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TECHNICAL METHODS FOR ASSESSING THE QUALITY OF AQUATIC ENVIRONMENTS IN WASHINGTON STATE:

A HANDBOOK OF THE SURFACE WATER INVESTIGATIONS SECTION

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ABSTRACT

The Surface Water Investigations Section of Ecology developed a handbook of technical methods for conducting water quality studies. The handbook describes survey planning, study design, and report writing activities, as well as assessment techniques for water, biota, and sediment quality. The handbook also provides an annotated bibliography and extensive reference section of water quality-related publications.

INTRODUCTION

The Surface Water Investigations Section (SWIS) of Ecology is one of four technical survey groups within the Environmental Investigations and Laboratory Services Program (EILS). The other three are Ambient Monitoring, Compliance Monitoring, and Toxics Investigations/Ground Water Monitoring.

SWIS is responsible for conducting intensive surface water quality studies statewide. Both point and nonpoint sources of pollution are investigated. Types of projects include, but are not limited to: receiving water studies for wastewater treatment plants; total maximum daily load (TMDL) and wasteload/load allocation (WLA/LA) determinations; limnology and aquatic ecology surveys; and nonpoint source assessments involving forest and agricultural practices. Projects generally address the ecological significance of conventional and toxic pollutants in water, biota, and sediment.

SWIS serves as an inside consultant to Ecology staff who require technical assistance in support of their water pollution control activities. Projects solicited by SWIS clients are usually complex in terms of scientific methodology, resource intensity, etc. SWIS findings are published in formal reports and technical memoranda, with emphasis on providing recommendations to management and staff concerning appropriate responses to water quality problems. Clients do not always implement these recommendations, nor are they bound to. Nonetheless, SWIS strives to assist clients in whatever manner possible.

The present handbook summarizes technical methods which SWIS staff follow in conducting water quality studies. The handbook outlines planning, study design, and reporting activities, as well as assessment techniques for water, biota, and sediment quality. An annotated bibliography provides a brief description of some technical manuals which SWIS staff consult for detailed guidance on water pollution assessment techniques. The handbook also contains an extensive reference section of water quality publications for additional reading.

The objectives of the handbook are threefold:

1. To promote consistency in water quality investigations conducted by SWIS.
2. To serve as a training tool for new staff within SWIS and others within Ecology.
3. To provide clients and others with a technical description of SWIS assessment methods.

The handbook unavoidably contains many acronyms. To facilitate reading, each acronym is usually defined when it first appears. In addition, Table 1 lists all acronyms used in the handbook and provides a definition for each.

PLANNING AND STUDY DESIGN

Planning Cycle

Projects that come into SWIS are generally of two types: unplanned and planned. Unplanned projects usually are reviews of work generated by other people, or a response to an emergency situation (e.g., find out what killed the fish in Sterile Creek last Tuesday). SWIS staff are expected to have about four days per month set aside for these unanticipated projects. Planned projects have gone through the administrative mill, and are assigned and scheduled as part of an annual planning cycle.

Briefly, the annual cycle begins in January or February when EILS management staff send out a memo to clients in regional offices and headquarters programs. The memo states when the EILS management team will be meeting with them to solicit projects for the coming fiscal year (July through June), and discuss the past year's successes and problems. The clients are asked to bring their project list to the meeting, and be willing to assign a priority rank to individual jobs. At this time, the SWIS manager often asks SWIS staff for suggested projects in particular regions (or the status of, and client response to, last year's projects). The rounds are made in late winter and early spring, and a list of all potential projects is drafted. The list is sent back to regional and headquarters staff for changes or additions, as well as confirmation of project rankings provided by the clients earlier.

In the meantime, general laboratory and resource budgets for each EILS section are put together. The EILS management team then meets and decides which section can best accomplish which projects. The SWIS project lists are evaluated in terms of: departmental goals, the prospects of completing a successful project (do-ability) and the client's commitment to use it, budget constraints, staff commitments, and the priorities of the requesting program. SWIS staff may be asked to calculate preliminary lab budgets for planning purposes, or to call clients for further clarification of their project objectives. By now it's May.

The EILS management team again meets to discuss each section's project ratings, and work on coordination of projects requiring staff from more than one section (e.g., wastewater treatment plant inspections with receiving water surveys). A new project rating list is sent to clients for comment.

By late May or early June, the list is ready for SWIS staff assignments. The projects have a very rough objective, scope, schedule, and budget. The way the projects are assigned to individuals varies: sometimes the SWIS manager assigns them, and sometimes the SWIS staff decide among themselves. Usually, the staff devise a plan for the coming year which includes assigned and carry-over projects, other duties, time for unanticipated work, training, and vacation/sick leave.

Project Proposal and Scope of Work

Given a particular project, the investigator is responsible for:

- Helping the client define the goal and objectives of the project, and determining the project's usefulness toward a solution to the problem;
- Creating a survey design that effectively addresses the client's needs;
- Seeing that the data are collected and evaluated; and
- Providing a timely final product with the form and content agreed to by the client.

The following is a suggested sequence to get through the proposal development stage. Not all projects are amenable to this particular sequence, but all investigators need some plan before going into the field.

A. Gathering Information and Developing Goals and Objectives

1. Call client to determine objectives and define scope of project: what kind of problem is suspected? (The sample check-list shown in Appendix A may be helpful in asking the right questions about parameters of interest.) Are there rules, regulations, or criteria pertinent to the situation? Can you accomplish what the client has in mind? If not, can you modify the objectives or provide other assistance? What is the ultimate use of your report, what is the client's commitment to use it, and what are his/her time constraints?

   Also, get project background information and local contacts (WTP operator's name, SCS agent, etc.). Discuss quirks in critical design conditions (e.g., industrial process influences effluent quality, but labor strike has caused plant slow-down). Does the site have known accessibility or equipment use difficulties? Does he/she want to be there, or can arrangements for regional/program help be made?

2. Identify preliminary objectives and scope; are they clear and obtainable with a firm commitment from the client that the information is necessary and will be used to resolve the problem? Are they reasonable given your limitations? Can you deliver the product with the budget and schedule allotted to the project? If any of the answers to these questions is "no", discuss the situation with the SWIS manager, and call the client back to resolve the issues.

3. Get additional background information to determine what you will encounter in the field and if there are others who have been or are working on similar questions at that site or similar sites.

- Maps: EILS map file and library has USGS quad, project, and oceanographic survey maps; Ecology cartography (Baran Hall) has several types of maps and extra USGS quads (for a price); DNR maps and surveys office has USGS quads, aerial photos of state lands, and specialty maps; DOT photogrammetric lab (Trosper Rd.) has aerial photos of Puget Sound shorelines, and lands near any state highway; county and city planning or public works offices have local maps and sewage system design maps; USFS and US Park Service have specialty maps of their jurisdictions.

- Discharge Monitoring Reports (DMRs): from regional office or WDIS computer system at HQ.

- Receiving water discharge and critical flow period data: Ecology Water Resources (instream flow regulation, ground water resources, and water rights); USGS publications (EILS library), computer network (ADAPS), and Tacoma, Pasco, Portland offices; USBR Yakima, Grand Coulee, various other offices; Puget Power and Washington Water Power, and PUD offices at hydroelectric sites; and irrigation districts.

- Current and historical surveys and water quality data: EILS PC STORET database files, project files (paper) and library (EILS finished project reports and those of others); Ecology regional files (correspondence, permit, and report); HQ and State libraries; Ecology Water Quality, Financial Assistance (including Lakes grants), and Hazardous Waste programs; EPA STORET data system; other agencies (Washington Departments of Wildlife, Fisheries, Natural Resources; Federal SCS Ag. Extension Service, USGS, EPA, USBR, USFWS, USFS, NMFS, Army Corps of Engineers; METRO; Indian tribes; city and county planning or health departments; private consultants; schools and universities.

- Reconnaissance surveys can be very helpful for gathering first-hand site information for a field plan and scope. If the project study area can be visited without an overnight stay, investigators often make a reconnaissance trip. A complex or unusually large project may require a reconnaissance trip, but if it is across the state, check with the SWIS manager before going.

- Methods manuals for analytical or data collection techniques: USGS, EPA (see Annotated Bibliography).

- Water quality, sediment and tissue criteria: State WACs and RCWs for Washington State criteria; Criteria for Sewage Works Design (Ecology 1985) for state mixing zone and sewage design guidelines; EPA gold book for federal criteria and guidelines; American Fisheries Society review of past federal criteria (the red book); FDA federal guidelines for chemicals in food;

International drinking water and food standards listed in various publications; DSHS (state) and EPA (federal) drinking water standards; State and Corps of Engineers dredge disposal criteria; USFWS fish and wildlife toxicity data and guidelines.

4. Refine objectives and scope: have the objectives been previously addressed? If so, have conditions changed since then, or can you use some of the historical information? Are you collecting the same information someone else is collecting? Can you cooperate and increase efficiency? Can some or all objectives of the project be met by working computer models, or performing mass balance calculations at your desk using available data? Check with the client if you change the objectives or scope of the project.

5. Preliminary field survey plan -- come up with a general idea of the following:

   - When the survey will be performed
   - The number of analytical samples needed (make a preliminary check with Manchester to see if they can manage the sample load and perform the analyses, or if a contract with an outside lab is necessary)
   - The types of media to be sampled
   - The QA/QC requirements for samples
   - Number of staff needed and for how many days
   - Any special equipment needs, or equipment scheduling problems
   - A preliminary cost estimate
   - A rough idea of locations, number of times sampled, composite or discrete samples.

6. Check with the client and SWIS manager to see if budget or time constraints are serious enough to modify plan.

B. Writing Proposal and Scope of Work

A project proposal is required for most work performed by SWIS and other Environmental Investigations sections. It is usually a one page summary showing "what, where, why, how, who, when, and for how much." The proposal is written when the investigator has a very good idea of project elements. Lab and equipment preliminary plans and an informal survey design have usually been worked through. The proposal is reviewed by the SWIS manager and client. Copies of the proposal are given to other EILS section managers for information and comment at least a few weeks before field work commences.

A scope of work is usually required only for an investigator's first few projects, a complex or especially sensitive project, or a resource-intensive project. The scope is a detailed description of elements in the project proposal (Yes, if you write a scope you still must write a proposal, too.). Its length and degree of detail vary depending on the complexity of the project, and the number of people inside and/or outside Ecology who will see it. The scope is ultimately reviewed by the SWIS manager and client; then it is submitted to the EILS management as previously described. Examples of a proposal and abbreviated scope of work are shown in Appendix B.

Field Preparation

A. Field Survey Design

Once the goals and objectives of the project have been set, designing an appropriate survey can begin. The goal of any survey design 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 survey design will be.

General guidelines for designing a survey are as follows:

1. Establish what limits you have on resources:
   - Budget
   - Equipment
   - Staff (who can help, what are there levels of experience, when are they available)
   - Field time
   - Data evaluation deadlines

2. Set the physical boundaries of the study area if these were not firmly set when the scope was agreed, 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 water quality outside the influence of any of the target discharges.

