which may be identified through the long-term monitoring include (but are not limited to): toxic and/or bacterial contamination of water, sediment, plants, and animals; nutrient enrichment; oxygen depletion; turbidity; acidification of fresh water; thermal changes; and sediment deposition. The long-term monitoring should detect changes in the elements addressed in the watershed characterization, namely: water quality; sources of contamination; and potentially threatened resources. Detection of statistical trends in water quality requires long-term data. It is usually difficult to detect a trend from small sample numbers. Generally, a minimum of five years of monthly sampling is necessary in order to detect a meaningful trend in water quality data. Although this depends on the size of the change observed between years compared to the variability of the data during a single year.

Any monitoring program to evaluate or characterize nonpoint source pollution must monitor land use (see Section VI) and the implementation of nonpoint source control actions (*i.e.*, BMPs). Intensive tracking of where and when BMPs are implemented and how well they are being maintained is necessary to link land treatment to water quality. Management measures tracking should provide the necessary information to determine whether pollution controls have been implemented, operated, and maintained adequately. Without this information, water quality monitoring data will be difficult to interpret. That is, there will be no way to determine if the management measures have been effective unless it is known to what extent the controls were implemented, maintained, and operated. Statistical associations can be drawn between implementation data and water quality data to indicate whether management measures have been successful in improving water quality and whether additional management measures are needed to meet water quality goals.

Sampling locations should be carefully selected. Moving long-term monitoring stations should be avoided, although additional stations can always be added. Spatial allocation of sampling stations is determined by knowledge and experience with the study area, while taking into account previous studies and results. All significant tributaries should be sampled in addition to areas with high pollutant loading potential, like urban areas (*i.e.*, stormwater), industrial sites, commercial dairies, silviculture, or agriculture. The uniqueness of individual drainages precludes guidance on specific station placement, however the sample scheme developed should enable long-term evaluation of any previously identified problem areas. For more specific guidance on long-term monitoring, refer to the references in the Annotated Bibliography section of this document.

Historical and/or pre-assessment data can help in sorting out variables to sample. How often samples are collected is usually a function of the objectives, budget, available personal, and logistics, although the more samples collected over time, the more knowledgeable and confident water quality managers will be in their decision making. A monthly sampling frequency is recommended for long-term monitoring (Lettenmaier, 1977; Gaugush, 1986).

Consistency is crucial over time for useful comparison of results. Definition of how the data will be used should be one of the first issues considered. Water quality managers need to develop the information expectations early in the project design, or it is unlikely they will be met. The information limits the monitoring system will produce should be quantified along with the information water quality managers will need. Long-term monitoring must also consider the use of routine (unbiased) versus storm event (biased) sampling, because of the significance of nonpoint impacts to watersheds.

Long-term monitoring will be used by the lead implementing agency and Ecology to evaluate the action plans, therefore a reporting schedule for monitoring information should be included in each watershed plan. Evaluations will be conducted during annual plan reviews by the lead implementing entity, Ecology, and others.

IV. Data Management

Data management is an important process in any water quality assessment program. Data management includes the recording process for collecting, analyzing, reporting, transferring, and storing data. The data management process should be defined during the planning phase of a data collection project, and includes preparing forms (field and laboratory) and procedures for entering data (on forms or in computer files).

Uniformity in data reporting formats allows data to be more easily transferred, and allows data users access to a much larger base of information. It is a goal of Ecology that all collected data be reported in compatible formats. Ecology currently does not have an agency standard for data management. However, the Puget Sound Water Quality Authority (PSWQA) outlined a data storage format for the Puget Sound Ambient Monitoring Program (PSAMP) which Ecology uses as an example of an appropriate data management system for water quality data. This format is designed to include all aspects of water quality data collection and laboratory analysis results. The PSAMP database was created to address environmental monitoring programs in Puget Sound. However, it also can be used for other water quality database management applications.

The PSAMP data format recommendations are described in PSWQA (1991). A description of each file type, and an outline of file components, are detailed in this document. An example of the PSAMP format is presented in Tables 2 and 3. Database files should contain basic information regarding sampling location, date, time, collection method, water quality information, and analytical methods.

A data file should consist of information collected from a single "survey" where water samples are continuously collected over the period of one or more days. The file format includes a field or column called SURVEY ID which is unique to each sampling session within the monitoring program.

An example of the data entry for two parameters, fecal coliform and total phosphorus, into a spreadsheet using the PSAMP format is displayed in Table 4. If the capability exists, investigators should attempt to meet the requirements of PSAMP. This makes survey data usable by a much broader audience.

Although the PSAMP database format provides for a good data management system, for smaller projects other formats may be used as well, as long as they are sufficiently documented. An example of a data spreadsheet with field and laboratory measurements is presented in Table 5. Note that there are two sample dates with 13 sites and 12 parameters for Anywhere Creek. Not all parameters were measured at each site, which explains the empty cells in the spreadsheet. In order to transfer the data presented in Table 5, a data dictionary would have to be created which provides information on the contents and structure of the database (*e.g.*, define: variable names, units of measurements, data qualifiers, etc.).

Each data file may contain one or more water quality parameters. The decision on how many parameters to include in each data file is left to the discretion of the investigator. For example, one may wish to separate nutrient and physical data into separate data files. On the other hand, it may be more convenient to retain all data from a particular survey in a single file. Individual data files should eventually be combined into a database. Creating a database facilitates different combinations of data queries.

Sample station locations should be archived along with the data. The location of sampling stations should be plotted on a U.S. Geological Survey 1:24000 (if coverage is available) or 1:62500 series topographic maps. Sampling stations should be clearly labeled with STATION ID designations. Ideally, latitude and longitude would be recorded for each site to facilitate data inclusion in a GIS layer.

Data Analysis and Presentation

One of the most difficult parts of any water quality assessment project is determining how the data should be analyzed and presented. Methods for data analyses should be determined *a priori*, along with and as a function of, the study objectives and sampling design. It can be difficult for investigators to avoid imposing their personal bias into the data analysis process. In order to maintain objectivity, investigators normally rely on statistical methods for analysis of water quality data.

If water assessment studies are properly designed, the need for qualitative interpretation of the data can be replaced by statistical testing. This is not to suggest that qualitative judgements are not needed, but the data should be analyzed and presented as objectively as possible.

The scope and breadth of statistics is formidable. Persons interested in developing an understanding of statistical design and analysis of environmental data should consult basic textbooks on the subject, such as *Biostatistical Analysis* by Zar (1984) or *Biometry* by Sokal and Rohlf (1983). However, there are a number of issues relative to water quality data that are particularly important to understand applying statistical analyses and presenting data. The following is a brief discussion of some of those important considerations.

As mentioned earlier, data analysis should be considered during the design of the project to avoid collecting unusable data. When analyzing water quality data, it is important to be aware if they are auto-correlated; non-normally distributed; contain seasonality; overly emphasize a particular time period; or contain observations below detection limits (censored).

These data characteristics can be a problem if not recognized. For example, the assumption that water quality data are distributed normally may lead to misinterpretation of a non-normally distributed parameter (*e.g.*, fecal coliform data). There are statistics and procedures to apply to a data-set to test, and in some cases, correct the data. In the book, *Engineering Approaches for Lake Management* by Rechow and Chapra (1983), these issues and the concept of "robust" statistics are reviewed (is the statistic appropriate, even when underlying assumptions are violated?).

After analysis, data are best presented with *simple* figures and tables. Avoid generating figures that rely on color for clarification, because these do not easily reproduce. Also avoid three-dimensional drawings unless they are very clear, because usually only the author knows what they mean. Finally, make sure each figure and table is self-explanatory (*i.e.*, can stand on its own). Captions should clearly explain the content, and footnotes should be used to highlight anything that might be unclear. A reader should not have to cross-reference text or other figures and tables to understand the content of a figure or table.

Reporting

After the data analysis is completed, it is time to write up the findings of the study. The underlying goal of the study report should be to address the original objectives stated in the project plan. The report should be focused toward deriving concise conclusions and recommendations based on the original objectives. If the project failed to achieve one or more of the original objectives, it should be stated in the conclusions and recommendations section of the report why they could not be met.

The following are some general considerations for report preparation:

- The format of reports is not fixed. However, there are some things that are included in most reports such as: introduction; methods; results and discussion; conclusions/recommendations; and references.

- The report should be clear and accurate. Jargon should be avoided; simplicity in style is preferred. Strive to be concise -- don't spend a paragraph to make a point when a sentence will suffice.

- Data which form the basis of conclusions and recommendations should always be made available in the report, either in tables, figures, appendices, or through the reference page.

- If the project is funded by Ecology, at least two copies of the draft report should be sent to the Ecology project officer for review. The authors are expected to address all review comments. If the authors disagree with certain comments, they should discuss their concerns with the Ecology project officer.

- A final report should be prepared after all review comments are resolved. Data should be contained on IBM-PC compatible floppy disks and conform to the protocols discussed in the Data Management section of this report.

V. Riparian Corridor Assessment

Introduction

This guidance discusses a survey approach that emphasizes visual observations to evaluate the physical and biological conditions of the water, stream channel, and habitat within the riparian (stream side) corridor. A riparian corridor includes the stream channel, over-bank areas and streamside vegetation, including any vegetative buffer strips that are present between the channel and the adjacent land use. The riparian corridor assessment also includes a description of land uses adjacent to the stream and identification of desirable water sampling locations. This assessment is important because it provides a method to determine the health of the riparian corridor, and accordingly, its ability to support beneficial uses such as fish and wildlife. The recommended approach can be used to obtain information for the initial assessment monitoring and long-term water quality assessments that are part of a watershed action plan. The approach consists of five elements:

- Element 1: Collection & Review of Existing Information
- Element 2: Windshield Survey
- Element 3: Field Assessment

- Element 4: Post-field Assessment
- Element 5: Special Surveys

Note: The combination of elements 1 and 2 is called the Pre-Assessment.

Pre-Assessment

There are two elements involved in the pre-assessment. In element 1, existing information is examined, such as water quality and quantity, environmental background factors, current land use, and aquatic habitat conditions. Published papers, unpublished data, or personal communications are used. The sources of this information are many and varied. The scoping tool used to conduct this literature/data search is found in Appendix I. This information is collected in order to furnish background data on the assessment area, which will provide an awareness of conditions/problems likely to be encountered in the field and assist in establishing objectives for the assessment. General information need not be site-specific and is applicable if it aids the surveyors in relating cause and effect in a watershed; for instance, between land uses and impairment of beneficial uses.

Element 2 consists of a windshield or drive-through survey to locate and identify land use types, familiarize the surveyors with the survey area, field check maps and aerial photos, and identify potential survey segments. This overview gives surveyors a chance to check the existing information obtained in Element 1 and conduct some "ground truthing." The pre-assessment should provide sufficient information to identify missing data, and locate probable nonpoint sources and sample sites before expensive survey work is done.

Field Assessment

Element 3, the field assessment, is a qualitative stream survey using primarily visual observations to characterize the physical condition of the stream channel, riparian vegetation, instream fish habitat, streamside wildlife habitat, other beneficial uses, and current adjacent land use. Various field assessment techniques and monitoring protocols have been published which are suitable for streams in Washington. Some of the more useful sources of field assessment methods are Hayslip (ed.)(1993); Bauer and Burton (1993); Schuett-Hames *et al.* (eds.)(1993); and McDonald *et al.* (1991). The techniques described in these references range from using strictly visual estimates to making field measurements of physical stream characteristics. The level of assessment chosen will depend on individual project objectives and the desired level of effort. Depending upon the experience of the surveyors, some training may be required. The state technical assistance program, pursuant to element E-5.3 of the 1991 Puget Sound Water Quality Management Plan, may be able to satisfy in part this training need. Local governments may also take an active role in providing training.

The objectives of the field assessment are to further confirm or update the data collected in the pre-assessment, identify data gaps, identify nonpoint sources of pollution, provide a general characterization of the riparian corridor, provide feedback information to the water quality collection programs, and identify critical stream reaches or potential special study areas.

During the field assessment, the surveyor should look for the following conditions from selected survey protocols:

1. Features that indicate how stormwater runoff (related to watershed activities) affects stream channel form and stability. Some examples are:

   - Undercut or collapsed stream banks.
   - Excessive lateral migration or downcutting of the channel.
   - Extensive channel erosion or sediment deposition.

2. Conditions that reduce or eliminate aquatic habitat. Some examples are:

   - Bottom gravels clogged or compacted with fine sediments.
   - Structures that block upstream migration of spawning fish, such as elevated culverts and grates.
   - Invasive or non-native aquatic plants, reeds, or grasses that clog the stream channel and reduce habitat for native bottom-dwelling plants and animals.
   - Streambanks trampled by livestock or disturbed by heavy equipment.

3. Stream corridor vegetation which provides canopy cover, stabilizes stream banks, provides in-stream large woody debris and wildlife habitat, and filters out pollutants in runoff from nearby land areas. Some examples are:

   - Tall trees that shade the stream, keep the water cool, and control the growth of channel-clogging vegetation.
   - Low lying bushes and grasses that provide food and cover for wildlife and retard the movement of runoff from adjacent uplands.
   - Large woody debris within the stream channel in stable configurations that provide cover, sediment storage, and habitat complexity which benefits fish and other aquatic life.

4. Visual indications of water quality impairment. These include:

   - Factors that cause the water to be cloudy, such as silts or industrial discharges.
   - Floating material such as extensive algal mats, trash, or abundant suds.
   - Odors foreign to a natural area, such as those from human/animal wastes or petroleum.

- Deposits of land-derived silt, such as from construction sites or trampled banks.

5. Adjacent land uses that potentially pollute the stream. These include:

   - Residential or commercial developments with paved surfaces which drain into the stream without adequate treatment.
   - Livestock with uncontrolled access to the stream, overgrazed pastures, and fields plowed up to the stream banks.
   - Logged areas with insufficient riparian buffers zones.
   - Paved and unpaved roads.

6. Point sources of pollution (*e.g.*, pipe outfalls) emanating from adjacent land uses. Some examples are:

   - Storm sewer outfalls.
   - Municipal sewage treatment plant outfalls.
   - Industrial plant outfalls.

Post-Field Assessment

Upon completion of the field assessment, field data are combined with information collected in the pre-assessment and a report is prepared. This report should assess the status of the riparian corridor according to the objectives established prior to the survey, and recommend needed studies. Based upon this report, detailed or special surveys can be planned.

Special Studies

Special studies will be conducted when necessary to expand or verify existing information. Many types of special studies may be necessary. Methods for each type of special study are beyond the scope of this guidance. This information may be obtained by reviewing scientific literature, consulting the Puget Sound Protocols, or contacting state technical assistance staff. These studies involve very precise measurements applied to a smaller site or specific stream reach. Some examples of these projects include establishing stream index sites to measure cumulative changes, sampling aquatic insect communities or fish populations (bioassessment), or conducting detailed studies to determine fish habitat improvement needs.

VI. Land Use Characterization

Introduction

Under the provisions of the Nonpoint Rule, information on land use and population, including existing and potential trends, should be included in the watershed characterization prepared as part of watershed planning. An effective land use characterization describes the relationship between land use and water quality and assesses how future land use changes in the watershed may impact beneficial uses of the water.

Land use data at two levels is needed to evaluate impacts on water quality:
1) describing what the land use is (*e.g.*, agricultural, forest, or residential); and
2) describing the condition of the land use (*e.g.*, within each land use type, each site would have varying levels of pollution potential depending on proximity to streams and wetlands, age of septic systems, type of soils, management practices, and so forth).

For purposes of watershed planning, the three basic elements for land use assessment are:

1. An initial, or base, land use inventory that characterizes and displays existing land use in the watershed.

2. A process for periodic updating of the base inventory.

3. An evaluation of the inventory which describes the direction of land use change in the watershed and discusses the relationship between land use and water quality.

   This section describes some of the common methods for collecting land use information. This section also discusses some important factors to examine when analyzing the information which has been collected. The desired end products of land use assessments are:

   - An understanding of the impacts that land use has on water quality; and

   - An identification of land use practices which should be changed or restricted to improve or maintain water quality.

Sources of Land Use Information

The land use characterization process starts with the development of an initial, or base, land use inventory. The USGS completed a land use survey in 1974 which is available for all areas of the state. If no recent inventory is available, a base inventory could be conducted using the USGS survey in conjunction with the watershed planning process.

In order to establish baseline information and correlate water quality monitoring results with changes in land use, information must be collected on land use within the watershed. Land use information can be compiled from a number of sources. The most reliable source of information is a land use survey consisting of a direct site inspection of each parcel of land. If practical, the individual parcel inspection should be used for the initial characterization. Other methods of compiling land use data are often combined with, or substitute for, parcel-by-parcel inspection. Other methods include the study of photographs or building permit data, and the review of special surveys or inventories.

1. Visual Survey

   A parcel-by-parcel visual, or "windshield," survey can be used to gather information on a variety of subjects. The visual survey, as described in this section, is intended to inventory land use throughout the watershed. A parcel-by-parcel survey is often conducted near the start of a planning process to identify the existing uses of the land within a specified area. The survey provides part of the base of information for an effective planning process, within the study area, at a certain point in time. Information is easily coded in the field on maps at a scale of 1":50' to 1":200' in urban areas, and to 1":800' in less developed areas. County assessor's maps, approximately 1":100' to 1":200' scale, are effective land use data base maps. Map coding can range from a few general classifications to detailed sets of classifications which more closely represent the full range of land uses.

   The visual survey and accompanying organization of field data into a widely usable form can be a very time-consuming undertaking. And, unless land use information is transferred to a more usable format, land use field maps can be bulky and difficult to handle due to large work space requirements. The detriments of a full-scale visual survey are offset by the relative infrequency of the need for this type of survey and the detailed quality of information gained. City and county planning departments are capable of conducting windshield land use surveys. Also, citizens can be easily trained to assist with the visual collection of land use data on a parcel-by-parcel basis.

While the visual type of land use survey may be conducted infrequently, a variety of techniques can be employed to update and augment the initial inventory information on an ongoing basis.

2. Aerial Photograph Analysis

A wide array of aerial photographs and satellite imagery, and in some cases video information, can be used to gather land use information. These information sources are also used for riparian corridor assessment and other types of resource evaluation needs.

Aerial photographs are a valuable tool when used in conjunction with visual surveys as a base map for field work, and a source of information for areas not readily visible from roadways.

Conventional aerial photographs are shot from overhead or sideways (obliques) using 9" x 9" black and white, color, or color infrared film. Carefully-timed, overlapping, overhead aerial photographs can be taken to provide stereo imaging for greatly enhanced detail analysis. Developed 9" x 9" film is often contact printed on same-sized paper or enlarged. Aerial photography is also available in digital format.

Aerial photography overflights are usually flown on a straight path, which allows the production of photo strips of the surveyed area. However, many deviations occur from the norm, such as when photographing obliques of an irregular shoreline. Aerial photographs of some areas are available on a yearly edition basis. Historical aerial photographs are available from the 1940's onward, with more frequent and extensive coverage in more recent times.

Aerial photographs are available from a number of different sources, such as private companies, state agencies, or the federal government. Satellite imagery is available in a variety of formats including color prints and a wide range of digital images produced from the bands in the visible and near-visible spectrum.

The usefulness of satellite imagery that is available to the public is limited due to scale, resolution, and interval of survey. However, good land use information can be garnered from satellite imagery on such factors as extent of developed areas within a region, relative health of vegetation (over large areas), and large scale patterns of air and water pollution. Appendix IV contains a list of sources of aerial photography and satellite imagery.

Video surveys are available for some roadway corridors, including many state highways. Video surveys can quickly gather and display much of the information of a traditional visual or windshield survey and allow detailed and repeated analysis of locations from the office video monitor.

The various types of photography provide the quickest and least expensive choices for collecting diverse and dispersed land use information. Information about the extent of timber harvest within a watershed, boating activity, grazing animal counts, and other significant but remote land uses can be effectively gathered through aerial photograph analysis.

3. Other Sources of Land Use Information

Local governments often generate and maintain certain types of information which can be used to identify land uses within a watershed. The county assessor maintains maps of parcels in the county and listings of the value of all improvements to the individual parcels. Some local governments now use geographic information systems (GIS) to maintain land use and other data.

The city or county planning department should be the first stop for obtaining local land use information. Planning departments frequently maintain and update land use maps, census information, aerial photographs, and other sources of land use information. The comprehensive plan map(s), available at planning or community development departments, can provide information on the general types of uses that could be developed within the watershed.

The county or city building department reports all permitted new structures, demolitions, and moves of residences (including mobile homes) to the state Office of Financial Management on an annual or more frequent basis. Building data are used to update census estimates and forecasts of population and housing.

Utilities can in some cases provide information on utility service areas and planned service expansions, numbers of customers served, and types of service and infrastructure.

Health departments collect and maintain information regarding on-site sewage disposal (septic) systems and other public-health related data which can relate to land use.

Special purpose districts, such as conservation districts, irrigation districts, and port authorities, collect and maintain information on certain items related to land use within their respective areas of jurisdiction. Some special districts can provide data on farm inventories, such as the numbers and types of farms in a watershed, the numbers of inspected and corrected animal waste disposal systems, kinds and numbers of agricultural best management practices (BMPs), changes in numbers and distribution of grazing animals, and related information. Special purpose districts can also maintain stream and irrigation system survey information which describes the condition of watercourses.

The federal government collects land use information which can be used for analyzing land use changes. Sources of federal information include census reports, aerial photographs, satellite data, and various maps and reports. The U.S. Geological Survey maintains a series of maps which provide basic land use information. Federal information is generally unavailable on a parcel-by-parcel basis.

Analysis of Land Use Information

Land use information can be gathered directly from the field or from a wide variety of secondary sources, as noted above. Once the information has been obtained, some manipulation is usually necessary to produce a usable product. The Nonpoint Rule calls for an initial land use characterization to be available at the beginning of the planning process. The Nonpoint Rule also calls for watershed plans to contain a long-term monitoring program that includes information on trends related to land use to help determine whether the nonpoint pollution control strategies in the plan are effective.

1. Initial Characterization

The initial land use characterization provides information on land use in the watershed. The scope of the characterization is dependent upon existing resources and products as well as the ability of the watershed management committee and staff to collect information. In some cases, citizen volunteers or community/environmental groups may be used to collect information. The initial characterization of land use is also used in the preparation of a problem definition statement to be included in an action plan.

The initial land use characterization should describe the current uses of the land within the entire watershed. Important land use categories that should be described and quantified include: numbers of houses (and, indirectly, population); areas of commercial and industrial development; miles of paved and unpaved road; flood plain and wetland areas; parks; schools; utility corridors; marinas and boating intensity; areas forested or recently harvested; farms and animal densities; solid waste disposal sites; open space areas; mining and gravel extraction locations; as well as any other land uses that could impact water quality. In addition, the watershed's drainage network should be described in order to relate land use categories spatially to watercourses.

2. Long-Term Monitoring Program

The land use portion of the long-term monitoring program should provide information on land use trends. This information is used in conjunction with other information to determine whether pollution control strategies are effective in reducing water pollution and improving water quality. This information provides a basis for recommending watershed management plan revisions.

When the initial land use inventory for a watershed has been completed, a process should be established to update the information on a periodic basis. If land use information is maintained in a computerized geographic information system (GIS), new information can be inserted into the data base. A GIS can also simplify the assessment of land use changes that occur over time. Upon completion of periodic updates of the land use characterization, recommendations for plan revision (if needed) would be made to the lead implementing agency. Examples of such recommendations include:

- revising the water quality sampling design to monitor new, or changing, land uses;
- concentrating technical assistance or public education in a certain area that is undergoing land use change; and
- adopting, modifying, or eliminating ordinances and/or regulations to reflect a change in the need for land use controls.