   - 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 unless efficiency data or data on a source of contaminants within the point source collection system are needed. Non-point sources can be defined by careful station placement or can be included in residual terms. 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. Set the survey confidence limits:

- Will an estimate based on a few samples meet the objectives and be defensible?

- 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; or increasing the duration of survey? The DESIGN computer program (Horner *et al.* 1988) may be helpful.

- 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, it doesn't make sense to measure discharge by timing a stick floating downstream, and then ask for low parameter detection limits from the lab.

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 the survey should ensure mass balance data are available and are collected where they will accurately represent the element of the equation. Sometimes lateral or vertical stratification of sampling is necessary to maintain accuracy (see A7, below). Other situations call for temporal stratification at a single site, or good understanding of time of travel within a survey area (see A6, 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 potential 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 toxics it is important to sample suspended sediment and organic carbon concentrations to accurately estimate the fate of the toxic. In addition, sediments are often the only medium where some toxics 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, ammonia concentrations need temperature and pH values to evaluate against water quality criteria; some metals require hardness values for evaluation; sediment analyses need grain size, TOC, and % solids, etc.

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 and Literature Cited 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 Chapra, 1983; Hammer and MacKichan, 1981; Sanders *et al*, 1983).

The timing of sample collection should be scheduled to best characterize the water quality problem, i.e. the critical period needs to be defined. Water quality impacts from municipal point sources are often most severe while the receiving water is at low flow e.g. the 7-day, ten year (7Q10) low flow event. 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, e.g. food processors output at harvest time when flows are slightly higher than the 7Q10. Non-point source impacts are generally more sporadic, and may be related to wet weather, storm events, or certain activities, e.g. irrigation, fertilizing, and harvest seasons, construction schedules, or the manure spreading/storing period. Seasonally stratified sampling designs are useful when a study area has a mix of point and non-point source impacts, i.e. samples are collected at two or more periods within the year to 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. Changes between sample runs can be compared, but the diurnal 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 following qualitative changes as a block of water moves downstream, or seaward. Specific event (rainstorm, treatment plant overloads, 7Q10, lowest mean tide, etc.) monitoring is important in some situations. It can also be difficult because sometimes the investigator has no control when the events will occur. Usually a "warning system" of local observers 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 SWIS staff.

Grab samples taken once or twice at selected stations is the most common method used. They can usually be collected quickly, with minimal equipment and processing needs. However, they may be less representative of the station, and should require careful planning and forethought before collection (see below).

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 obtain valuable information on diurnal cycles. Equipment security, scarcity, maintenance, and calibration are the major difficulties with using data-loggers for 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 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 has also been 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 survey 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

Table 2. Sampling guidelines for suspected pollutant sources: 1 = normally useful; 2 = occasionally useful; 3 = seldom useful (Huntamer and Smith, 1988).

	Primary WTP	Secondary WTP	Advanced WTP	Receiving Waters	Drinking Water	Domestic Wells	Stream Samples	Marine Samples	Brewery	Cooling Water	Boiler Water	Steam & Electric	Agricul. Runoff
PHYSICAL AND GENERAL INORGANICS													
Turbidity	-	-	-	2	1	1	2	2	1	-	-	-	1
pH	1	1	1	1	1	1	1	2	1	1	1	2	1
Conductivity	1	1	1	1	2	1	1	3	-	1	1	-	2
Total Alkalinity	-	1	1	2	2	2	2	2	-	-	1	-	3
Acidity	-	-	-	-	-	-	-	-	-	-	-	-	-
Hardness, Total	-	-	-	2	-	2	2	-	-	1	1	-	3
Chloride	-	-	-	3	1	1	2	-	-	1	1	-	3
Fluoride, Total	-	-	-	-	1	1	-	-	-	2	-	-	-
Sulfate	-	-	-	-	2	2	-	-	-	-	2	-	-
Cyanide, Total	-	-	-	3	-	3	3	-	-	2	2	2	3
Color	-	-	-	3	2	2	3	3	1	-	-	-	2
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	1	1	1	3	-	3	2	-	1	-	-	-	2
TOC-Total Organic Carbon	2	2	2	2	-	3	3	2	-	-	-	-	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	1	1	1	2	-	3	3	3	1	-	-	-	3
Percent Total Solids	1	1	1	-	-	-	-	-	-	-	-	-	-
NUTRIENTS													
Ammonia	1	1	1	1	1	1	1	1	2	1	1	1	1
Nitrate-Nitrite	1	1	1	1	1	1	1	1	1	1	1	-	1
Total Phosphorus	1	1	1	2	-	3	1	1	1	2	2	2	1
Soluble Reactive Phosphorus	2	2	2	2	-	-	1	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 2. Continued.

	Primary WTP	Secondary WTP	Advanced WTP	Receiving Waters	Drinking Water	Domestic Wells	Stream Samples	Marine Samples	Brewery	Cooling Water	Boiler Water	Steam & Electric	Agricult. Runoff
GC/MS ORGANIC SCANS													
Base-Neutrals/Acids	2	2	2	2	-	-	2	-	-	1	1	-	-
Base-Neutrals Only	-	-	-	-	-	-	-	-	-	-	-	-	-
Acids Only	-	-	-	-	2	-	-	-	-	-	-	2	-
Volatile Organisms	2	2	2	2	3	1	2	-	-	1	-	-	-
GC ORGANIC SCANS													
Pesticides/PCBs	2	2	2	2	2	-	2	-	-	-	-	-	1
PCBs Only	-	-	-	-	-	-	-	-	-	2	2	1	-
Purgeable Halocarbons	-	-	-	-	-	1	2	-	-	-	-	-	2
Herbicides	-	-	-	-	2	-	2	-	-	-	-	-	1
MISCELLANEOUS ORGANICS													
PAH Polycyclic Aromatics	-	-	-	-	-	-	-	-	-	-	-	-	-
Oil Identification	-	-	-	3	-	-	-	-	-	-	-	2	-
Phenolics	3	3	3	3	1	3	3	3	-	2	2	1	3
Oil & Grease	-	-	-	3	-	3	-	3	1	1	1	1	3
Flashpoint	-	-	-	-	-	-	-	-	-	-	-	-	-
Halogenated Hydrocarbons	-	-	-	-	-	-	-	-	-	-	-	-	-
TOX	-	-	-	1	2	-	-	-	1	-	-	-	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 2. 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 2. 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	-

8. Ask for advice if you need it, and check cost estimate against budget.

9. Fill out laboratory request for analysis form at least six weeks ahead of survey. It is best to send in a preliminary request as soon as you can. A preliminary request may stimulate additional discussion between yourself and laboratory staff.

10. Check out equipment area to see if EILS has necessary equipment and if it is already scheduled for use. Some people in SWIS have been assigned as stewards for pieces of equipment (Martek units, Data loggers, Hydrolabs, etc.). Check with the stewards about equipment availability and special requirements. Some special equipment can be borrowed from other sections in Ecology (Water Resources, Hazardous Waste, Spill Management and Safety) or other agencies (USGS, EPA, METRO, Departments of Fisheries or Wildlife).

11. Check equipment to see if it is operable, and also to familiarize yourself with its proper operation. If it is not operable, either schedule its repair or find an alternative. Always inform the equipment repair chief or steward about defective equipment. Check with SWIS manager about new equipment purchases. If you are unfamiliar with a certain type of equipment, schedule an orientation with the steward or someone else who is familiar with its operation.

12. Sometimes back-up equipment is nice to take along, however, consider the needs of other staff when taking back-ups.

13. Check if field reagents are fresh and adequate. Manchester can provide some refills, others require outside purchase.

14. If you need a boat for your survey, be sure to sign one out in advance. There are very specific written procedures for boat check-out and usage. You may need special training before you are permitted to operate a particular boat. Check with your equipment repair chief if you have any questions or concerns about boat usage.

C. Reconnaissance Trip

If practical, or if the project is complex enough, a reconnaissance trip to the project site may be warranted. A recon trip 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:

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

2. Observing if chosen sites are representative and safely accessible.

3. Collecting some preliminary field data (e.g. dissolved oxygen, conductivity, pH, and discharge) to run in models or in simple calculations.

4. Talking to WTP operators about discharge routines, upsets, cycles, production volumes, and problems.

D. Final Preparations

There are some details to attend to before going into the field:

1. Lab request filled out (six weeks ahead), and bottle and cooler request called to lab (two to three weeks ahead).

2. Lodging reservations (at least one week ahead).

3. Review of survey plans with assisting staff (as early as possible).

4. Inform reception area staff about schedule for office departure, site arrival, and return.

5. Double-check with field contacts on meeting places, schedules, etc. (couple of days ahead).

6. Equipment check-list (see Appendix C) and check-out (weeks to a few days ahead).

7. Clean compositors or other sampling equipment (day or two ahead).

8. Label preparation (EILS Ambient Section label software or by hand; a couple of days ahead if appropriate) and lab sample submittal forms. Use non-running ink and water-resistant paper.

9. Van packing, safety equipment, foul-weather equipment, van fueling and readiness.

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, become limited. A few field considerations:

1. Keep a detailed and legible notebook. Entries should include: project name, weather conditions, sampling date and time, site descriptions, and water quality

or other data. Bound notebooks are not required unless enforcement action is likely.

2. Keep a sense of order. Sample upstream to downstream (or reverse) to best meet project objectives. The upstream to downstream order on a small stream can sometimes create contamination problems downstream while upstream sites are sampled. The reverse order does not allow observation of a specific block of water. Estuarine or tidal river areas also can have strange station sampling orders depending on the tide changes.

3. 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.

4. Watch and be prepared for unexpected sources of contamination, and be flexible enough to deal with them.

5. 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.

6. Pack samples in cooler in a way which minimizes 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.

7. Put "Sample Data and Analysis Required" form into a plastic bag, then seal it and send with samples.

8. Protect field meters against excessive exposure to water, shock, heat, or cold. Take meters and calibration reagents into motel room during cold nights. Secure meters in van and boats against jolting and falling.

9. Chain and camouflage long-term monitoring devices when they are 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 (1989), Plafkin *et al.* (1989), APHA *et al.* (1989), and EPA/PSEP (1990). Other references can be found in sections that follow, and in the Annotated Bibliography.

WATER QUALITY ASSESSMENT

The methods summarized in this section are drawn largely from the screening procedures presented by Mills *et al.* (1985), which provide a detailed procedure for screening surface and ground water systems for most conventional and toxic pollutant problems. In general, the screening studies conducted by SWIS arise when our clients (usually the regional offices or the Water Quality Program) request a general water quality study (e.g., is the creek meeting water quality standards or is urban stormwater runoff degrading receiving water quality?). Screening surveys generally include identification of observed or potential water quality standards violations based on WAC 173-201 and applicable EPA criteria.