One of the most valuable functions of an action plan's long-term monitoring program is the identification of trends within the watershed. The land use portion of the long-term monitoring program identifies increases and decreases of the various uses of the land within the watershed. These and other land use trends are then compared with water quality monitoring trends, nonpoint control (BMPs) changes, and other information to determine the effectiveness of the watershed planning process and to suggest changes to improve water quality program elements.

VII. Annotated Bibliography

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One of the few statistics texts that describes advantages and disadvantages of each method and under what conditions they should be applied. Multivariate analysis is particularly useful for biological studies in that underlying patterns in large data sets are identified, which may reveal relationships between biota and their environment.

Gilbert, R.O., 1987. Statistical Methods for Environmental Pollution Monitoring. Van Nostrand Reinhold Company, New York. 320 pp.

Provides sampling designs and statistical tests suited to water pollution data. Numerous examples and case studies are given to illustrate the use of these procedures with real data.

Hammer, M.J., and K.A. MacKichan, 1981. Hydrology and Quality of Water Resources. John Wiley and Sons, New York. 486 pp.

Presents and integrates both the hydrology and quality of ground water, flowing waters, and impounded systems. Contains a useful discussion of oxygen modeling in streams and rivers.

Hellawell, J.M., 1978. Biological Surveillance of Rivers: A Biological Monitoring Handbook. Water Research Centre, Stevenage, England. 332 pp.

Methodology for conducting surveys and monitoring programs are reviewed for each biotic component of the aquatic environment. This handbook serves as an excellent guide for establishing a sample design and collection methods.

Hynes, H.B.N., 1970. The Ecology of Running Waters. Liverpool University Press, Liverpool, England. 555 pp.

This text has served as the standard reference for information regarding the ecology of aquatic ecosystems. A review of information regarding physical/chemical parameters, algae/periphyton, benthic macro-invertebrates, and fish contains a comprehensive literature review and insightful integration of all the components.

Lettenmaier, D.P., 1977. Detection of Trends in Stream Quality: Monitoring Network Design and Data Analysis. Charles W. Harris Hydraulics Laboratory, Department of Civil Engineering, University of Washington, Technical Report No. 51, Seattle, Washington. 95 pages.

This document reviews Ecology's Ambient Monitoring Program, and analyses certain records from the existing network for trends. The trade off between reduction in statistical power (trend detection) of tests on stratified data (collected one year in three) and continuous sampling is investigated. Techniques for assessing auto-correlated time series for trends are reviewed and a number of practical problems in data analysis are discussed, with emphasis on graphical screening techniques.

Merritt, R.W., and K.W. Cummins, 1984. An Introduction to the Aquatic Insects of North America, 2nd ed. Kendall-Hunt Publishing Company, Dubuque, IA. 722 pp.

This is the most widely used key for identifying freshwater aquatic insects. A review of trophic classification, habits, and habitat preference accompanies each section.

Mills, W.B., D.B. Porcella, M.J. Ungs, S.A. Gherini, K.V. Summers, Lingfung Mok, G.L. Rupp, G.L. Bowie, and D.A. Haith, 1985. Water Quality Assessment: A Screening Procedure for Toxic and Conventional Pollutants in Surface and Ground Water - Part I. EPA Report 600/6-85-002a, Athens, GA. 609 pp.

Provides simplified methods for assessing the loading and fate of conventional and toxic pollutants in water. Much of the data required for these methods is provided in the document.

------, 1985. Water Quality Assessment: A Screening Procedure for Toxic and Conventional Pollutants is Surface and Ground Water - Part II. EPA Report 600/6-85-002b, Athens, GA. 444+ pp.

Provides simplified methods for assessing the loading and fate of conventional and toxic pollutants in water. Much of the data required for these methods is provided in the document. Part II presents assessment techniques for impoundments, estuaries, and ground water.

Nielsen, L.A., and D.L. Johnson (eds.), 1983. Fisheries Techniques. American Fisheries Society, Bethesda, MD. 468 pp.

This text describes methods involved in planning and implementing fisheries surveys. It contains information authored by many experts.

Pennak, R.W., 1989. Freshwater Invertebrates of the United States. John Wiley and Sons, New York. 628 pp.

This key presents comprehensive information regarding freshwater organisms, including protozoans, arthropods, and mollusks. It was one of the first keys of its type that covered a large variety of organisms.

Plafkin, J.L., M.T. Barbour, K.D. Porter, S.K. Gross, and R.M. Hughesm, 1989. Rapid Bioassessment Protocols for use in Streams and Rivers: Benthic Macroinvertebrates and Fish. EPA Report 444/4-89-001, Washington, DC.

Provides several methods for rapidly assessing the status of invertebrate or fish communities in a stream. The methods vary in complexity, but all five techniques include habitat assessments as part of the bioassessment.

Prescott, G.W., 1978. How to Know the Freshwater Algae. Wm. C. Brown Company Publishers, Dubuque, IA. 293 pp.

Provides keys to the freshwater algae, as well as information concerning habitat and distribution of species.

------, 1980. How to Know the Aquatic Plants. Wm. C. Brown Publishers, Dubuque, IA. 158 pp.

Provides keys to macrophytes, as well as information concerning habitat and distribution of species.

Resh, V.H., and D.M. Rosenberg (eds.), 1984. The Ecology of Aquatic Insects. Praeger Publishers, New York. 803 pp.

A reference providing information regarding the ecology of macrobenthics which are discussed by numerous experts in this text. An extensive literature review accompanies each chapter, which serves as an excellent start point for aquatic insect investigations.

Sanders, T.G., R.C. Ward, J.C. Loftis, T.D. Steele, D.D. Adrian, and V. Yevjevich, 1983. Design of Networks for Monitoring Water Quality. Water Resources Publications, Littleton, CO. 328 pp.

This book was developed from a Colorado State University short course of the same name. Articles cover various monitoring design issues: statistical representation, station location, sampling frequency, parameter selection, and step-by-step procedures for setting-up a network.

Schuett-Hames, D., A. Plues, L. Bullchild, and S. Hall (eds.). 1993. Timber-Fish-Wildlife Ambient Monitoring Program Manual. TFW-AM9-94-001. Northwest Indian Fisheries Commission, Olympia, WA.

This manual presents detailed protocols used for long-term monitoring of stream and riparian zone characteristics and assessment of watershed cumulative effects. The manual includes modules for stream segment identification, reference point surveys, habitat unit surveys, large woody debris surveys, salmonid spawning gravel composition, and stream temperature.

Scott, W.B., and E.J. Crossman, 1975. Freshwater Fishes of Canada. Fisheries Research Board of Canada, Bulletin 184, Ottawa, Ontario. 966 pp.

A comprehensive review of each fish species regarding distribution, habits, and identification are covered in this text. This work is regarded as one of the best of its kind in fisheries biology.

Slack, K.V., R.C. Averett, P.E. Greeson, and R.G. Lipscomb, 1973. Methods for Collection and Analysis of Aquatic Biological and Microbiological Samples. Techniques of Water-Resources Investigations of the U.S. Geological Survey, Book 5, Laboratory Analysis. Washington, DC. 165 pp.

Methods discussed in this document are strictly related to biological surveys of freshwater ecosystems. Information regarding sample design, collection, and analysis can be found in this work for each biotic component of the aquatic environment.

Smith, G.M., 1950 The Fresh-Water Algae of the United States, 2nd ed. McGraw-Hill Book Company, New York. 719 pp.

A comprehensive guide to the natural history of algal families, this book also contains keys and detailed illustrations that assist in identification.

U.S. Forest Service. 1994. Stream Channel Reference Sites, an Illustrated Guide to Field Technique. General Technical Report RM-245. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 61 pp.

This guide presents detailed field protocols for establishing long-term stream monitoring sites, and provides a suggested minimum procedure. In addition to covering the basics of physical measurement and surveying, protocols are presented for channel cross-section surveys, surveys of floodplains and bankfull indicators, longitudinal profiles, stream discharge, and characterizing stream bed and bank materials.

USGS (United States Geological Survey), 1965. Techniques of Water-Resources Investigations of the United States Geological Survey. Washington, DC.

A series of manuals which describe specialized work methods in water investigations, Subject areas include: measurement of stream discharge and time of travel; determination of organic and inorganic substances in water; and methods for collection and analysis of aquatic biological and microbiological samples.

Weber, C.I., (ed.) 1973. Biological Field and Laboratory Methods for Measuring the Quality of Surface Waters and Effluents. U.S. Environmental Research Center, Cincinnati, Ohio.

An excellent manual for use in planning and implementing freshwater biological studies. A discussion of methods of analysis and a good review of available literature accompanies each section regarding a biotic component.

Welch, E.B., 1980. Ecological Effects of Wastewater. Cambridge University Press, Cambridge, UK.

Presents general concepts about aquatic ecology, including limnology, biology, and nutrient cycling. Also discusses effects of waste discharge on plankton, periphyton, macrophytes, invertebrates, and fish.

Wydoski, R.S., and R.R. Whitney, 1979. Inland Fishes of Washington. University of Washington Press, Seattle. 220 pp.

This document contains a great deal of information regarding fish species found in basins and drainages of Washington State. Identification, behavior, desired habitat, and distribution are discussed for each species.

Zar, J.H., 1984 Biostatistical Analysis. 2nd ed., Prentice-Hall, Inc., Englewood Cliffs, NJ. 718 pp.

A good introductory and reference text for statistical treatment of biological and water quality data.

VIII. References

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Cohen, Jacob, 1988. Statistical Power Analysis for the Behavioral Sciences. Lawrence Erlbaum Associates, Publishers, Hillsdale, New Jersey. 567 pages.

Ecology, 1991. Guidelines and Specifications for Preparing Quality Assurance Project Plans. Ecology, Quality Assurance Section, Manchester, WA, 17 pp.

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Gaugush, R.F., 1986. Statistical Methods for Water Quality Investigations, Environmental and Instruction Report E-86-2, Waterways Experiment Station, Corps of Engineers, 3909 Halls Ferry Rd., Vicksburg, MS 39180-6199, 214 pp.

------, R.F., 1987. Sampling Design for Reservoir Water Quality Investigations, Environmental and Instruction Report E-87-1, Waterways Experiment Station, Corps of Engineers, 3909 Halls Ferry Rd., Vicksburg, MS 39180-6199, 79 pp.

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Hammer, M.J. and K.A. MacKichan, 1981. Hydrology and Quality of Water Resources. John Wiley and Sons, New York, 486 pp.

Hayslip, G.A. (ed.), 1993. EPA Region 10 In-Stream Biological Monitoring Handbook. EPA Region 10, Seattle, WA.

Hirsch, R.M., James R. Slack, and Richard A. Smith, 1982. Techniques of Trend Analysis for Monthly Water Quality Data. Water Resource Research, Volume 18, No. 1, pages 107-121.

Huntamer, D. and J. Hyre, 1991. Laboratory User's Manual. Washington State Department of Ecology, Olympia, WA.

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Mills, W.B., G.L. Bowie, T.M. Grieb, K.M. Johnson, and R.C. Whittemore, 1986. Stream Sampling for Wasteload Allocation Applications. EPA Report 625/6-86/013, Washington, DC.

Plafkin, J.L., M.T. Barbour, K.D. Porter, S.K. Gross, and R.M. Hughes, 1989. Rapid Bioassessment Protocols for Use in Streams and Rivers: Benthic Macroinvertebrates and Fish. EPA Report 444/4-89-001, Washington, DC.

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USGS (United States Geological Survey), 1965. Techniques of Water-Resources Investigations of the United States Geological Survey. Washington, DC.

Ward, R.C., J.C. Loftis, and G.B. McBride, 1990. Design of Water Quality Monitoring Systems. Van Nostrand Reinhold, New York, 231 pp.

Zar, J.H.. Biostatistical Analysis. (2nd edition), 1984. Prentice-Hall, Inc., Englewood Cliffs, NJ, 718 pp.

Tables and Appendices

Table 1. Sampling Guidelines for Suspected Pollutant Sources.
1 = normally useful; 2 = occasionally useful; 3 = seldom useful; "-" = generally not useful (Huntamer and Hyre 1991).

	Agricul. Runoff	Primary WTP	Secondary WTP	Advanced WTP	Receiving Waters	Drinking Water	Domestic Wells	Stream Samples	Marine Samples	Brewery	Cooling Water	Boiler Water	Steam & Electric
PHYSICAL AND GENERAL INORGANICS													
Turbidity	1	-	-	-	2	1	1	2	2	1	-	-	-
pH	1	1	1	1	1	1	1	1	2	1	1	1	2
Conductivity	2	1	1	1	1	2	1	1	3	-	1	1	-
Total Alkalinity	3	-	1	1	2	2	2	2	2	-	-	1	-
Acidity	-	-	-	-	-	-	-	-	-	-	-	-	-
Hardness, Total	3	-	-	-	2	-	2	2	-	-	1	1	-
Chloride	3	-	-	-	3	1	1	2	-	-	1	1	-
Fluoride, Total	-	-	-	-	-	1	1	-	-	-	2	-	-
Sulfate	-	-	-	-	-	2	2	-	-	-	-	2	-
Cyanide, Total	3	-	-	-	3	-	3	3	-	-	2	2	2
Color	2	-	-	-	3	2	2	3	3	1	-	-	-
Salinity	-	-	-	-	-	-	-	-	1	-	-	-	-
OXYGEN DEMAND AND CARBON													
BOD_5	-	1	1	1	1	1	-	2	-	1	-	-	-
BOD_5-Carboneous	-	3	1	2	2	-	-	-	-	-	-	-	-
COD-Chemical Oxygen Demand	2	1	1	1	3	-	3	2	-	1	-	-	-
TOC-Total Organic Carbon	2	2	2	2	2	-	3	3	2	-	-	-	-
SOLIDS													
TSS-Total Suspended Solids	-	1	1	1	1	-	3	1	2	1	1	1	1
TS-Total Solids	-	1	1	1	-	-	-	-	-	-	-	-	-
TVSS Volatile Solids	-	3	1	1	-	-	-	-	3	-	-	-	-
SS Settleable Solids	3	1	1	1	2	-	3	3	3	1	-	-	-
Percent Total Solids	-	1	1	1	-	-	-	-	-	-	-	-	-
NUTRIENTS													
Ammonia	1	1	1	1	1	1	1	1	1	2	1	1	1
Nitrate-Nitrite	1	1	1	1	1	1	1	1	1	1	1	1	-
Total Phosphorus	1	1	1	1	2	-	3	1	1	1	2	2	2
Soluble Reactive Phosphorus	1	2	2	2	2	-	-	1	1	-	1	1	-
TKN Kjeldahl Nitrogen	-	3	3	3	3	-	-	-	3	-	-	-	-
BIOLOGICAL													
Fecal Coliform Bacteria	1	1	1	1	1	1	1	1	1	1	-	-	1
Total Coliform Bacteria	-	-	-	-	3	-	-	-	-	-	-	-	2
Fish Bioassay	-	-	-	-	-	-	-	-	-	-	-	-	-
Percent Lipids	-	-	-	-	-	-	-	-	-	-	-	-	-

Table 1. Continued.

	Agricult. Runoff	Primary WTP	Secondary WTP	Advanced WTP	Receiving Waters	Drinking Water	Domestic Wells	Stream Samples	Marine Samples	Brewery	Cooling Water	Boiler Water	Steam & Electric
GC/MS ORGANIC SCANS													
Base-Neutrals/Acids	-	2	2	2	2	-	-	2	-	-	1	1	-
Base-Neutrals Only	-	-	-	-	-	-	-	-	-	-	-	-	-
Acids Only	-	-	-	-	-	2	-	-	-	-	-	-	2
Volatile Organics	-	2	2	2	2	3	1	2	-	-	1	-	-
GC ORGANIC SCANS													
Pesticides/PCBs	1	2	2	2	2	2	-	2	-	-	-	-	-
PCBs Only	-	-	-	-	-	-	-	-	-	-	2	2	1
Purgeable Halocarbons	2	-	-	-	-	-	1	2	-	-	-	-	-
Herbicides	1	-	-	-	-	2	-	2	-	-	-	-	-
MISCELLANEOUS ORGANICS													
PAH Polycyclic Aromatics	-	-	-	-	-	-	-	-	-	-	-	-	-
Oil Identification	-	-	-	-	3	-	-	-	-	-	-	-	2
Phenolics	3	3	3	3	3	1	3	3	3	-	2	2	1
Oil & Grease	3	-	-	-	3	-	3	-	3	1	1	1	1
Flashpoint	-	-	-	-	-	-	-	-	-	-	-	-	-
Halogenated Hydrocarbons	-	-	-	-	-	-	-	-	-	-	-	-	-
TOX	1	-	-	-	1	2	-	-	-	1	-	-	-
Trihalomethanes	-	2	2	2	-	2	3	3	-	-	-	-	-
METALS													
Priority Pollutant Metals	-	-	-	-	-	-	-	-	-	-	-	-	-
EP TOX Metals	-	-	-	-	-	-	-	-	-	-	-	-	-
Specific Metals													
Copper	-	1	1	1	1	2	2	2	3	-	1	1	1
Nickel	-	-	-	-	1	-	-	-	3	-	2	1	1
Chromium	-	2	2	2	2	2	2	3	2	-	2	2	2
Lead	-	2	2	2	2	2	2	2	2	-	2	2	1
Zinc	-	1	1	1	2	2	2	2	3	-	2	2	1
Cadmium	-	1	1	1	1	2	2	2	2	-	-	-	-

Table 1. Continued.

	Paint & Ink	Aluminum Mill Effluent	Landfill Leachate	Toxic Waste Sites	Chemical Plants	Inorganic Chemicals	Oil Refineries	Ground Water	Timber Industry	Electro-plating	Car Washes	Meat Prod. Industry	Pulp Mill Effluent
PHYSICAL AND GENERAL INORGANICS													
Turbidity	-	2	2	2	-	-	2	-	-	-	1	1	2
pH	2	1	1	1	1	1	1	1	1	1	1	1	1
Conductivity	-	1	1	1	-	1	1	1	-	-	-	-	-
Total Alkalinity	-	3	2	-	-	-	3	2	-	-	1	-	2
Acidity	-	-	-	-	-	-	-	2	-	-	-	-	-
Hardness, Total	-	3	3	2	-	-	3	2	-	-	-	-	3
Chloride	-	3	1	-	-	1	2	1	-	-	-	-	3
Fluoride, Total	1	1	-	-	1	-	-	2	-	-	-	-	-
Sulfate	-	-	3	-	1	-	-	2	-	-	-	-	-
Cyanide, Total	-	2	3	2	1	1	2	2	-	-	-	-	3
Color	-	3	2	-	-	-	2	2	1	-	-	1	2
Salinity	-	-	-	-	-	-	-	-	-	-	-	-	-
OXYGEN DEMAND AND CARBON													
BOD_5	-	-	-	-	-	-	-	-	-	-	-	-	-
BOD_5 Carbonaceous	-	-	-	-	-	-	-	-	-	-	-	-	-
COD-Chemical Oxygen Demand	1	3	1	1	1	2	1	-	1	1	1	1	1
TOC-Total Organic Carbon	1	3	2	2	1	-	1	2	2	-	-	-	1
SOLIDS													
TSS-Total Suspended Solids	-	1	2	-	1	1	1	2	1	1	1	1	-
TS-Total Solids	-	1	2	-	-	1	2	2	2	-	-	-	-
TVSS-Volatile Solids	-	-	-	-	-	-	-	-	2	-	-	-	-
SS-Settleable Solids	-	3	3	-	-	-	3	-	1	-	-	1	1
Percent Total Solids	-	-	-	-	-	-	-	-	-	-	-	-	-
NUTRIENTS													
Ammonia	-	2	1	-	1	2	1	1	2	-	2	1	2
Nitrate-Nitrite	-	-	2	-	-	2	2	2	-	-	-	-	2
Total Phosphorus	-	2	3	-	-	-	2	2	-	-	1	1	2
Soluble Reactive Phosphorus	-	-	-	-	-	-	-	-	-	-	-	-	-
TKN Kjeldahl Nitrogen	-	-	-	-	-	-	-	-	-	-	-	-	-
BIOLOGICAL													
Fecal Coliform Bacteria	-	3	3	-	-	-	-	-	-	-	-	1	-
Total Coliform Bacteria	-	-	-	-	-	-	1	-	-	-	-	2	-
Fish Bioassay	-	-	-	2	-	-	1	-	-	-	-	2	-
Percent Lipids	-	-	-	-	-	-	-	-	-	-	-	-	-

Table 1. Continued.

	Paint & Ink	Aluminum Mill Effluent	Landfill Leachate	Toxic Waste Sites	Chemical Plants	Inorganic Chemicals	Oil Refineries	Ground Water	Timber Industry	Electro-plating	Car Washes	Meat Prod. Industry	Pulp Mill Effluent
GC/MS ORGANIC SCANS													
Base-Neutrals/Acids	1	-	2	1	1	-	1	2	3	-	-	-	2
Base-Neutrals Only	-	-	-	-	-	-	-	-	-	-	-	-	-
Acids Only	3	-	-	-	1	2	2	-	1	-	-	2	-
Volatile Organics	1	1	1	1	1	1	1	2	3	-	-	-	1
GC ORGANIC SCANS													
Pesticides/PCBs	-	-	-	1	1	-	2	2	2	-	-	-	2
PCBs Only	-	-	-	1	2	-	-	3	-	-	-	-	1
Purgeable Halocarbons	1	-	-	2	-	-	-	1	-	-	-	-	-
Herbicides	1	-	-	2	2	-	-	2	1	-	-	-	1
MISCELLANEOUS ORGANICS													
PAH Polycyclic Aromatics	1	-	-	2	-	-	-	2	2	-	-	-	-
Oil Identification	-	-	-	-	-	-	1	2	-	-	-	-	-
Phenolics	1	2	2	2	1	2	1	2	1	-	-	1	2
Oil & Grease	1	2	3	2	1	1	1	2	1	1	1	1	2
Flashpoint	-	-	-	-	-	-	-	-	-	-	-	-	-
Halogenated Hydrocarbons	-	-	3	2	-	-	-	3	-	-	-	-	-
TOX	-	-	-	-	-	-	-	1	-	-	-	1	1
Trihalomethanes	-	-	-	-	-	-	-	2	-	-	-	-	-
METALS													
Priority Pollutant Metals	-	-	1	1	1	-	-	-	-	-	-	-	-
EP TOX Metals	-	-	-	-	-	-	-	-	-	-	-	-	-
Specific Metals													
Copper	1	2	2	2	1	2	2	1	1	2	1	1	-
Nickel	-	2	2	2	1	2	2	-	1	-	1	-	-
Chromium	2	2	2	-	1	-	-	1	-	-	1	2	-
Lead	2	2	2	2	1	2	2	2	-	2	1	2	-
Zinc	2	2	2	1	1	2	2	2	1	2	1	2	-
Cadmium	2	2	2	2	1	2	2	2	2	-	-	2	-

Table 1. Continued.