Pollutant Loading Calculations

Receiving waters are subjected to pollutant loading from a variety of point and nonpoint sources. Point sources are identifiable discrete discharges from municipal, institutional, and industrial waste water collection and treatment systems. Nonpoint sources are diffuse or distributed, and enter a waterbody through dispersed and often poorly defined pathways. SWIS studies typically are focused on surface water inputs.

Point source loading can usually be estimated from available data (e.g., NPDES Discharge Monitoring Reports- DMRs - on file at regional offices or the Industrial Section). Usually at least flow data are available in DMR's. The sampling plan for the survey will probably include collection of effluent quality data using either grab or composite sampling techniques. Historical quality data for some pollutants of interest may also be contained in the DMRs. If no monitoring data are available and sampling is not feasible, then effluent quality may be estimated by reported concentrations for similar effluents. Typical pollutant concentrations in a variety of effluents are presented in Mills *et al.* (1985). Hallinan (1988) has compiled a summary of metals concentrations in effluents from Washington State municipal WTPs. Wasteloads from point sources are calculated as the product of flow and concentration.

Nonpoint source loads to a waterbody are typically greatest during the wet season, and may be insignificant during dry weather. Sampling to characterize nonpoint loads typically involves identifying tributary drains and surface channels that discharge to the waterbody. These inputs are most often sampled as near as possible to the point of entry to the receiving water.

If the nonpoint sources are too diffuse (i.e., no distinct channel or surface input), then the nonpoint load may be characterized by including sampling stations immediately above and below the suspected input within the receiving water and attributing increased loading between stations to nonpoint sources. Direct sampling of ground water quality from representative wells may also be included if ground water loading is expected to be significant. For example, nutrient loading estimates from septic systems may be based on upgradient and dowgradient ground water sampling to evaluate nutrient retention in drainfields. Extensive evaluations of ground water usually involve the EILS Toxics Investigations and Ground Water Monitoring Section.

The quantity of nonpoint pollutant loading is affected by the land-use and land-cover characteristics of a drainage basin. Estimates of basin-wide loadings often are based on application of unit areal loading rates from specific land-use/land-cover types over the total areas for each type within a basin. Unit areal loading rates may be found from reported values in literature or sampling of representative areas within a basin. A variety of more complex nonpoint loading simulation models are also available, which require field studies for calibration of numerous coefficients. Inventories of diverse land-use/land-cover characteristics within a basin may be aided by the use of Geographic Information Systems (GIS) such as ARC-INFO.

Rivers and Streams

A. Mixing Zones

A mixing zone is the area adjacent to an effluent outfall where mixing results in the dilution of effluent with the receiving water. If a major focus of the project is to describe near-field effects of a discharge (e.g. acute toxicity in the mixing zone), then it is usually not realistic to assume that complete mixing with the receiving water occurs quickly. It may be necessary to design sampling surveys and perform model simulations to describe the mixing zone. SWIS has a simple spreadsheet that allows estimation of effluent dilution from a point source to a river (see Appendix D) assuming that dilution is influenced mainly by ambient turbulence and dispersion, and not as much by the initial momentum and buoyancy of the effluent plume. Dilution models are summarized in more detail below.

The following general considerations apply to evaluating mixing zones in river systems:

1. A diagram or written description of the as-built diffuser length and diameter, port orientation, port diameters, and arrangement with respect to the river bottom or seabed (e.g. slope) and to other ports should be obtained. Also, the integrity of the diffuser structure should be verified.

2. Other outfalls or discharges which may influence the dilution zone under study should be identified and characterized as part of the dilution zone study.

3. The mixing study should be conducted during periods of river discharge that are near the 7-day-10-year (7Q10) or 1Q10 low flow.

4. Plant discharge should be at the typical existing condition for the season of study. The study should address extrapolating results to evaluate dilution for the permitted discharge rate at the 7Q10 and 1Q10 critical design events.

5. Field studies should include characterization of representative channel geometry (e.g., depth, width, velocity, and slope) in the river reach that contains the dilution zone. This data will be useful for input to theoretical transverse mixing models (Fischer *et al.* 1979).

6. River discharge should be approximately constant during the dilution zone study. River discharge rates should be accurately measured (accuracy +/- 5-10%) using standard techniques (USGS 1962).

7. A suitable conservative tracer should be identified for calculating the volume fraction of effluent at sampling points downstream from the discharge. Tracers that occur in the effluent may be used provided that the tracer concentration in the effluent is sufficiently elevated to detect approximately 1 percent effluent. As an approximate guideline, the concentration of tracer in the effluent should be higher than the ambient concentration (upstream from the input) by at least 100 times the precision of the method being used to measure the tracer. For example, if conductivity is being used as a tracer, and the precision of the method used to measure conductivity is $\pm$ 2 umhos/cm, then the effluent should have a conductivity of at least 200 umhos/cm greater than the upstream condition.

8. A common way to characterize effluent dilution zones is to conduct dye studies using Rhodamine WT. Mills *et al.* (1986) describe in detail a way to conduct dye studies of dilution zones.

9. Since one of the products of a dilution study is to develop dilution isopleths, the survey should include a suitable number of cross-channel (perpendicular to direction of flow) transects. As a rule of thumb, the change in the maximum tracer concentration across the channel between transects should not exceed a factor of three or four (Mills *et al.*, 1986). A minimum of two downstream transects, one at 30 and one at 300 feet downstream from the discharge, should be made (current mixing zone policy allows a maximum length of 300 feet for exemption from water quality standards for discharges to rivers). Additional transects would be helpful to better describe dilution isopleths. If complete mixing does not occur within 300 feet, then additional transects below 300 feet until complete mixing is observed would be desirable.

   The upstream concentration of the tracer should also be measured (approximately three cross-channel samples would probably suffice). Each downstream transect should contain at least 5-10 sampling points across the channel, with emphasis on the zone of significant effluent concentration. Each transect should have enough sampling points to extend either into the region of the receiving water beyond the discharge influence or to the river banks.

Each of the downstream transect sampling points should include discrete sampling at enough depths in the water column to define vertical distribution of effluent. As a rule of thumb, sampling at 0.5 to 1.0 meter depth intervals from surface to bottom should be sufficient.

10. The method for determining and maintaining location within the sampling grid should be identified.

11. The study report should contain plan view and cross-sectional tracer concentration and dilution isopleths.

12. The report should also contain a tabular summary of the channel geometry, river flow, plant flow, and tracer concentration data measured, as well as a discussion of the methods and results. Dilution factors observed during the study should be extrapolated to the design condition of river and plant discharge.

13. Dilution from both discharge-induced and ambient-induced mixing processes can be estimated from computer models. EPA's plume models (Muellenhoff *et al.* 1985) can be used to estimate discharge-induced mixing from initial plume momentum and buoyancy. The methods in Fischer *et al.* (1979) can be used to estimate ambient-induced dilution from turbulence and dispersion (see SWIS spreadsheet RIVPLUME in Appendix D). Both processes can be considered if the output from a discharge-induced mixing model is used as input to a suitable ambient dilution model such as the EPA model RDIFF (Yearsley 1987). SWIS has a relatively new program, CORMIX1 (Doneker and Jirka 1990), which predicts the initial dilution and downstream dispersion of effluent discharged from a single port diffuser. CORMIX1 is an expert system (i.e., it checks for data consistency, executes appropriate models, interprets simulation results, and suggests design alternatives to improve dilution).

B. River Segmentation

Far-field modeling of river water quality is generally accomplished by dividing the river system into segments or reaches. Analyses of river systems normally begin at a segment where the boundary conditions are known (i.e. upstream from point and nonpoint loads) and proceed sequentially downstream. The initial upstream condition usually represents the background loading from natural processes. Sampling stations in rivers are generally located at the boundaries of segments. The following general rules apply when segmenting rivers (although they may be superseded by more direct knowledge):

1. Point sources and tributaries enter the river at the upstream boundary of a segment.

2. Distributed nonpoint sources enter throughout the length of a segment.

3. Pollutant concentrations at the upstream end of segments are obtained by mixing the pollutant concentration in the river with the point source or tributary input (if there are any). If the focus of the survey is on near-field effects (e.g., acute toxicity in the mixing zone), then it is probably not realistic to assume complete mix near the point of discharge, as discussed above.

4. Generally, constant hydraulic variables (e.g., depth and velocity) are used throughout a segment. If there is a gradual change in hydraulic variables over distance, an average value can be used. If hydraulic variables are known to change significantly, then new segments should be created.

5. Decay rates, reaeration rates, and other rate coefficients remain constant within a segment. If rate constants are known to change significantly, then a new segment may be created.

   Typically, a major objective of river sampling surveys is to characterize the physical and chemical conditions of each stream segment for the time of sampling and for a set of design conditions which may represent a reasonable worst-case scenario.

C. Dissolved Oxygen and BOD

Many wastes discharged into waterways contain biologically oxidizable materials that exert an oxygen demand. The most commonly used technique to estimate the effect of a BOD load on a river is the Streeter-Phelps equation (Mills *et al.* 1985), which is presented in detail in EPA guidance documents. Oxygen is consumed by first-order decay of BOD. At the same time, the atmosphere replenishes oxygen at a rate proportional to the depletion from saturation.

SWIS has a simple spreadsheet (DOSAG.WK1-Lotus) that calculates the critical D.O. sag (minimum D.O.) and distance downstream to the critical sag for a single point source discharge to a river. An example of this spreadsheet is presented in Appendix D. If D.O. profiles are to be predicted for more complicated systems (e.g., multiple discharges or stream reaches), then a more complicated model should be used, like SWISs BASIC program DOSAG.EXE or EPAs QUAL2E model.

Stream sampling surveys for D.O. are usually designed to provide calibration data for input to Streeter-Phelps models. D.O. sags typically become apparent several miles downstream from a BOD load. Therefore, preliminary calculations of D.O. sag and location may be useful in designing locations for sampling stations. BOD decay rates and D.O. reaeration rates often are calculated from published relationships with discharge, velocity, depth, and stream slope (Mills *et al.* 1985).

The Streeter-Phelps equation requires an estimate of the load of "Ultimate Oxygen Demand" (UOD) from all carbonaceous and nitrogenous sources to predict D.O. depletion. Direct measurement of ultimate carbonaceous BOD (CBODU; Stamer *et al.*, 1983) is preferable for model calibration and validation. However, an approximation from 5-day carbonaceous BOD ($CBOD_5$) can be made as follows, assuming a CBOD decay rate (base e) of 0.23/day (Mills *et al.*1985):

$$(\text{CBODU in mg/L}) \approx 1.46 * (\text{CBOD}_5 \text{ in mg/L})$$

This assumption has significant implications to water quality modeling because the ratio of CBODU/$CBOD_5$ is both wasteload and receiving water specific (Bowie *et al.*, 1985). Ultimate to 5-day ratios as high as 30 have been reported for some paper industry wastewaters.