	Leather Tanning	Cement/Concrete Industry	Iron/Steel Industry	Hazardous Waste	Organic Pesticides	Cooling Tower Blowdown	Boiler Blowdown	Sediment Samples	Fish & Shellfish	Electronics Industry	Chemical Spills	Acid Rain	Wood Treatment
PHYSICAL AND GENERAL INORGANICS													
Turbidity	-	-	-	-	-	-	-	-	-	-	-	-	-
pH	1	1	1	1	1	-	-	-	-	-	-	1	1
Conductivity	-	-	-	-	-	-	-	-	-	-	-	-	1
Total Alkalinity	-	1	-	-	2	-	-	-	-	-	-	1	-
Acidity	-	-	-	-	-	-	-	-	-	-	-	1	-
Hardness, Total	-	-	1	-	2	-	-	-	-	-	-	-	-
Chloride	-	-	1	-	2	-	-	-	-	-	-	-	-
Fluoride, Total	-	-	-	-	-	-	-	-	-	-	-	-	-
Sulfate	-	-	1	-	1	1	-	-	-	-	-	1	-
Cyanide, Total	-	-	1	-	1	1	-	-	-	-	-	-	-
Color	1	-	-	-	-	-	-	-	-	-	-	-	-
Salinity	-	-	-	-	-	-	-	-	-	-	-	-	-
OXYGEN DEMAND AND CARBON													
BOD_5	-	-	-	-	-	-	-	-	-	-	-	-	-
BOD_5-Carbonaceous	-	-	-	-	-	-	-	-	-	-	-	-	-
COD-Chemical Oxygen Demand	1	2	-	-	1	-	-	-	-	-	-	-	1
TOC-Total Organic Carbon	1	-	-	2	1	-	-	1	-	-	-	-	2
SOLIDS													
TSS-Total Suspended Solids	1	1	1	-	1	1	-	-	-	-	-	-	-
TS-Total Solids	1	-	-	-	-	1	-	-	-	-	-	-	-
TVSS-Volatile Solids	1	-	-	-	-	-	-	-	-	-	-	-	-
SS-Settleable Solids	-	-	-	-	2	-	-	-	-	-	-	-	-
Percent Total Solids	-	-	-	-	-	-	-	1	1	-	-	-	-
NUTRIENTS													
Ammonia	1	-	1	-	-	1	2	-	-	-	-	1	-
Nitrate-Nitrite	-	-	-	-	2	-	-	-	-	-	-	-	-
Total Phosphorus	-	1	-	-	2	-	1	-	-	-	-	-	-
Soluble Reactive Phosphorus	-	-	-	-	-	-	-	-	-	-	-	-	-
TKN Kjeldahl Nitrogen	-	-	-	-	-	-	-	-	-	-	-	-	-
BIOLOGICAL													
Fecal Coliform Bacteria	-	-	-	-	-	-	-	-	2	-	-	-	-
Total Coliform Bacteria	-	-	-	-	-	-	-	-	-	-	-	-	-
Fish Bioassay	-	-	-	2	-	-	-	-	-	-	-	-	-
Percent Lipids	-	-	-	-	-	-	-	-	1	-	-	-	-

Table 1. Continued.

	Leather Tanning	Cement/Concrete Industry	Iron/Steel Industry	Hazardous Waste	Organic Pesticides	Cooling Tower Blowdown	Boiler Blowdown	Sediment Samples	Fish & Shellfish	Electronics Industry	Chemical Spills	Acid Rain	Wood Treatment
GC/MS ORGANIC SCANS													
Base-Neutrals/Acids	1	-	2	2	2	-	1	1	3	-	-	-	-
Base-Neutrals Only	-	-	-	-	-	-	-	-	-	-	-	-	-
Acids Only	-	-	1	2	3	-	1	-	-	-	-	-	1
Volatile Organics	-	-	-	1	2	2	-	2	3	-	-	-	1
GC ORGANIC SCANS													
Pesticides/PCBs	2	-	-	1	1	-	-	1	1	-	-	-	1
PCBs Only	-	-	-	2	-	-	-	1	1	-	-	-	-
Purgeable Halocarbons	-	-	-	2	2	2	-	-	3	-	-	-	-
Herbicides	-	-	-	2	1	-	-	3	3	-	-	-	-
MISCELLANEOUS ORGANICS													
PAH Polycyclic Aromatics	-	-	1	2	-	-	-	2	-	-	-	-	1
Oil Identification	-	-	-	-	-	-	-	3	-	-	2	-	2
Phenolics	2	-	1	2	1	2	1	2	2	-	-	-	1
Oil & Grease	1	-	1	-	1	1	1	-	-	-	-	-	1
Flashpoint	-	-	-	2	-	-	-	-	-	-	-	-	-
Halogenated Hydrocarbons	-	-	-	2	3	-	-	-	-	-	-	-	-
TOX	-	-	-	-	-	-	-	-	-	-	-	-	1
Trihalomethanes	-	-	-	-	-	-	-	-	-	-	-	-	-
METALS													
Priority Pollutant Metals	-	-	-	-	-	-	2	2	-	-	-	-	-
EP TOX Metals	-	-	1	-	-	-	-	-	-	-	-	-	-
Specific Metals													
Copper	-	1	2	-	1	1	1	1	-	-	-	1	1
Nickel	-	1	2	1	1	-	2	3	-	-	-	3	1
Chromium	-	-	2	1	-	-	2	2	-	-	-	1	1
Lead	-	-	2	1	1	-	1	1	-	-	-	3	1
Zinc	1	1	2	1	1	-	1	1	-	-	-	2	1
Cadmium	-	1	2	1	1	-	1	1	-	-	-	-	-

Table 2. Field Observation File Specifications.

Field Name	Description	Maximum Field Length	Required ?	Codes
SURVEY ID	Identification of monitoring survey	8	Y	
STATION ID	Identifier for station	8	Y	
DATE	Date of observation/sample collection (yymmdd format)	6	Y	
TIME	Time of observation/sample collection (military format)	4	Y	
PERIOD	Period over which sample was collected (hhmm)	4	Y	
UPPER DEPTH	Upper depth where observation was made (nearest .1 m)	6	Y	
LOWER DEPTH	Lower depth where observation was made (nearest .1 m)	6	Y	
TIDE STAGE	Code for tide stage at which observation was made	1	N	1=Ebb 2=Ebb Slack 3=Flood 4=Flood Slack
VARIABLE	Variable measured or observed	10	Y	FLOW=flow DO=dissolved oxygen WTEMPERATUR=temperature, water TURBIDITY=turbidity CONDUCT=conductivity pH=pH WATERDEPTH=water depth
VALUE	Value of variable reported	10	Y	
QUALIFIER	Description to guide in interpretation of data	1	N	
SIGNIFICANT DIGITS	Number of significant digits reported in data value	1	N	
METHOD	Code for methods used	8	Y	OA=Dissolved oxygen-Winkler/Carpenter OB=Dissolved oxygen-Probe/Electrode T1=Turbidity-Turbidometer T2=Turbidity-Transmissometer (1 cm path) T3=Turbidity-Fluorometer T4=Turbidity-Nephelometer T5=Turbidity-Transmissometer (10cm Path)

Table 2. (Continued)

Field Name	Description	Maximum Field Length	Required ?	Codes
QUALITY LEVEL	Quality assurance level assigned to data by reviewer	1	N	1= Data collected in accordance with Puget Sound Protocols or methods acceptable for PSAMP and there are no data quality problems 2= Same as above except problems arose and were corrected 3= Data was not collected in accordance with protocols or quality control problems could not be corrected 4= Data were lost
UNITS	Units in which data value is reported	2	Y	MS=ppm (mg/kg) ML=ppm (mg/L) DC=degrees celsius UC=umhos/cm MC=meters/sec PH=pH
MEASUREMENT BASIS	Weight basis for data value measurement (wet or dry)	1	N	D=dry weight W=wet weight

Table 3. Water Chemicals/Conventionals File Specifications.

Field Name	Description	Maximum Field Length	Required ?	Codes
SURVEY ID	Identification of monitoring survey	8	Y	
STATION ID	Identifier for station	8	Y	
DATE	Date of observation/sample collection (yymmdd format)	6	Y	
TIME	Time of observation/sample collection (military format)	4	Y	
PERIOD	Period over which sample was collected (hhmm)	4	Y	
UPPER DEPTH	Upper depth where observation was made (nearest .1 m)	6	Y	
LOWER DEPTH	Lower depth where observation was made (nearest .1 m)	6	Y	
TIDE STAGE	Code for tide stage at which observation was made	1	N	1=Ebb 2=Ebb Slack 3=Flood 4=Flood Slack
VARIABLE	Variable measured or observed	10	Y	AMMONIA=Ammonia, Total (ug/L) PHOSPHATE=Phosphorus, Total (ug/L) ORTHO PHOS=Ortho Phosphate (ug/L) NO3-N=Nitrate (ug/L) NO2-N=Nitrite (ug/L) TOT SOLIDS=Total Suspended Solids (mg/L) ALUMINUM=Aluminum (ug/L) ANTIMONY=Antimony (ug/L) ARSENIC=Arsenic (ug/L) CADMIUM=Cadmium (ug/L) CHROMIUM=Chromium (ug/L) COPPER=Copper, Total (ug/L) IRON=Iron (ug/L) LEAD=Lead (ug/L) MANGANESE=Manganese (ug/L) MERCURY=Mercury, Total (ug/L) NICKEL=Nickel, Total (ug/L) SILVER=Silver (ug/L) ZINC=Zinc (ug/L) CATIONS=Cations (mg/L) ANIONS=Anions (ng/L) FECALMPN=Fecal Coliform (MPN/100 mL) FECALMF=Fecal Coliform (cfu/100 mL) HARDNESS=Total Hardness (mg/L) ALKLNTY=Alkalinity (mg/L)

Table 3. (Continued)

Field Name	Description	Maximum Field Length	Required ?	Codes
VALUE	Value of variable reported	10	Y	
QUALIFIER	Description to guide in interpretation of data	1	N	
SIGNIFICANT DIGITS	Number of significant digits reported in data value	1	N	
METHOD	Code for methods used	8	Y	P8603CS=Recommended methods for analysis of sediment conventionals SM85CW=Standard Methods (APHA 1985) P8608M-CVAA=Cold vapor atomic absorption spectrometry P8608M-GFAA=Graphite furnace atomic absorption spectrometry P8608M-ICP=Inductively coupled plasma emmission spectroscopy P8608M-HGAA=Hydride generation atomic absorption P8610F-SW=Recommended methods for fecal coliform analysis in water or sediment
QUALITY LEVEL	Quality assurance level assigned to data by reviewer	1	N	1=Data collected in accordance with Puget Sound Protocols or methods acceptable for PSAMP and there are no data quality problems 2=Same as above except problems arose and were corrected 3=Data was not collected in accordance with protocols or quality control problems could not be corrected 4=Data was lost
UNITS	Units in which data value is reported	2	Y	MS=ppm (mg/kg) ML=ppm (mg/L) DC=degrees celsius UC=umhos/cm MC=meters/sec PH=pH
MEASUREMENT BASIS	Weight basis for data value measurement (wet or dry)	1	N	D=dry weight W=wet weight

Table 4. Formatted Data File Following PSAMP Recommendations for Standardization of Data Reporting.

Survey ID	Station ID	Date	Time	Period	Flow	Depth Upper	Depth Lower	Variable	Value	Qualifier	Signif Digits	Method	QA Level	Units	Variable	Value	Qualifier	Signif Digits	Method	QA Level	Units
AnyCrk1	P1.3	881221	0833	0015	41.7	0.1	0.3	FECALMPN	20		2	SM85CW	1	MPN	PHOSPHATE	0.200		3	P8603CS	1	mL
AnyCrk1	P2.5	881221	1053	0010	30.6	0.1	0.3	FECALMF	520		2	SM85CW	1	CFU	PHOSPHATE	0.130		3	P8603CS	1	mL
AnyCrk1	P5.2	881221	1130	0010	22.5	0.1	0.3	FECALMF	220		2	SM85CW	1	CFU							
AnyCrk1	P6.0	881221	0924	0015	15.4	0.1	0.3	FECALMF	530		2	SM85CW	1	CFU	PHOSPHATE	0.340		3	P8603CS	1	mL
AnyCrk1	P7.3	881221	1310	0015	7.7	0.1	0.3	FECALMF	250		2	SM85CW	1	CFU	PHOSPHATE	0.370		3	P8603CS	1	mL
AnyCrk1	F0.8	881221	1325	0010	21.4	0.1	0.3	FECALMPN	32		2	SM85CW	1	MPN							
AnyCrk1	F4.3	881221	1345	0015	9.4	0.1	0.3	FECALMF	66		2	SM85CW	1	CFU							
AnyCrk1	UN2.0	881221	1500	0015	8.9	0.1	0.3	FECALMF	79		2	SM85CW	1	CFU	PHOSPHATE	0.120		3	P8603CS	1	mL
AnyCrk1	P3.7	881221	1415	0015	26.4	0.1	0.3	FECALMF	66		2	SM85CW	1	CFU	PHOSPHATE	0.100		3	P8603CS	1	mL
AnyCrk1	UN5.4	881221	1545	0010	4.5	0.1	0.3	FECALMF	170		2	SM85CW	1	CFU							
AnyCrk1	P7.1	881221	1010	0015	10.8	0.1	0.3	FECALMF	170		2	SM85CW	1	CFU	PHOSPHATE	0.150		3	P8603CS	1	mL
AnyCrk1	UN8.0	881221	1235	0010	3.1	0.1	0.3	FECALMF	1	U	2	SM85CW	1	CFU							
AnyCrk1	F2.5	881221	1212	0010	15.5	0.1	0.3	FECALMF	20		2	SM85CW	1	CFU							
AnyCrk2	UN2.0	890109	0855	0015	8.1	0.1	0.3	FECALMF	75		2	SM85CW	1	CFU	PHOSPHATE	0.170		3	P8603CS	1	mL
AnyCrk2	P3.7	890109	1230	0010	24.4	0.1	0.3	FECALMF	26		2	SM85CW	1	CFU	PHOSPHATE	0.150		3	P8603CS	1	mL
AnyCrk2	UN5.4	890109	1125	0010	4.1	0.1	0.3	FECALMF	110		2	SM85CW	1	CFU							
AnyCrk2	P7.1	890109	1030	0015	9.9	0.1	0.3	FECALMF	370		2	SM85CW	1	CFU	PHOSPHATE	0.320		3	P8603CS	1	mL
AnyCrk2	UN8.0	890109	1430	0015	2.9	0.1	0.3	FECALMF	240		2	SM85CW	1	CFU	PHOSPHATE	0.440		3	P8603CS	1	mL
AnyCrk2	F2.5	890109	1420	0010	14.1	0.1	0.3	FECALMF	200		2	SM85CW	1	CFU							
AnyCrk2	P1.3	890109	1450	0015	38.6	0.1	0.3	FECALMPN	80		2	SM85CW	1	MPN							
AnyCrk2	P2.5	890109	1510	0015	28.8	0.1	0.3	FECALMF	210		2	SM85CW	1	CFU	PHOSPHATE	0.120		3	P8603CS	i	mL
AnyCrk2	P5.2	890109	1600	0015	21.1	0.1	0.3	FECALMF	210		2	SM85CW	1	CFU	PHOSPHATE	0.220		3	P8603CS	i	mL
AnyCrk2	P6.0	890109	1552	0010	14.0	0.1	0.3	FECALMF	63		2	SM85CW	1	CFU							
AnyCrk2	P7.3	890109	1147	0015	6.8	0.1	0.3	FECALMF	330		2	SM85CW	1	CFU	PHOSPHATE	0.150		3	P8603CS	1	mL
AnyCrk2	F0.8	890109	1335	0010	20.4	0.1	0.3	FECALMPN	120		2	SM85CW	1	MPN							
AnyCrk2	F4.3	890109	1315	0010	8.7	0.1	0.3	FECALMF	1	U	2	SM85CW	1	CFU							

Table 5. Raw Data Table of Field and Laboratory Measurements for Anywhere Creek.

Anywhere Creek Date	Station	Temp (°C)	Cond (umhos)	pH (units)	DO (mg/L)	Flow (cfs)	Turb (NTU)	TSS (mg/L)	NO3+NO2 (mg N/L)	NH3 (mg N/L)	TP (mg P/L)	FC (cfu/100 mL)	BOD5 (mg O^2/L)
12/20/88	P1.3	5.25	171	6.99	8.7	46.7	3	6	2.600	0.530	0.200	20	3 U
12/20/88	UN2.0	5.69	105	6.60	9.0	3.9	2	4	0.970	0.050	0.130	520	
12/20/88	P2.5	5.51	186	6.99	5.3			2				220	
12/20/88	P3.7	5.62	172	6.94	6.0	36.8	2	6	2.200	0.370	0.340	530	3
12/20/88	P5.2	5.47	171	6.97	8.5	20.2	3	4	2.000	1.200	0.370	250	
12/20/88	UN5.4	5.70	201	7.06	6.1			2				32	
12/20/88	P6.0	6.73	217	7.29	8.4			3				66	
12/20/88	P7.1	4.77	81	7.23	12.7	11.2	2	4	2.000	0.020	0.120	49	3 U
12/20/88	P7.3	4.63	82	7.15	12.4	5.3	3	2	1.800	0.020	0.100	66	
12/20/88	UN8.0	6.76	154	7.01	10.8			4				3	
12/20/88	F0.8	4.32	109	7.18	12.3	14.7	3	8	2.500	0.030	0.150	170	3 U
12/20/88	F2.5	4.58	106	7.00	11.9			9				170	
12/20/88	F4.3	5.52	102	7.19	11.7			8				20	
01/09/89	P1.3	4.44	140	6.77	9.4	73.0	3	26	2.900	0.080	0.170	3	3 U
01/09/89	UN2.0	5.00	100	6.24	9.4	4.8	2	7	1.200	0.050	0.150	26	
01/09/89	P2.5	4.82	167	6.75	6.3			2				110	
01/09/89	P3.7	4.71	155	6.72	7.2	34.7	2	7	2.200	0.200	0.320	360	3 U
01/09/89	P5.2	4.86	157	6.81	9.1	29.2	3	6	2.200	1.000	0.440	240	
01/09/89	UN5.4	5.33	207	6.92	6.0			2				200	
01/09/89	P6.0	6.46	210	7.20	8.8			3				80	
01/09/89	P7.1	4.21	76	7.09	12.8	18.6	3	6	2.100	0.010	0.120	210	3 U
01/09/89	P7.3	4.11	75	6.68	12.4	9.7	3	5	2.100	0.110	0.220	210	
01/09/89	P8.1	4.11	63	7.29	12.8			5				63	
01/09/89	F0.8	3.54	97	6.84	12.4	29.4	3	28	2.500	0.060	0.150	330	3 U
01/09/89	F2.5	4.21	99	7.00	12.0			12				120	
01/09/89	F4.3	4.80	95	7.20	12.2			9				6	

APPENDIX I
SCOPING OUTLINE

Sources of Existing Information

(1) Water Quality Data

(a) Contacts:

- local water and sewer districts
- local health departments
- DOH (shellfish/bacterial and red tide information)
- WDFW (water quality impacts on fisheries)
- USGS, Water Resources Division
- Ecology (ambient monitoring information)
- PSWQA (ambient monitoring information)
- colleges & universities
- Indian tribes
- Conservation Districts

(b) Reports:

- Nonpoint Source Pollution Assessment (319 Report, Ecology)
- Statewide Water Quality Assessment (305(b) Report, Ecology)
- Intensive Survey and TMDL Reports (Ecology - EILS Program)

(c) Data Bases:

- Water Body Tracking System (Ecology)
- STORET (EPA)
- Water Quality file (EPA)
- drinking water data system - FRDS (EPA)
- Wastewater Permit Life Cycle System - WPLCS (Ecology)

(2) Water Quantity Data

(a) Contacts:

- USGS
- colleges & universities
- Ecology (water rights & quantity information)
- county stormwater and flood control
- utility districts

(b) Reports:

- stream gage records in Water Data Reports (USGS)
- watermaster records (local water districts and others)
- drainage and irrigation districts
- county/local surface water management

(c) Data Bases:

- STORET (EPA)
- National Water Data Exchange - NAWDEX (USGS)
- Water Data Storage & Retrieval System - WATSTORE (USGS)
- River Reach file (EPA)
- Climatic (precipitation) data (NOAA-NCDC)

(3) Aquatic Biology Surveys

(a) Contacts:

- local health departments
- Indian tribes (spawner & habitat surveys)
- WDFW (spawner & habitat surveys, catch information)
- DNR (aquatic resources & lease information)
- Ecology (bioassessment monitoring)
- U.S. Environmental Protection Agency
- U.S. Fish and Wildlife Service
- colleges & universities

(b) Reports:

- Stream Catalog (WDFW)

(c) Data Bases:

- Priority aquatic sites for biological diversity & conservation (DNR)

(4) Environmental/Background Factors

(a) Contacts:

- developers (soil percolation tests)
- health departments (on-site sewage treatment systems)
- Indian tribes
- conservation districts (farm plan information)

- Ecology (various information on hazardous waste sites, wetland inventories, coastal zones & shorelines, others)
- EPA (hazardous waste sites)
- COE (wetlands/water bodies dredge & disposal permit information - Section 10 & 404- permits)

(b) Reports:

- soil surveys (conservation districts & USDA NRCS)
- slope stability maps (DNR)
- river assessment studies (WDFW)
- local geology (DNR)
- National Survey of Fishing, Hunting and Wildlife Associated Recreation (FWS)

(c) Data Bases:

- National Wetlands Inventory (FWS)
- stream stabilization index (USDA Forest Service)

(5) Current Land Use

(a) Contacts:

- county assessor/planning/or environmental health offices
- city and county planning & zoning departments
- conservation districts
- Puget Sound Council of Governments (population & growth information)

(b) Maps, Remote Sensing & Data Bases:

- zoning and comprehensive plan maps (local and state)
- forest land management information - GEOMAPS (DNR)
- aerial photos and satellite imagery (Note: due to the importance of these tools to land use assessment and the number of sources available, the sources have been listed separately as Appendix IV).
- USGS land use and land cover data

(6) Identify Missing Data

In order to identify missing data, a checklist with the following components should be utilized to itemize and organize missing data:

- water quality/quantity
- aquatic/riparian habitat
- soil/land form stability
- current land use
- projected land use
- beneficial uses

(7) Windshield Survey

When conducting the windshield survey during the pre-assessment, the following tasks should be completed:

- confirm presence and location of land uses
- orientate surveyors to watershed and drainage patterns
- perform visual check of maps and/or photos
- identify survey reach segments by land use type
- locate access points such as bridges & road crossings
- obtain or confirm permission to cross private land

Acronyms defined :

COE	U.S. Army Corps of Engineers
DNR	Washington Department of Natural Resources
DSHS	Washington Department of Social & Health Services
Ecology	Washington Department of Ecology
EILS	Environmental Investigations & Laboratory Services Program
EPA	U.S. Environmental Protection Agency
FWS	U.S. Department of the Interior, Fish & Wildlife Service
NOAA-NCDC	U.S. Department of Commerce, National Oceanic & Atmospheric Administration, National Climactic Data Center
PSWQA	Puget Sound Water Quality Authority
USDS-SCS	U. S. Department of Agriculture, Soil Conservation Service
USGS	U.S. Department of the Interior, Geological Survey
WDFW	Washington Department of Fish and Wildlife

APPENDIX II

by Joy Michaud

METHODS FOR ESTIMATING PRECIPITATION CONDITIONS, STREAM FLOW, AND POLLUTANT LOADINGS

I. Precipitation

Runoff due to precipitation is the means by which most nonpoint pollutants are washed from the watershed to area streams or water bodies. The amount of precipitation influences stream flow conditions, watershed saturation, pollutant runoff rate, septic system or treatment plant failure, and other factors.