Ammonia and organic N may also affect instream dissolved oxygen, thus they should be considered as sources of "nitrogenous" BOD (NBOD), which is usually estimated as:

$$(\text{NBOD in mg/L}) \approx 4.57 * (\text{Ammonia+Organic-N mg/L})$$

The UOD is then determined as the sum of CBODU and NBOD. Other sources and sinks of D.O. that may be important to consider include benthic demand, photosynthesis, and respiration.

D. Nutrients and Eutrophication

The most limiting algal nutrients, nitrogen and phosphorus, can be elevated in rivers from point and nonpoint loads. However, increased nutrient levels do not always result in algal blooms. For example, algal growth may be restricted by turbidity and short residence time in the river environment. Even if other factors limit algal growth in rivers, nutrient loading will be of interest if the river discharges to a lake or estuary, in which case the eutrophication problem may be transferred downstream.

E. Bacterial Indicators

Coliform bacteria are commonly used as an indicator of potential pathogen contamination. Until recently, coliforms were regarded as less sensitive to environmental stress than enteric pathogens. Therefore, coliforms were considered a more conservative index of potential pathogen levels.

Recent evidence (Bowie *et al.* 1985) concerning enteric viruses and opportunistic pathogens suggests that coliform bacteria are not the ideal indicator, because some pathogens may: die-off at a slower rate than coliforms; have major non-fecal sources; or grow in the environment.

The coliform group consists of both fecal and non-fecal components. The fecal coliform (FC) test may be influenced by the presence of Klebsiella species which are commonly abundant in pulp mill effluents.

In addition to FC, fecal streptococci (FS) provide another commonly used indicator of fecal contamination. As with FC, FS have both fecal and non-fecal components. Enterococci and *S. faecalis* are more specific to fecal sources than non-enteric streptococci. FS and particularly enterococci have much slower die-off rates than FC and total coliform. Thus, they are more persistent in the environment and may be a more sensitive indicator of the presence of pathogens.

The ratio of FC/FS has been used to discriminate between human and non-human sources of fecal contamination (Geldreich and Kenner 1969). If the ratio exceeds approximately one (although four is sometimes cited as the cutoff value), the source is presumed to be human fecal material. FC/FS less than one is presumed to be of non-human origin. The major problem with the FC/FS ratio is that it can be dramatically altered once the material enters natural waters, particularly if the sampling location is not close to the source.

F. Toxic Substances

The fate of toxic substances in natural waters is potentially very complex. Toxicants are influenced by sorption with suspended solids (particularly organic carbon), volatilization and decay of dissolved material, and diffusion and resuspension interactions with sediment. The most important fate processes depend on source characteristics (Mills *et al.* 1985). A detailed description of the major fate processes for different sources of toxic substances is beyond the scope of this handbook.

The most often cited modeling approach for toxics is applied in EPA's WASP4 model (Ambrose *et al.* 1988) and SMPTOX2 model (Limno-Tech 1986). Suspended solids are first modeled using a first-order sedimentation rate. A partitioning coefficient (which is specific to the toxic substance being considered and the suspended solids concentration) is then used to determine the fractions of the substance that are dissolved and sorbed to solids. Volatilization rates are generally determined from Henry's law. A lumped first-order decay reaction that includes volatilization, biodegradation, photolysis, and hydrolysis is then applied to the dissolved fraction. Interactions with the sediments (resuspension and diffusion) may also be simulated with WASP4.

Due to the complexity of toxics modeling, most sampling surveys will be aimed at simply identifying whether or not priority pollutants are present in appreciable amounts. In practice, most mass balance modeling (especially in dilution zones) will probably be based on the assumption that the toxic substance is conservative in the environment.

Lakes and Reservoirs

A. Eutrophication

Eutrophy means literally a state of good nutrition. Eutrophication of lakes is caused by excessive inputs of algal nutrients, namely nitrogen and phosphorus. Phosphorus is most often the critical limiting nutrient. Studies of lake and reservoir eutrophication typically involve at least year-long monitoring of lake nutrient and algal biomass levels at bi-weekly to monthly intervals, as well as continuous monitoring of hydraulic and nutrient loading from tributaries and point sources. A detailed description of the monitoring needs for a lake eutrophication diagnostic study is contained in Cooke *et al.* 1986. This type of study requires a long-term commitment of labor and laboratory resources, and is not routinely conducted by SWIS.

Most often SWIS screening studies for eutrophication will include short-term sampling of loading sources (e.g., agricultural drains, tributaries, etc.) rather than monitoring of the lake that is the receiving water. In these types of studies, nutrient loads are measured in a large number of sources simultaneously, and the various loading sources are ranked to identify major sources which may deserve further investigation (e.g., to identify specific nonpoint sources upstream).

Another type of eutrophication study may involve limited sampling of a large number of lakes. This type of study usually does not provide enough data to do a diagnostic analysis of eutrophication, but it may provide a basis for ranking identified problem areas. These types of screening surveys may also provide enough data to develop regional empirical calibrations of phosphorus model parameters (e.g., the phosphorus sedimentation rate). Reckhow and Chapra (1983) provide a detailed description of how limited data from a large number of lakes may provide insight for predicting regional eutrophication effects.

B. Dissolved Oxygen

Organic substances introduced to a lake with inflowing water, falling onto its surface, or generated in the water column via algal productivity may exert a BOD and thus reduce D.O. concentrations. Other D.O. sinks include benthic demand, chemical oxidation, and algal and plant respiration. Sources of D.O. are atmospheric reaeration, algal photosynthesis, and D.O. in inflowing water, including rainfall. During summer stratification, D.O. is highest in the upper mixed layer due to photosynthesis and reaeration. D.O. decreases with depth and may reach zero, particularly if organic loading from algal production is high. If the lake completely mixes during winter and spring, D.O. concentrations will be largely uniform over depth.

C. Toxicant Screening

As in rivers, the fate processes of toxicants in lakes are complex. In general, screening techniques in lakes are conservative because they assume that loss mechanisms (e.g., volatilization, sorption, etc.) are insignificant. As a result, simple dilution models are often used to predict concentrations as a preliminary screening. Most sampling efforts are aimed at quantifying the loading of priority pollutants in point and nonpoint source inflows. Concentrations in the receiving water may then be calculated by a dilution model and compared to the actual concentration observed, as well as to water quality criteria.

Estuaries

A. Mixing Zones

Field studies to characterize buoyant plumes in marine or estuarine receiving waters are generally focused on defining the critical ambient conditions of vertical density stratification and current speed/direction. Dye studies may also be used, especially in situations where flushing characteristics of the receiving water are suspected of limiting available dilution. The following general considerations apply to evaluating mixing zones in estuarine systems:

1. A diagram or written description of the as-built diffuser length and diameter, port orientation, port diameters, and arrangement with respect to the seabed and other ports should be obtained. If possible, perform a hydraulic evaluation of diffuser performance at the design flow (e.g., method of Rawn *et al.* 1961) as part of the study scope. For multiple port diffusers, the design flow of each port should be estimated based on the as-built diffuser configuration, since unequal flow may influence the actual dilution achieved. It is not necessary to calculate dilution for each port, but only for the segment of the diffuser with the worst dilution characteristics -- that is, the port with the highest design flow.

2. Worst-case ambient density profiles should be selected for input to buoyant plume dilution models. At a minimum, dilution in the cases of minimum and maximum stratification at the permitted design flow should be evaluated. Density profiles may be estimated from existing data if available. Otherwise, a sampling program to define density structure should be performed.

3. Since ambient currents may affect dilution, a modest current speed may be assumed (lowest 10th percentile of ambient currents). If no data are available, then current monitoring must be performed or current velocity assumed to be zero.

4. Several mathematical models are available from EPA which are appropriate for different oceanographic and diffuser conditions (Muellenhoff *et al.* 1985; Doneker and Jirka 1990). The dilution zone study should include a definition of input to plume models, including: discharge depth, flow rates per port, density of effluent, density gradients in the receiving water, ambient current speed and direction, diffuser port sizes, port spacing, and port orientation.

5. An evaluation of mixing beyond the zone of initial dilution may be included if current speed data are available (e.g., method of Brooks 1960; Doneker and Jirka 1990).

B. Flushing Time Calculation

Flushing rates should be determined for estuaries which are suspected of having considerable tidal exchange. Flushing rates account for both tidal exchange and freshwater inflow. In some cases, flushing evaluations should also include characterization of refluxing, where a portion of the outflowing wastes are recirculated (recycled), thus reducing available dilution.

Flushing time is a measure of the time required to transport a conservative pollutant from some specified source location within the estuary or embayment (usually, but not necessarily, the most remote point or "head") to the mouth. Processes like pollutant decay and sedimentation, which can alter pollutant distribution within an estuary, are not considered in the concept of flushing. The flushing time and estuary volume also determine the dilution "discharge" available from tidal exchange, which is in addition to dilution available from freshwater inputs.

Two common methods are used to estimate estuary flushing. Both are described in detail in Mills *et al.* (1985) and are briefly summarized below:

1. Modified tidal prism method:

   - Segment the estuary so that each segment length reflects the excursion distance a particle can travel over one tidal cycle.

   - Calculate the exchange ratio for each segment, which is the portion of water which is exchanged with adjacent segments during each tidal cycle. The exchange ratio is the intertidal volume divided by the sum of intertidal volume and low tide volume.

   - Calculate segment flushing time as inverse of exchange ratio.

   - Calculate total estuarine flushing time by summing over all segments.

2. Fraction of freshwater method (assumes vertical stratification absent):

- Graph the estuarine salinity profiles.
- Divide the estuary into segments selected so that salinity is reasonably constant over the length of each segment.
- Calculate each segment's fraction of freshwater based on salinity of local seawater and each segment's actual salinity.
- Calculate the quantity of freshwater in each segment.
- Calculate the exchange time in each segment as the ratio of freshwater in each segment over river discharge.
- Calculate total estuary flushing time as sum of segment flushing times.

C. Far-field Approach to Pollutant Distribution

Two general approaches are usually used in evaluating pollutant distributions in estuaries: far-field and near-field. In the far-field approach, pollutant loads are assumed to completely mix over the entire cross-section of the estuary or over a smaller portion of the estuary. The flushing rate methods discussed above are far-field methods that describe the transport of conservative pollutants. Pollutant distributions can be calculated by linking transport models (modified tidal prism or fraction of freshwater) with pollutant fate processes, which are usually described as either conservative or first-order decay.

The most common technique is to assume that the pollutant is conservative (i.e., losses only by dilution), which tends to over-predict concentrations and therefore err on the side of protecting water quality. The segmenting scheme used in the flushing rate analysis is often used in pollutant distribution calculations. Pollutant concentrations are calculated by assuming that the pollutant distribution will be identical to the freshwater distribution in the estuary segments.