Accumulated rainfall for the preceding 24-hour and 72-hour period should be reported for each monitoring event. (Contact the National Weather Service for information on the precipitation gage located closest to the watershed.) An estimate of watershed moisture conditions can also be valuable when interpreting results. One simple method for estimating watershed moisture conditions is through calculating the Antecedent Precipitation Index (API). The index is calculated using precipitation data for the 14 days preceding the first day of sampling and the following equations (modified after Linsley, 1975):

For API_1 to API_{15}

$$API_1 = P_1$$
$$API_2 = API_1(k) + P_2$$
$$API_3 = API_2(k) + P_3$$

generalized equation:

$$API_x = API_{(x-1)}(k) + P_x$$
$$API_{15} = API_{14}(k) + P_{15}$$

Where:

- API = Antecedent Precipitation Index
- API_1 = API 14 days before first day of sampling
- API_{15} = API for that day of sampling
- k = Recession factor for evaporation (varies seasonally) (Range: 0.85-0.98)
- P_1 = Precipitation 14 days before the first day of sampling

API_{15} is the value that would be reported for each sampling event. Although this is a rough indicator, it allows comparison of watershed moisture conditions between sampling events.

II. Estimating Discharge In Streams and Channels

The importance of obtaining good hydrological information cannot be overemphasized. Accurate discharge measurements link precipitation to runoff and allow calculation of pollutant loadings. The hydrologic character of a stream and its change through time can be important indicators of the effects of development or stormwater controls.

A. Development of a Gaging Station

A staff gaging station should be set up at the mouth of the watershed. The purpose of the gaging station is to develop a relationship between stream height (stage) and flow. Once this relationship is established, it will no longer be necessary to measure flow with a wading rod and current meter each sampling trip. Further, the information (used in conjunction with precipitation data) can be used to estimate changes in stream flow as watersheds develop. (Note: It is possible a gaging station already exists in the watershed. The USGS has established a network of gaging stations throughout the country. Contact the USGS Water Resources Division in Tacoma [telephone (360) 593-6510] for information on gaging station locations.)

1. Site Selection Criteria

It is important to select a proper location to establish a staff gage station or a flow monitoring site. Proper site selection will improve the accuracy of flow measurements at all stream discharge levels. The following criteria should be considered when establishing a discharge measurement station, however, it is rarely possible to meet all the criteria recommended here. Be aware of the limitations of the site selected and possible effects on measurements.

(a) Stream Reach Criteria

(1) The stream should be straight for 300 feet upstream and downstream of the discharge site.

(2) Flow is confined to one channel at all stages of discharge; *i.e.*, there are no surface or subsurface bypasses, up to flood stage.

(3) Stream bed is subject to minimal scour and relatively free of plant growth.

(4) Stream banks are stable, high enough to contain maximum flows, and free of brush.

(5) Gaging stations should be located a sufficient distance upstream of tributaries and tidal action to prevent these from affecting stage/discharge measurements.

(6) All discharge stages should be measurable somewhere within the reach (it is not necessary to measure low and high flows at the exact same cross-section).

(7) The site should be readily and safely accessible.

(b) Cross-section Criteria

In selecting a cross-section within a stream reach, consider the following:

(1) Stream banks should be relatively high and stable.

(2) A straight section of the stream should be chosen, where stream banks are parallel to each other.

(3) Depth and velocity must meet minimum requirements of the method and instrument being used.

(4) The stream bed should be relatively uniform with few boulders or heavy aquatic plant growth.

(5) Flow should be uniform and free of eddies, slack water, and excessive turbulence.

(6) Sites downstream of rapid changes in stage and velocity should be avoided.

2. Setting Up a Staff Gage

(a) Attach staff gage vertically on a permanent structure (concrete piling, revetment, etc.).

(b) Set the zero point of the staff gage below the lowest level of stream flow to prevent negative values of gage height.

(c) Establish a datum point on the gage, and make two or three reference marks at the same level on nearby permanent features. (Use a point on the gage that is above the highest expected gage height to prevent flow-related erosion of the marks.) The datum may also be referenced to an official surveyor's benchmark. By establishing reference elevations, the datum can be recovered if the staff gage is destroyed.

(d) Set the gage datum to an accuracy criterion of 0.01 foot and recheck it at least every two to three years.

3. Establishing a Rating Curve

(a) Take stream flow measurements over a wide range of gage heights. It will be easy to establish data points for average stream flows, but the relationship will not hold for high and low flows. Consequently, it is very important to get measurements during high and low stream flows so that a wide range of conditions is represented on the rating curve. Ideally, measurements for low, average, and high flows should be separated by an order of magnitude.

(b) Note the gage height both before and after measuring flow. (If wave action occurs, read height as the average of the elevations of peaks and troughs.)

(c) Plot the measured stream flow (x-axis) versus gage height (y-axis). Provide a sufficient number of points to allow a smooth curve to be drawn through the points. As noted above, be sure the high and low ends of the curve are represented in the relationship.

(d) Make periodic checks of the discharge curve, especially after high waters or floods. Recalibrate the curve if checks indicate the stream flow/gage height relationship has changed, usually due to significant sediment deposition or erosion of the stream bed.

NOTE: Stream height can also be measured as the distance from the surface of the water to a permanent point above the stream. A bridge provides a convenient place for these measurements. Make a permanent mark on the bridge so stream height is always measured from the same location. Lower a marked, weighted tape until the weight just touches the water surface - record the distance. Use this measurement as the gage height in establishing the rating curve. As with an instream gage, this method assumes there is no change in the bottom profile of the cross-section. Check the profile periodically.

B. Stream Flow Measurement Techniques

1. Current Meter Measurements

(a) Select an appropriate cross-section.

(b) String measuring tape at right angles to the direction of flow and measure the width of the cross-section. (Leave the tape tightly strung across the stream.)

(c) Divide the width into approximately 15 to 20 points of measurement. (If previous flow measurements have shown uniform depth and velocity, fewer points may be used. Smaller streams may also require fewer points.) Measuring points should be closer where depths or velocities are more variable. Cross-sections with uniform depth and velocity can have equal spacing.

(d) At each of the measuring points:

(1) Record the distance from the water's edge of the initial starting bank,

(2) Record the depth, and

(3) Record the velocity using a current meter.

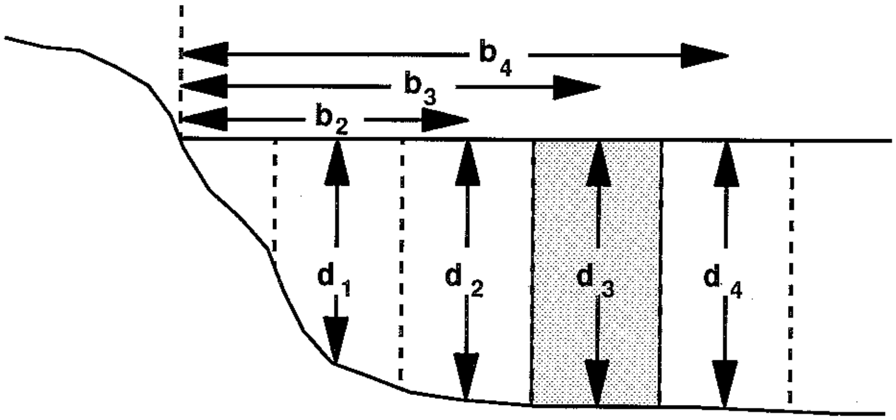
MEASURING STREAM VELOCITY: Stream velocity varies horizontally (from left bank to right bank) and vertically (top to bottom). Horizontal differences are accounted for by measuring velocity along a cross section of the stream, as described above. To correct for vertical differences, hydrologists have developed a standard technique to ensure consistency in determining average velocity. This technique assumes that the "average" vertical stream velocity occurs at some percentage of the stream depth. This percentage changes with stream depth. In streams where the maximum depth is 2.0 feet or less, the average stream velocity is assumed to occur at six-tenths of total depth (as measured from the surface). In streams deeper than 2.0 feet, the velocity is measured at two-tenths and eight-tenths of the total depth. Velocity is calculated as the average of these two measurements.

(4) Calculate discharge as a summation of discharge in partial areas. Compute discharge in a partial area using the equation:

$$q_3 = v_3 d_3 (b_4 - b_2)/2$$

where: b_2 = distance from initial point to the preceding point (feet)
b_4 = distance from initial point to the following point (feet)
d_3 = mean depth of partial area 3 (feet)
v_3 = average velocity in partial area 3 (feet/second)
q_3 = discharge in partial area 3 (cfs)

Variables are illustrated below:



generalized equation:

$$q_x = v_x d_x (b_{x+1} - b_{x-1})/2$$

Note: In this example, the shaded area represents the partial area for which discharge is being calculated.

2. Float Method

When usual flow measurement methods cannot be used; *e.g.*, during extremely high flows, or when equipment is not available, a floating object can be used to estimate velocity. The object can be an orange, a plastic sample bottle partially filled with water, or other semi-buoyant object.

(a) Locate a straight stretch of stream.

(b) Select two cross-sections within the stretch, measure (or estimate) their cross-sectional area and distance between them. (Sites should be far enough apart that float movement between sites exceeds 20 seconds.)

(c) Release the float at the upstream site and record the time it takes to reach the downstream site. Repeat at quarter-points across the width of the stream and average the measurements.

(d) Calculate the velocity as distance travelled divided by average travel time.

(e) Calculate the adjusted (true mid-depth) mean velocity of the water by multiplying the surface velocity by 0.85.

(f) Calculate discharge by multiplying velocity by the average cross-sectional area.

III. Measuring Flow From Pipes

The flow measurement techniques described above also work for pipe discharges under certain conditions; *e.g.*, if there is upstream access to release the float or tracer. However, often it is not possible to use these techniques with a pipe. The following methods can be used to estimate pipe discharge.

A. Volumetric Measurement

In this method, discharge is calculated by observing the time required to fill a container of known volume. A limiting factor of this technique is that it can only be used with small discharges (*i.e.*, where all of the flow can be caught in one container). This technique can also be used to estimate discharge over a weir or at any place where flow is concentrated into a narrow stream.

1. Place bucket or other container below the discharge.

2. Time how long it takes to fill the container. Repeat three times (or more if there is a large difference between results). Whenever possible, the time interval should exceed 20 seconds.

3. Calculate discharge as the volume of the container divided by the average time to fill it.

B. Discharge of a Jet of Water

This technique can be used on any discharge regardless of size. The limitations are that the pipe must be horizontal and the fluid must be confined on all sides (*e.g.*, a pipe that is running full, with the fluid emerging in free fall). See illustration below.

1. Measure or estimate the diameter of the pipe.

2. Measure the distance from the end of the pipe to the spot where the stream of water hits ground ("x").

3. Measure the vertical distance from "x" to the midpoint of the pipe orifice ("y").

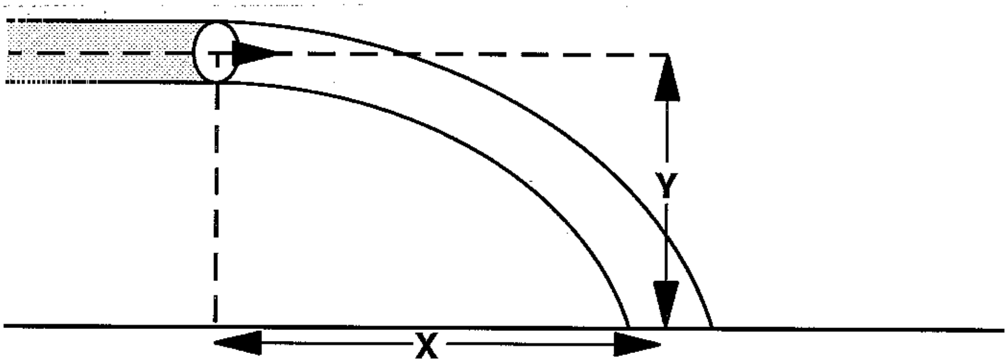
4. Calculate the velocity ("V") as:

$$V = 4.01(x)/\sqrt{y}$$

5. Calculate the area ("A") of the pipe as:

$$A = \pi r^2$$

6. Calculate the discharge volume by multiplying area by velocity. Units of measurement must be the same.



C. Dilution Method

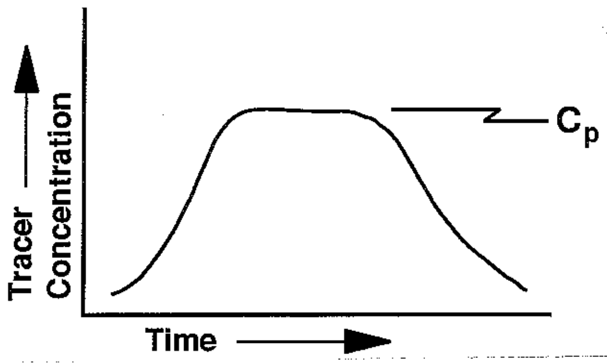
Use common salt, fluorescein or rhodamine dye, or any easily measurable material not present in the stream and not likely to be lost by chemical or biological reactions. (Do not use any material that may damage the stream environment. The USGS recommends use of Rhodamine Wt dye because it is relatively unaffected by photosynthesis and adsorption and is minimally toxic compared to other common dyes.) Two methods are presented here. The first requires a constant-rate injection of the solution, the second allows for the solution to be "dumped" at one time. For both methods, it may be necessary to estimate the amount or concentration of tracer material needed, to minimize cost and possible environmental effects. The necessary computations are described in "Measurement of Discharge by Dye-dilution Methods" (USGS, 1965).

1. Constant-rate injection

(a) A known concentration of tracer material is injected into the stream at a constant rate (q) for a given period of time.

(b) Samples are collected at a site far enough downstream to ensure complete mixing of the tracer with receiving water. Sufficient samples must be collected to form a concentration-time curve as shown below.

(c) The peak concentration (C_p) is estimated from the concentration-time curve.



(d) Stream discharge (Q) is calculated as:

$$Q = q[C_s - C_p)/(C_p - C_b)]$$

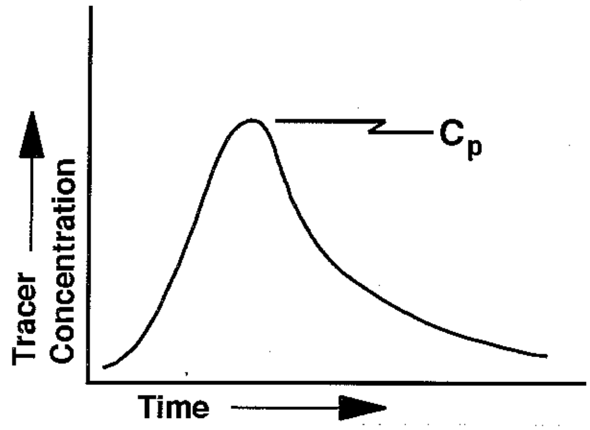
Where: Q, q, and C_p are defined above

C_s = Initial concentration of tracer
C_b = Background (stream concentration of tracer)

2. Sudden-dump Method

(a) A known concentration of a tracer solution is dumped into the stream.

(b) Samples are collected far enough downstream to ensure complete mixing of tracer in the stream. Collect enough samples at an appropriate frequency to develop a concentration-time curve as shown below.



(c) The stream discharge (Q) is calculated as:

$$Q = (V_s * C_s)/[\int_0^\infty (C-C_b)dt]$$

Where: Q, C_s, and C_b are defined above
V_s = Volume of tracer solution introduced
C = Tracer solution concentration at a given time

The expression $(C - C_b)dt$ can be approximated by the term:

$$\sum_{i=1}^{N} (C_i-C_b)\ (T_{i+1}-T_{i-1})/2$$

Where: C and C_b are defined above
i = sequence number of the sample
N = the total number of samples
T_i = time when sample C_i was taken
T_{i+1} = time when sample following sample C_i was taken (C_{i+1})
T_{i-1} = time when sample preceding sample C_i was taken (C_{i-1})

The final concentration of the tracer in the stream needs to be accurately measured in either of these methods.

IV. Calculating Pollutant Loads

The calculation of loads permits a direct quantitative comparison of the pollutant contributions of streams or stream segments. An accurate measurement of stream flow is essential to calculate loads.

NOTE: Conventional use of loading estimates entails a temporally integrated value. An example is an annual loading estimate based on continual flow measurements and concentrations measured over a wide range of flows. In the case of the monitoring strategy for watershed action plans, the loading estimates will be based on instantaneous flow and concentration measurements. The information will be used to compare loadings at a "snapshot" in time. This difference does not affect the calculation procedure; however, it should be noted in the text and tables to clarify the difference to readers.

Calculation Procedure:

Loads are calculated by multiplying concentration by stream flow (discharge) at the time of sampling :

$$L = f * c * d$$

where L = load
f = units conversion factor (see table below)
c = concentration of pollutant
d = discharge

Conversion Factors

Concentration unit	mg/L	mg/L	#FC/100 mL
Flow units	cfs	mgd	cfs
Conversion factor	5.39	8.34	284.7
Load units	lbs/day	lbs/day	#FC/sec

Loading values cannot be calculated for turbidity or pH since these parameters are not mass measures.

APPENDIX III

by Joy Michaud

SEDIMENT COLLECTION AND ANALYSIS PROCEDURES

Monitoring for organics and metals in sediments is only intended as a pollutant screen. The information will be used to determine whether there may be a problem with certain pollutants in the watershed, and whether more detailed studies are necessary. The sampling method described below will meet this objective. More stringent sampling protocols may be required where study objectives are different.

Many organic compounds and metals are associated with fine-grained sediments that are slow to settle out of the water column. Therefore, the timing and location of sampling is designed to target fine-grained sediments. Sampling should be planned for the late summer low flow period when most settling has occurred. Samples should be collected from depositional materials at the mouth of the stream, or at an upstream pool if the mouth is inaccessible. The sample will consist of a composite of three grab samples collected from the upper two inches of sediment. (The outer edges of the delta will contain finer materials and should be targeted.) A stainless steel sampler (*e.g.*, pipe dredge) should be used to collect the sample. Unrepresentative materials (stones and large woody debris) should be removed from the sample and noted on the field log. All efforts should be made to avoid contamination of the sample. Samplers should wear clean rubber gloves and avoid touching the sample. Airborne contamination should be minimized by covering or sealing the sample as soon as possible. The three grab samples should be well homogenized with a stirrer before sub-sampling for different parameters. All sampling equipment should be made of non-contaminating material (*e.g.*, stainless steel, glass, or teflon). Utensils and sampling equipment should be priority pollutant cleaned (acid and solvent-rinsed and air-dried) before use at each station.

Grain size, percent solids, and total organic carbon (TOC) must be measured in each sediment sample so the data can be normalized to comparable units of measurement. A subsample of the original homogenized sediment sample should be used for these analyses. Recommended protocols for sediment sampling analysis are described in the following:

EPA/PSEP (EPA/Puget Sound Estuary Program), 1989b. Recommended Protocols for Measuring Conventional Sediment Variables in Puget Sound Sediment and Tissue Samples. U.S. Environmental Protection Agency, Region 10, Office of Puget Sound, Seattle, Washington, 65 pp.

------, 1989c. Recommended Protocols for Measuring Metals in Puget Sound Water, Sediment and Tissue Samples. U.S. Environmental Protection Agency, Region 10, Office of Puget Sound, Seattle, Washington, 29 pp.

------, 1989d. Recommended Protocols for Measuring Organic Compounds in Puget Sound Sediment and Tissue Samples. U.S. Environmental Protection Agency, Region 10, Office of Puget Sound, Seattle, Washington, 57 pp.

Ecology, 1994. Technical Guidance For Assessing The Quality Of Aquatic Environments. Environmental Investigations and Laboratory Services Program, Report 91-78, Revised February 1994.

APPENDIX IV

SOURCES OF AERIAL PHOTOGRAPHY AND SATELLITE IMAGERY

National High Altitude Photography Program (NHAP)

U.S. Geological Survey
EROS Data Center
Customer Services Section
Sioux Falls, SD 57198
(605) 594-6151
FAX: (605) 594-6859

Satellite Imagery (Landsat Data)

EOSAT
21550 Oxnard Street, Suite 300
Woodland Hills, CA 91367
(818) 596-2388
FAX: (818) 716-2617

Geographic Search for Aircraft Data

U.S. Geological Survey
Earth Science Information Center
345 Middlefield Road, MS 532
Menlo Park, CA 94025-3591
(415) 329-4390
FAX: (415) 329-5130

Aerial Photography - Other Federal

U.S. Department of Agriculture, ASCS
Aerial Photography Field Office - Sales Branch
2222 West 2300 South
P.O. Box 30010
Salt Lake City, UT 84130-0010
(801) 975-3503
FAX: (801) 975-3532
(Aerial photos from the '50s, nationwide)

U.S. Army Corps of Engineers
Seattle District Office
Survey Branch
MAIL: P.O. Box 3755, Seattle, WA 98124-2255
DELIVERIES: 4735 Marginal Way S, Seattle, WA 98134-2385
(206) 764-3552
FAX: (206) 764-6676
(Concentrates on Puget Sound waterways and Columbia Basin)

Aerial Photography - State

State of Washington, Department of Natural Resources
Photo and Map Sales
1111 Washington Street South
P.O. Box 47031
Olympia, WA 98504-7031
(360) 902-1234; SCAN: 902-1234
FAX: (360) 902-1779; FAX SCAN: 902-1779

State of Washington, Department of Transportation
Geographic Services
1655 South 2ND Avenue
P.O. Box 47384
Olympia, WA 98504-7384
(360) 753-2162; SCAN: 234-2162
FAX: (360) 664-0836; FAX SCAN: 366-0836
(Limited to transportation corridors)

For highway corridor videos - contact the WADOT Transportation Data Office at (360) 753-1375.

Private Vendors

Walker and Associates
12652 Interurban Avenue South
Seattle, WA 98168
(206) 244-2300
FAX: (206) 244-2333
No published 1-800 number
(Large archive of historical photography)

W.A.C. Corporation
and
Digital Geographic Systems (a separate company)
520 Conger Street
Eugene, OR 97402-2795
(800) 845-8088
FAX: (503) 485-1258
(WAC: Western Washington flight coverage)
(Digital: Digital imagery from photos)

There may be other private vendors.

Please forward information for future updates to: Bob Duffy, Washington Department of Ecology, P.O. Box 47600, Olympia, WA 98504-7600; (360) 407-6412; SCAN: (360) 407-6412; FAX: (360) 407-6426; SCAN FAX: (360) 407-6426.

Addendum
An out-of-print brochure produced by the Washington State Department of Natural Resources in 1986 provides an excellent, although somewhat dated, reference aid to map users.

The brochure includes a brief orientation to maps, as well as short descriptions of different map products. These are followed by agency listings, with the types of products produced or available. Numerous federal and state agencies produce cartographic products. These products range from general coverage to specific item information.

The brochure lists the major governmental producers of cartographic products with their 1986 addresses and phone numbers. Private companies that produce and sell maps and information have not been listed. It is suggested that these companies be located by consulting local telephone directory yellow pages under "maps".

If you have trouble locating a copy of this brochure in your own library, contact the Department of Natural Resources at (360) 902-1234 and request a photocopy.