D. Pollutant Distributions from Sewage Outfalls

Near-field analyses consider the buoyancy and momentum of the wastewater as it is discharged into the receiving water. The actual amount of mixing that occurs is calculated as an integral part of the method. Pollutant concentrations usually are calculated by assuming that the pollutant is conservative (i.e., loss processes are assumed to be negligible during the short period over which initial dilution occurs). This allows comparison of calculated pollutant concentrations with water quality criteria, which are applicable at the boundary of the initial dilution zone. The computer models discussed earlier are generally used to estimate initial dilution (Muellenhoff *et al.* 1985; Doneker and Jirka 1990).

TMDL ANALYSES

In 1971, the State of Washington enacted legislation which required dischargers to use "all known, available and reasonable methods of treatment" (AKART) prior to discharge regardless of the quality of the water to which the wastes are discharged. The requirements of AKART, also called technology-based control, represents a philosophy that all dischargers should provide a high level of treatment.

The primary mechanism for implementing Washington's water quality standards is provided under Section 303 of the Clean Water Act. Section 303(d) requires the states and EPA to establish total maximum daily loads (TMDL's) for all water quality limited segments (i.e., those waters which cannot meet standards after application of technology-based controls). The TMDL for a given pollutant is then apportioned between point sources (wasteload allocations - WLAs) and nonpoint sources (load allocations - LAs). The allocations are implemented through NPDES permits, grant projects, and nonpoint source controls. A portion of the TMDL may be set aside as a reserve to accommodate future growth. A reserve may also be allocated to provide a margin of safety in waters of particular sensitivity or complexity. Ecology policy for the TMDL process is currently being formulated by SWIS (Kendra 1990).

EPA has developed a series of comprehensive technical guidance documents which describe in detail the procedures for performing TMDL/WLA/LA analyses (see Annotated Bibliography). The following discussion summarizes some of the information and techniques in these Technical Support Documents (TSDs), but the reader is advised to consult the actual TSDs before applying the concepts directly.

Chemical Specific vs. Whole Effluent Approach

EPA has outlined two approaches to developing water quality-based WLAs for point sources: 1) chemical specific; and 2) whole effluent. The chemical specific approach is typically applied to conventional pollutants (e.g., BOD) or toxic pollutants on an individual basis. The whole effluent approach applies to discharges which may exhibit some toxicity to aquatic life, but the specific chemicals which cause the toxicity are unknown. EPA recommends the use of both approaches in an integrated strategy to protect aquatic life and human health.

A. Chemical Specific Approach

The chemical specific approach uses water quality criteria to limit specific toxicants individually. In the case of toxic substances, both acute and chronic toxicity are considered. The principal considerations of the chemical-specific approach are:

- Treatment systems are more easily designed to meet chemical requirements if the pollutant is known.
- The fate of the pollutant can be estimated through simulation modeling.

- Chemical analyses may be less expensive than whole effluent biomonitoring.

- All toxicants in complex wastewaters may not be identified.

- Chemical analysis can be expensive, especially for organic toxicants.

B. Whole Effluent Approach

The whole effluent approach to toxics control involves the use of toxicity tests to measure toxicity of effluents. An analogy between toxicity and BOD is made by EPA (1985). Both are quantifiable measurements of an aggregated biological effect. Whole effluent toxicity is expressed in "toxic units", which are the inverse of the effluent dilution that causes a toxic effect (acute toxic units are the inverse of the LC_{50} dilution; chronic toxic units are the inverse of the NOEL dilution). In modeling applications, the toxic units are treated exactly as if they were concentrations to calculate the toxicity of diluted effluent in the receiving water.

The principle considerations of the whole effluent approach are:

- The aggregate and/or synergistic toxicity of all constituents in a complex effluent is measured, and toxic effects can be limited by limiting only one parameter -- effluent toxicity.

- The bioavailability of toxic constituents is assessed, and the effects of constituent interactions are measured.

- Properties of specific chemicals are not addressed.

- Toxicity treatability data are lacking.

- Toxicity which is "released" upon interaction of effluent and receiving water is not addressed.

- Fate processes are not well understood and modeling is limited to simple dilution (i.e., toxicity is usually considered to be conservative in the receiving water).

Development of TMDL, WLA, and Permit Limits

TMDL and WLA analyses range in complexity from very simple (e.g., single discharger, negligible nonpoint loading, and conservative pollutant) to very complex (e.g., multiple dischargers, significant nonpoint loads, and complex fate processes). Both near-field and far-field effects may be the focus of the WLA. In general, conventional pollutants like BOD require far-field analyses, while toxicants like chlorine require near-field analyses.

An interesting feature of developing TMDLs and WLAs is that existing effluent loading need not be known to determine the water quality-based WLA. The process begins with consideration of applicable water quality criteria or standards which must be met. The available dilution and fate processes are dictated by the characteristics of the receiving water. The simplest example of a WLA (i.e., a single discharger of a toxic or conservative pollutant with no nonpoint or background load) best illustrates the water quality basis of the TMDL/WLA approach:

$$WLA = WQS * DF$$

Where WLA is the allowable effluent pollutant concentration, WQS is the water quality standard, and DF is the dilution factor in the receiving water. The background concentration (Cb) of a pollutant from unidentified or uncontrollable sources upstream can be factored into a WLA for a single discharger as follows:

$$WLA = (WQS * DF) - Cb * (DF - 1)$$

Although the existing effluent concentration is not needed to derive the WLA, it is needed to decide whether or not a water quality-based permit is required. In general, EPA recommends development of a water quality-based permit if the currently permitted effluent load is above approximately 30 percent of the WLA.

Once the WLA is determined, the TSDs may be consulted to derive appropriate permit limits which incorporate effluent variability. SWIS has developed spreadsheets which calculate permit limits for chemical specific and effluent toxicity approaches, as shown in Appendix D (WQBP-CON for chemical specific; WQBP-TOX for whole effluent toxicity). These spreadsheets also calculate WLAs for the simple case of a single discharge of a toxic or conservative pollutant and known background or upstream concentration.

A. Rivers and Streams

1. Design conditions

A major consideration of the TMDL/WLA analysis is the design condition, which is the assumed set of conditions (i.e., quantity and quality of river and effluent) which represent an unlikely enough circumstance to meet the frequency requirement of acceptable water quality violations (e.g., no more than one violation of chronic or acute toxicity every three years). EPA recommends using the 7-day-10-year low flow (7Q10) as a design river flow for chronic evaluations and 1Q10 for acute evaluations.

Evaluation of seasonal permit limits should ensure that the risk of water quality impairment is no higher than that allowed under a nonseasonal program (Rossman 1989; GKY and Associates 1984). The recurrence intervals for seasonal design flows can be selected to maintain environmental equivalency with the annual 7Q10 or 1Q10 as follows (GKY and Associates 1984):

Permit Time Interval	Annual Risk Equivalent Return Period (yrs)
Annual	10
Semiannual	20
Quarterly	38
Monthly	114

For example, if seasonal permits are calculated for semiannual periods (six months), then the design flow for equivalent risk (annual ten percent risk) would be 7-day low flows with 20-year recurrence intervals from each six-month season.

Design parameters for other conditions of the receiving water (e.g., velocity, depth, temperature) are those which would be found during the design flow. If historical data are available, the design conditions for parameters other than flow are usually taken as restrictive values in the data record (e.g., maximum, 95th percentile, or 90th percentile for temperature, pH, etc.), with the objective of conservatively estimating conditions present when the design flow occurs. SWIS recommends the use of the most restrictive (highest or lowest) five percentile from Ecology ambient monitoring data, if available, for estimating design conditions for parameters other than discharge.

2. BOD, dissolved oxygen, and eutrophication

The considerations for TMDL modeling of D.O. are the same as those presented earlier. The Streeter-Phelps model (either in a spreadsheet like DOSAG or in a complex river model like QUAL2E) is used to estimate the D.O. sag that will occur for a projected BOD load. A procedure to estimate the WLA from a predicted D.O. sag is presented in the TSDs.

Eutrophication problems in rivers are sometimes difficult to frame in terms of a WLA because there are no widely accepted nutrient criteria if the river is the only waterbody of concern. However, if the river discharges to a lake or reservoir, there are some general criteria for prevention of lake eutrophication which may be used to set the riverine TMDL. For example, Ecology developed the TMDL for phosphorus loading to the Spokane River based on the protection of Long Lake, a downstream impoundment of the Spokane River.

3. Toxics

For single dischargers, TMDLs for toxics are most often based on near-field water quality (i.e., meeting acute criteria within the dilution zone and chronic criteria at the boundary of the dilution zone). Therefore, dilution zone characterization (through tracer or dye studies and/or plume modeling) is usually an integral part of the toxics WLA. If the dilution factor and upstream/background conditions are known, then the

WLA and permit limits can be calculated easily (e.g., using SWIS spreadsheets WQBP-CON or WQBP-TOX; see Appendix D). However, in many cases the analysis is complicated by the presence of more than one discharger. In these instances, a TMDL must be apportioned equitably among the point and nonpoint sources, including some reserve for uncertainty and future growth. The procedures for conducting complex WLAs are somewhat site-specific and beyond the scope of this handbook.

TMDL modeling of complex systems can be simplified by assuming that the toxic substance (or whole effluent toxicity) is conservative in the receiving water. Therefore, simple dilution models can be used to predict the concentration profile in a river assuming additivity of all sources. However, this technique may tend to be overly restrictive since it does not account for processes like pollutant decay or sedimentation which tend to cleanse the system. If the outcome of dilution modeling requires very expensive or unfeasible levels of treatment, then it would be appropriate to build complexity into the modeling framework. This would be done by attempting to include fate processes in the model to account for loss mechanisms in the receiving water (e.g., sedimentation, decay, etc.). Appropriate models for evaluating toxic discharges to rivers are provided in the TSDs and in Thomann and Mueller (1987). A phased approach to adding complexity is usually best. A good rule for WLA modeling is to start with the simplest approach possible (e.g., dilution models) and only add complexity (e.g., fate processes) if the dilution model is judged to be overly conservative.

B. Lakes and Impoundments

1. Design conditions

This receiving water category encompasses lakes and reservoirs with mean residence times in excess of 15 days (WAC 173-201). Seasonal variations in water level, wind speed and direction, and solar radiation should be determined to define the critical design period. In the case of long and narrow reservoirs, areas above the plunge point (the point where stream-like flow ends and density-induced mixing and stratification begin) can be analyzed as rivers, and areas below as reservoirs.

Since effluent density relative to ambient density conditions may vary seasonally, no one season can be selected as the most critical dilution situation for all cases involving near-field studies. Therefore, near-field analyses should include an evaluation of all seasons to select the most limiting. All seasonal analyses should assume an ambient velocity of zero unless persistent currents are documented.

2. Eutrophication

TMDLs for control of eutrophication are generally designed to limit nutrient inputs. In most lakes, phosphorus is the nutrient which most limits algal growth. Therefore, phosphorus mass balance models (usually on an annual time scale) are used to predict lake nutrient levels for various loading scenarios. The TMDL for phosphorus loading would correspond to the critical loading that would maintain the desired trophic status. The most appropriate models are presented in the TSDs. Also, Reckhow and Chapra (1983) present state-of-the-art techniques for lake eutrophication modeling.

3. Dissolved oxygen

The TSD for conducting TMDLs for BOD in lakes is not yet available from EPA. However, the principles discussed earlier still apply. In general, D.O. modeling for lakes must account for organic matter produced within the lake by photosynthesis, as well as external inputs from point sources.

4. Toxics

The principles of conducting TMDLs for toxics in lakes are similar to those discussed for streams and rivers. Most toxics WLAs are focused on near-field effects. Therefore, dilution modeling or dye studies for characterizing mixing zones are usually an integral part of the WLA analysis.

C. Estuaries and Coastal Bays

1. Design conditions

Determining the nature and extent of the estuarine discharge plume is complicated by tides, river inflows, wind intensity and direction, thermal and saline stratification, and other environmental factors. Because of the complexity of circulation and mixing processes, the available dilution water cannot be determined from the rate of receiving water discharge (e.g., 7Q10).

In estuaries without stratification, the critical dilution condition includes a combination of low-water slack at spring tide and design low river flow. In estuaries with stratification, a site-specific analysis of periods of minimum and maximum stratification, both at low-water slack, must be made to evaluate which scenario results in the lowest dilution. The worst case extent of the plume should also be checked by considering off-design conditions of maximal tidal current velocity.

2. BOD, dissolved oxygen, and eutrophication

Specific guidance from EPA on TMDLs for estuarine D.O. and eutrophication problems are not yet available. In general, the principles are similar to those for lakes and reservoirs. D.O. modeling should include the effect of algal production, in addition to point source BOD loading. As in lakes, eutrophication problems are linked with D.O. problems because increased algal production results in greater internal production of oxygen demanding material. Nitrogen usually limits algal productivity more frequently than phosphorus in estuaries. However, algal productivity in estuaries is often limited by factors other than nitrogen and phosphorus (e.g. light). Therefore, eutrophication studies in estuaries require identification of specific factors that control algal growth. These types of studies are usually not conducted by SWIS due to complexity and consequent level of effort.

3. Toxics

The principles of conducting TMDL analyses for toxics in estuaries are similar to those discussed for lakes. Discussion of specific elements of estuarine TMDLs for toxics is beyond the scope of this handbook. Most toxics WLAs are focused on near-field effects. Therefore, dilution modeling or dye studies for characterizing mixing zones are usually an integral part of the WLA analysis.

BIOLOGICAL SURVEYS

Freshwater Communities

Analysis of the biological component of freshwater ecosystems is of great value in examining habitat condition, trends over time, and cumulative impacts of pollution sources. The biological component is comprised of various groups of organisms (e.g. fish, benthic macroinvertebrates, plankton, etc.) and should be surveyed based on the purpose of a particular investigation. Each group may provide specific types of environmental information based on habitat requirements and the suitability of existing habitat. The source of impact can often be identified by inventorying possible point- and non-point source impacts in the drainage.

Water quality sampling and analysis has historically been used to assess suspected environmental health problems. The use of biological information in environmental assessment integrates water quality over time, which differs from water samples that relay information in a discrete time interval. Biotic and water quality information are complementary and elucidate extant or impending degradation of an aquatic environment.

Sampling the biological component of an aquatic ecosystem usually involves more effort than projects concerned solely with water sampling. For this reason, the biotic component is not included in many project efforts. The investigator's lack of experience and adequate knowledge of the subject may also affect implementation of biological sampling and analysis. The purpose of this section is to provide a starting point for biological investigations. Each biotic component of the aquatic environment is discussed in terms of sample design and related considerations, equipment involved in sampling, and information that may be obtained from a survey following biological analysis. The components are further differentiated by the type of waterbody sampled: lakes and impoundments versus rivers and streams.

The first step in project planning is to formulate an objective(s) based on the types of questions asked regarding the biotic component. These questions usually originate in aquatic ecosystems where people may have an interest, either aesthetic, recreational, or biological. A sample design should then be formulated with regard to the objective(s) and the type of analysis that will be applied to the data set. Table 3 provides a guideline of appropriate statistical data analyses for each biotic component of the aquatic environment.

The multivariate analytical techniques shown in Table 3 offer information on natural groupings within data sets. These natural groupings usually are of biological significance. Once characteristics of the natural groups have been identified, a comparison can be made to controlling physical and chemical variables in the environment, again using multivariate approaches. For example, application of principal component analysis has been used to identify significant variations in water quality within and among waterbodies.

Table 3. Methods for assessing freshwater communities.

Analytical Technique	Macro-phytes	Peri-phyton	Plank-ton	Inverte-brates	Fish	Habitat
Similarity Index	X	X	-	X	X	-
Diversity Index	-	X	X	X	X	-
Cluster Analysis	X	X	X	X	X	-
Ordination[1]	-	X	-	X	X	-
-Reciprocal Averaging						
-Detrended Correspondence						
Rapid Bioassessment[2]	-	-	-	X	X	-
Principal Components[3]	-	-	-	-	-	X
Hilsenhoff Biotic Index[4]	-	-	-	X	-	-
Index of Biotic Integrity[5]	-	-	-	-	X	-
Discriminant Analysis[6]	-	-	-	-	X	-
TWINSPAN[7]	-	X	-	X	-	-

[1]Rohm *et al.* (1987)
[2]EPA (1989)
[3]Whittier *et al.* (1988)
[4]Hilsenhoff (1977)
[5]Karr *et al.* (1986)
[6]Larsen *et al.* (1986)
[7]Whittier *et al.* (1987)

Habitat evaluation is an important component of any biological survey and should be designed to reflect the type of habitat impairment (e.g., agriculture, forest practices). Agricultural practices often result in increased bank erosion where cattle grazing is prevalent. Forest practices also increase sediment transport to stream beds. There are many other potential stream effects elicited by these activities which depend upon site specific characteristics. Information regarding habitat assists in interpreting biological community structure. There are numerous protocols for habitat evaluation provided in Plafkin *et al.* (1989), Ralph (1990), and Cupp (1989). Plafkin's method may be most appropriate for SWIS surveys because it is a rapid assessment technique. The method used in habitat evaluation should be consistent over time to adequately reflect habitat changes.

The sample design considerations which follow address general but pertinent points for initiating a project. These considerations are important design characteristics derived from several standard sources (Slack *et al.* 1973; Weber 1973; Hellawell 1978; APHA *et al.* 1989). Sample design varies widely among projects, thus the rationale for consulting more than one reference. The sources cited above comprehensively review techniques that are only summarized in this document. Those standard sources should be consulted for detailed guidelines in implementing a biological survey.

A. Periphyton

General Sampling Considerations:

The autotrophic community often exhibits the first signs of impending environmental stress. In order to determine the effect of an impact on the periphyton community, the sample design should include a good control station to define the ambient condition, as well as stations located within, and downstream of, the impact zone. Examination of the periphyton community requires effort by an individual experienced in taxonomy and sampling methods.

1. Sample design for lakes and impoundments

   - Sample sites should be located adjacent to areas of concern and also in an unaffected reference area.

   - Sampling should be restricted to depths within the euphotic zone.

2. Sampling design for rivers and streams

   - Sample sites should be spatially located above the pollution source and at one or more points below the pollution input.

   - Larger streams should be sampled on both margins.

3. Sampling technique

   - Scrape submerged natural substrate of known area for quantitative estimates (e.g. stones). Uniformity of habitat characteristics should be maintained among the sample sites: depth, water velocity, light penetration.

   - An alternative is to set an artificial substrate in the aquatic environment for a period of 2 - 6 weeks (e.g., glass slides, 25 x 75 mm). Note: the slide face should be set at an angle perpendicular to the prevailing current in rivers and streams.

4. Potential survey information:

   - Population structure
   - Abundance estimates
   - Spatial distribution
   - Chlorophyll *a* (biomass indication)

B. Phytoplankton and Zooplankton

Plankton populations are often surveyed as an indicator of the trophic status of lentic waterbodies. The presence of certain taxa may indicate a nutrient enriched condition, in which case source control could be in order. Studies of phytoplankton production may be useful in understanding nutrient cycling within a waterbody. Sedimentation of diatoms relays information regarding the historical record of diatom population growth within a waterbody, which in turn may give clues about the eutrophic history of an aquatic system.

1. Sample design for lakes and impoundments

   - Sampling should occur at regular depth intervals (e.g., 1 meter intervals from surface-to-bottom for zooplankton).

   - Composites of plankton samples from depth intervals may provide a general description of community structure.

   - Zooplankton samples may be taken from the epilimnion, metalimnion, and hypolimnion, but phytoplankton sampling is usually restricted to the euphotic zone.

   - Sampling should be carried out on a monthly basis, although survey objectives may indicate a more or less rigorous sampling regime.

2. Sampling design for rivers and streams

- Routine monitoring of rivers and streams is not advised due to the highly variable nature of plankton distribution in running water.

3. Phytoplankton samplers:

   - Kemmerer bottle
   - Van Dorn bottle

4. Zooplankton samplers:

   - Clarke-Bumpus
   - Wisconsin net

5. Potential survey information:

   - Population structure
   - Abundance estimates
   - Spatial distribution
   - Biomass determination (cell volume AFDM)
   - Chlorophyll a (phytoplankton biomass indication)
   - Production/respiration (light/dark bottle)

C. Macrophytes

Macrophytes serve as a food source, habitable substrate, and protection for various aquatic organisms. Proliferation of macrophytes in an aquatic environment often indicates a eutrophic status of a waterbody. Location of macrophyte growth may be an indication of nutrient sources within an aquatic system. Once macrophytes have appeared in a lake or riverine environment, eutrophication has probably reached moderate to advanced stages where sediments and/or water column nutrients are prevalent. Sampling aquatic macrophytes is conducted by locating a control station or transect where the ambient condition may be defined. Areas in the waterbody where suspected nutrient input has been identified should be sampled for comparison to the control condition.

1. Sample design for lakes and impoundments

   - Divide waterbody into regions or blocks and randomly sample a predetermined number of blocks.

   - Establish randomly positioned transects within the blocks.

   - Remove macrophytes from an area encompassed by a quadrat (e.g., 1 m^2) that is placed at equal intervals along the length of the transect.

2. Sampling design for rivers and streams

- Same as above, except that sampling should be conducted from a downstream location with successive collection in an upstream direction. This method minimizes the risk of contaminating downstream sites via upstream plant removal.

3. Potential survey information

- Population structure
- Spatial distribution
- Standing crop (dry weight)

D. Macroinvertebrates

Benthic macroinvertebrate communities provide information regarding habitat condition and suitability for colonization. Much attention has recently been given to assessment of the biological component of aquatic environments using benthic macroinvertebrates as an indicator group. Macroinvertebrate population and community metrics are useful in defining available food resources, the influence of the physical/chemical environment, and ecological interactions among taxa. Benthic macroinvertebrate communities are best examined under similar habitat conditions in both control and impacted sites. Differences in community structure and function between control and impacted sites are more easily attributable to pollution sources when habitat differences are minimized.

1. Sample design for lakes and impoundments

- Site placement should be based on simple- or stratified random sampling procedures.

- Whole lake transects should be sampled so as to represent all depths.

- Transects may radiate out on a short or long axis from pollution sources or reference sites.

2. Sampling design for rivers and streams

- Site placement should be based on simple- or stratified random sampling procedures.

- Samples should be taken upstream and downstream of pollution sources.

- Rapid bioassessment techniques (EPA 1989; especially protocol 2) have been used by SWIS investigators in past surveys.

3. Sampling equipment

- Lakes: Ekman, Petersen, and Ponar grabs.

- Rivers: Kick net, Surber sampler, modified Hess sampler, artificial substrates, and drift nets.

4. Potential survey information:

- Population structure
- Abundance estimates
- Spatial distribution
- Trophic structure
- Similarity/diversity

E. Fish

Fish surveys frequently define the presence/absence of populations in sample regions. Habitat evaluation is an important consideration when sampling for fish due to preferences exhibited by each species. Fish surveys represent a larger-scale investigation based on natural or anthropogenic habitat alteration within a drainage. Fish communities often reflect the quality of the physical and chemical environment of a given location. Investigations of point source influences on receiving water are usually approached by identifying an upstream control site and comparing this fish assemblage to that found in a downstream receiving site.

1. General sampling considerations

- Sampling should be carried out in areas of the drainage in which the target species is located (i.e., specific habitats).

- Consideration should be given to general land use adjacent to the drainage or waterbody which may be a source of pollution input.

- Avoid choosing sample sites for their convenient access. One of the following sampling designs should be used based on the type of habitat found in the waterbody: simple random sampling, stratified random sampling, clustered sampling, or systematic sampling (Nielsen and Johnson 1983).

2. Sampling equipment

- Lakes: electrofishing, hook and line, gill net, seines, setlines, popnets.

- Rivers: electrofishing, hook and line (see also rapid bioassessment protocols IV and V, EPA 1989).

3. Potential survey information:

   - Spatial distribution
   - Abundance estimates
   - Species composition

Fish and Shellfish Tissue

SWIS surveys may sometimes involve sampling of fish or shellfish tissue for conventional or toxic parameters. Pollutants can accumulate in aquatic organisms through exposure to ambient water (bioconcentration) or ingestion of contaminated food (bioaccumulation). Both exposure routes could produce measurable levels of pollutants which may have gone unnoticed in periodic water sampling.

The following discussion is divided into two sections, conventionals and toxics. A brief overview of sampling and analysis is provided for each, but the reader is advised to consult other texts, like the Puget Sound protocols (PSEP 1986) for additional information.

A. Conventional Pollutants

Surveys of conventional pollutants in tissue usually concern contamination of edible marine shellfish with fecal coliform bacteria. Tissue sampling for fecal coliform is often accompanied by water column sampling in order to identify potential sources of bacterial contamination. A few considerations:

1. A species of local recreational or commercial importance should be selected (e.g., pacific oysters, little neck clams, bay mussels, etc.).

2. A composite sample will be required to achieve the minimum tissue bulk required for analysis (200 g). The number of organisms per composite will vary with organism size, but a general guideline would be 10 oysters, 15 clams, or 20 mussels.

3. If local shellfish populations are of insufficient size or otherwise incompatible with sampling design considerations, shellfish can be collected from a remote site, placed in plastic mesh bags with suitable substrate, and transplanted into the area of interest for a 2-4 week exposure period prior to sampling. A potential problem with this approach, however, is sample security (e.g., from vandalism). Also be aware that you may need a special permit to "transplant" shellfish to your study area.

4. Sampled organisms should be rinsed with on-site sea water, sealed in plastic bags, iced, and transported within 24 hours to a laboratory for analysis by the multiple-tube fermentation technique (MPN).

5. Analytical results should be compared to the marketability standard of 230 fecal coliform per 100 g tissue (MPN) set by the U.S. Food and Drug Administration (FDA) and Washington State Department of Health.

B. Toxic Pollutants

Tissue studies conducted by SWIS more often concern toxic rather than conventional pollutants. The Toxics Investigations Section of EILS customarily assumes the lead on projects whose primary scope is the assessment of toxicant contamination of tissue. Tissue toxics sampling by SWIS is usually a secondary survey objective, but a few points of guidance are warranted:

1. Fish are most often the group of concern, but freshwater and marine shellfish may be more appropriate in certain circumstances. The target species should preferably be consumed by humans (health issue) and widely distributed in the area of interest (to allow among-site comparisons). However, the choice of a target organism may be dictated by your sampling success or the success of others (e.g., if you intend to compare your results to that of other investigators, you should collect the species they collected). Sampling of species from different trophic levels (e.g., grazer vs. predator) may be insightful if biomagnification of toxicants through the food chain is suspected.

2. The optimal sampling season will depend on habitat constraints and the life history characteristics of the target organism. For example, sampling of edible fish tissue during a spawning season may produce misleading results given that the energy stores (lipids) of sexually maturing fish are often catabolized to support gonad development.

3. The type of tissue sampled will depend on project-specific considerations. For example, if the target species is a game fish consumed by humans, the ideal tissue to sample would be skinless muscle fillets. However, if the target fish species is consumed by predators like eagles, a whole-fish sample would be more appropriate. If the contaminant of concern accumulates in a particular part of the organism, the affected tissue or organ may be sampled via dissection.

4. Composite sampling should be employed to reduce variability among individual organisms and assure adequate sample for analysis. Composite samples should consist of several organisms (or parts thereof) for each species collected at a site.

The number of organisms per composite will vary with organism size, but a general guideline would be 5 fish, 10 oysters, 15 clams, or 20 mussels.

5. Collected fish (or invertebrates) should be individually wrapped in aluminum foil (dull side in), sealed in labeled plastic bags, and iced. (NOTE: If the sample is for metals analysis, skip the foil and place organisms directly into plastic bags.) Shellfish should be afforded a 24-hour depuration period in on-site water to allow for sediment to clear the alimentary canal.

6. Fresh fish should be processed as soon after collection as possible, or frozen until a later date. Processing should occur in a clean environment, preferably a laboratory. Tissues should be dissected with scalpels and ground with a blender or commercial meat grinder. All dissecting and grinding equipment should be stainless steel or glass, and pre-cleaned using (in order) Liqui-Nox or equivalent detergent, hot tap water, 10 percent nitric acid, deionized water, and nanograde acetone (note - acetone is only required if organic toxicants are involved). Equipment should be oven-dried after cleaning to evaporate traces of acetone.

7. Toxicant scans should be accompanied by subsample analyses for total solids and percent lipids so that data can be corrected to dry weight and normalized for fat content (organic toxicants typically associate with lipids).

8. Contaminant levels in tissue suitable for human consumption may be related to FDA action levels for human health, EPA risk assessment guidelines for human carcinogens, and/or EPA acceptable daily intake levels for non-carcinogens (FDA 1985; EPA 1989). Toxicant levels in whole fish may be compared to maximum predatory concentrations recommended by the National Academy of Sciences (NAS/NAE 1973) or U.S. Fish and Wildlife Service (e.g., Eisler 1985, 1987).

Additional guidance for conducting bioaccumulation studies may be found in Callahan *et al.* (1979a,b), Mabey *et al.* (1982), and Tetra Tech Inc. (1985).

SEDIMENT CONTAMINATION SURVEYS

Assessment of sediment quality may be a priority objective on some SWIS surveys. Sediment quality can be affected by both conventional and toxic pollutants, though the latter are usually of most concern. The following discussion addresses some considerations in designing and performing sediment studies. The reader should consult pertinent references, like the Puget Sound protocols (PSEP 1986), for additional details.

Conventional Pollutants

Conventional parameters which are sometimes of interest in aquatic sediments include organic matter, nutrients, and bacteria. Organic material, measured as total volatile suspended solids, may be of concern in receiving waters which are subject to organic solids loading (e.g., from fish hatcheries). Core sampling for nitrogen and phosphorus can provide a long-term history of nutrient loading rates to lakes (atmospheric fallout of cesium-137 or lead-210 serves as a reference for dating the sediment core). Bacteria, specifically fecal coliform, can remain viable in sediment if substrate quality and food resources are adequate. During freshets, increased flows can disturb accumulated sediments and resuspend bacteria, thus sediments may be a significant source of bacterial loading in some systems. In practice, sediment monitoring for organic matter, nutrients, and bacteria is rarely conducted during SWIS surveys.

Toxic Pollutants

Toxicants dissolved in water often adsorb onto suspended particles which eventually settle and accumulate as sediment. Consequently, sampling of stream or lake sediments can provide a historical record of chemical conditions in the overlying water. Water sampling programs may fail to detect toxicant contamination if levels are below detection limits or toxicant inputs are sporadic. In these instances, sediment sampling may be considerably more revealing. Here are some guidelines for sediment toxicant monitoring:

1. Sampling should be performed in depositional areas of running waters, like pools, embayments, or back-eddies. If depositional areas are unavailable, the sampler should seek sites where fine sediments (clays, silts, and detritus) are abundant relative to sandy or coarse sediments.

2. Ponar and Van Veen grab samplers are useful in lakes and slow-moving rivers or streams. In faster waters, an Emery pipe dredge should be used. River sediments tend to be scoured during high flows, thus sampling should be timed toward the end of low flow season.

3. The top 2 cm of sediment should be taken for analysis; avoid material which has come in contact with the sides of the sampling instrument. Samples collected with a pipe dredge may be too well mixed to separate surficial sediments; if so, make note of the approximate depth of sampling (e.g, 4-5 cm of sediment). A composite of two or more samples will help reduce variability and assure adequate sample for analysis.

4. Individual or composite samples should be homogenized using beakers and spoons, placed in priority-pollutant cleaned glass jars with teflon-lined lids, iced, and shipped to the laboratory for analysis.

5. Sampling and homogenization equipment should be stainless steel and pre-cleaned using (in order) Liqui-Nox or equivalent detergent, hot tap water, 10 percent nitric acid, deionized water, and nanograde acetone (acetone is not required if only metals are being sampled). Sampling gear should be well rinsed with ambient water between sampling sites, and sampling should proceed in order of anticipated increasing contamination. If possible, a sufficient number of beakers and spoons should be pre-cleaned to allow use of uncontaminated homogenization equipment at each site.

6. Subsamples should be taken for total solids, grain size, and TOC determination in order to correct results to dry weight and normalize for particle size and organic carbon (TOC and fines, like silt or clay, can greatly affect the ability of sediments to adsorb both organic and inorganic toxicants). Correlation analysis can assist in determining if normalization is appropriate.

7. Sediment core sampling, especially in lakes, may provide a long-term history of sediment contamination. Atmospheric fallout of cesium-137 or lead-210 can serve as a reference for dating core segments.

8. Detection of toxicants in relatively high concentration may dictate the need for sediment toxicity bioassays.

Additional information concerning the environmental fate of priority pollutants may be found in Callahan *et al.* (1979a,b) and Mabey *et al.* (1982).

SEDIMENT CONTAMINATION SURVEYS

Assessment of sediment quality may be a priority objective on some SWIS surveys. Sediment quality can be affected by both conventional and toxic pollutants, though the latter are usually of most concern. The following discussion addresses some considerations in designing and performing sediment studies. The reader should consult pertinent references, like the Puget Sound protocols (PSEP 1986), for additional details.

Conventional Pollutants

Conventional parameters which are sometimes of interest in aquatic sediments include organic matter, nutrients, and bacteria. Organic material, measured as total volatile suspended solids, may be of concern in receiving waters which are subject to organic solids loading (e.g., from fish hatcheries). Core sampling for nitrogen and phosphorus can provide a long-term history of nutrient loading rates to lakes (atmospheric fallout of cesium-137 or lead-210 serves as a reference for dating the sediment core). Bacteria, specifically fecal coliform, can remain viable in sediment if substrate quality and food resources are adequate. During freshets, increased flows can disturb accumulated sediments and resuspend bacteria, thus sediments may be a significant source of bacterial loading in some systems. In practice, sediment monitoring for organic matter, nutrients, and bacteria is rarely conducted during SWIS surveys.

Toxic Pollutants

Toxicants dissolved in water often adsorb onto suspended particles which eventually settle and accumulate as sediment. Consequently, sampling of stream or lake sediments can provide a historical record of chemical conditions in the overlying water. Water sampling programs may fail to detect toxicant contamination if levels are below detection limits or toxicant inputs are sporadic. In these instances, sediment sampling may be considerably more revealing. Here are some guidelines for sediment toxicant monitoring:

1. Sampling should be performed in depositional areas of running waters, like pools, embayments, or back-eddies. If depositional areas are unavailable, the sampler should seek sites where fine sediments (clays, silts, and detritus) are abundant relative to sandy or coarse sediments.

2. Ponar and Van Veen grab samplers are useful in lakes and slow-moving rivers or streams. In faster waters, an Emery pipe dredge should be used. River sediments tend to be scoured during high flows, thus sampling should be timed toward the end of low flow season.

3. The top 2 cm of sediment should be taken for analysis; avoid material which has come in contact with the sides of the sampling instrument. Samples collected with a pipe dredge may be too well mixed to separate surficial sediments; if so, make note of the approximate depth of sampling (e.g, 4-5 cm of sediment). A composite of two or more samples will help reduce variability and assure adequate sample for analysis.

4. Individual or composite samples should be homogenized using beakers and spoons, placed in priority-pollutant cleaned glass jars with teflon-lined lids, iced, and shipped to the laboratory for analysis.

5. Sampling and homogenization equipment should be stainless steel and pre-cleaned using (in order) Liqui-Nox or equivalent detergent, hot tap water, 10 percent nitric acid, deionized water, and nanograde acetone (acetone is not required if only metals are being sampled). Sampling gear should be well rinsed with ambient water between sampling sites, and sampling should proceed in order of anticipated increasing contamination. If possible, a sufficient number of beakers and spoons should be pre-cleaned to allow use of uncontaminated homogenization equipment at each site.

6. Subsamples should be taken for total solids, grain size, and TOC determination in order to correct results to dry weight and normalize for particle size and organic carbon (TOC and fines, like silt or clay, can greatly affect the ability of sediments to adsorb both organic and inorganic toxicants). Correlation analysis can assist in determining if normalization is appropriate.

7. Sediment core sampling, especially in lakes, may provide a long-term history of sediment contamination. Atmospheric fallout of cesium-137 or lead-210 can serve as a reference for dating core segments.

8. Detection of toxicants in relatively high concentration may dictate the need for sediment toxicity bioassays.

Additional information concerning the environmental fate of priority pollutants may be found in Callahan *et al.* (1979a,b) and Mabey *et al.* (1982).

REPORTING CONSIDERATIONS

At this point, the data analysis is presumably complete and it is time to write up your findings. Remember that the underlying goal of all SWIS studies is to address the original objectives of the survey -- that is, the specific concerns of the client. The report should be focused toward deriving concise conclusions and recommendations. If you have failed to achieve one or more of your original objectives, you should meet with the SWIS manager prior to writing the report.

SWIS staff publish two types of reports depending upon the scope of the project: technical memoranda and formal bound reports. Technical memoranda are usually prepared for smaller projects -- for example, those involving little or no field work and limited data analysis. Formal bound reports are based on intensive surveys of short duration (3-10 days) or studies of longer duration (multi-season or multi-year). If the information contained in a formal bound report is of broad public interest, the report may be published through the Information and Education Office as a numbered Ecology report.

The following are some general considerations for report preparation:

1. The format of technical memoranda and formal bound reports is not fixed. However, there are some things that are included in most reports. The example table of contents in Appendix E lists some of the more important sections which a report should cover (note - a table of contents is usually only included in relatively lengthy formal reports). Technical memoranda may only have three or four sections; for example, a short introductory passage, a brief description of methods, a combined results and discussion section, and recommendations.

2. Each writer is encouraged to use the style he or she finds best, as long as it maintains clarity and accuracy. 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.

3. Some guidelines for report length:

    - Technical memoranda are usually less than 10 pages in final form, including tables, figures, appendices, etc.

    - In final form, the narrative portion of formal bound reports should not exceed 10 pages, with total report length less than 40 pages. Reports based on studies of long duration may exceed 40 pages, but the writer should bear in mind that the probability of their work being read is often inversely proportional to the weight of the final product.

4. 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.

5. Draft reports should be typed double-spaced, though tables and figures need not be in polished form. All draft reports are reviewed by the SWIS manager. If you are uncomfortable with some aspect of your draft (e.g., you're not sure it makes sense), you can ask one of your peers in SWIS to look it over before submitting it to the manager. The manager will ensure that the report is technically sound and clearly written, and that the conclusions and recommendations are justifiable.

6. Writers are expected to address all of the manager's comments on draft reports. If you disagree with certain comments, you are welcome to meet with the manager for discussion. The manager may or may not want to review a second draft of the report, depending on the extent of editorial or technical damage.

7. After the SWIS manager has approved your first draft (or subsequent revisions), it is handed over to clerical staff for formal typing. The product is then submitted to one or more peer reviewers from another Environmental Investigations section (Ambient, Compliance, or Toxics). The peer review is not intended to be as thorough as the manager's review, but instead focuses on verifying that the conclusions and recommendations are supported by the data presented. The peer review draft is also sent to the client for review. Technical memoranda are generally not afforded peer review.

8. Again, the writer is expected to address all comments submitted by the peer reviewer and client. Disagreements are handled through discussion with the SWIS manager, who may refer you back to the peer reviewer or client for further consultation.

9. Draft data and reports are usually not distributed widely, unless a general review is warranted. Distribution requires agreement by the SWIS manager, client, and investigator. Distribution prior to final publishing is generally a function of the political volatility of a project.

10. Changes to the peer review draft are submitted to clerical staff for final typing. The SWIS manager may or may not wish to see the final before it is copied, bound, and published; however, the condition of the final document is the sole responsibility of the author. Final reports are circulated to several other offices within the agency. The original is kept in main files, and extra copies stored in the EILS library. All project notes, data, etc., should be placed in a single file and stored in the lead investigator's files indefinitely.

ANNOTATED BIBLIOGRAPHY

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Presents background on TMDL procedures, some general information on modeling, and a discussion of several allocation schemes for distributing the TMDL among multiple dischargers.

Delos, C.G., W.L. Richardson, J.V. DePinto, R.B. Ambrose, P.W. Rodgers, K. Rygwelski, J.P. St. John, W.J. Shaughnessy, T.A. Faha, and W.N. Christie, 1984. Technical Guidance Manual for Performing Wasteload Allocations, Book II - Streams and Rivers: Chapter 3 - Toxic Substances. EPA report 440/4-84-022, Washington, DC, 203+ pp.

Presents detailed guidance on modeling the fate of toxicants discharged to streams and development of WLAs for same. Contents include modeling framework, parameter estimation, and model application.

Downing, D., and S. Sessions, 1985. Innovative Water Quality-Based Permitting: A Policy Perspective. Journal WPCF 57:358-365.

Presents preliminary findings of a project to evaluate innovative water quality-based permits, Two generic innovations are: 1) those that make greater use of stream assimilative capacity (e.g., seasonal permits); and 2) those that involve allocation trading (e.g., between point sources).

Driscoll, E.D., J.L. Mancini, and P.A. Mangarella. Technical Guidance Manual for Performing Wasteload Allocations, Book II- Streams and Rivers: Chapter 1 - Biochemical Oxygen Demand/Dissolved Oxygen. EPA report 440/4-84-020, Washington, DC

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A manual for the design of sewage collection and treatment systems; includes description of various treatment processes.

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Provides guidance to watershed management committees as they gather and evaluate water quality information to define and control nonpoint source problems. Major sections include water quality monitoring and riparian corridor/land use assessments.

EPA, 1980. Technical Guidance Manual for Performing Wasteload Allocations, Simplified Analytical Method for Determining NPDES Effluent Limitations for POTWs Discharging into Low-Flow Streams. Washington, DC, 64 pp.

Presents a mass-balance method for ammonia and the Streeter-Phelps method for oxygen as two simple techniques for use on small streams receiving secondarily-treated municipal wastewater.

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This manual is essentially a supplement to Book II Chapter 1, BOD/oxygen impacts in streams. It superimposes the effect of nutrient inputs and excessive phytoplankton growth on the basic dissolved oxygen analysis.

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Appendix A. Planning Check List

Project____

Client____________________
Date_______________

Type of Survey

Point Source

___Municipal, ___Industrial, ____Combined, ____Other
___Number of point sources to be investigated

Type of work

___NPDES permit evaluation: ___ Water quality based
___ Technology based
___ New permit
___ Renewal/Current Compliance
___ Mixing zone evaluation
___ Total maximum daily load analysis (TMDL)
___ Class II inspection: ___ Influent and Effluent only
___ Full deal (Compliance Section)
___ Other:______________________________________

Non-Point Source

___One type, ___Several types
___Agriculture: ___ livestock,___ row crop,___other:
___Silviculture
___Urban run-off: ___storm drains,___ CSOs
___Development/Construction/Septic tanks, etc.
___Mining/Resource Extraction
___Other:____

Type of Work

___Enforcement
___Best management practices evaluation
___Policy development/planning
___Other:_______________________________________

Other Surveys

___Baseline investigation
___Phase I Lake diagnostic study
___Bioassessment/habitat assessment
___Pre-enforcement
___Pre-SuperFund

Waterbody Types

___River: ___free-flowing, ___regulated, ___tidal
___Stream: ___perennial, ___intermittent, ___regulated
___Lake: ___natural, ___reservoir
___Estuary
___Bay
___Puget Sound: Describe__________________________
___Ground Water: Describe_________________________
___Combination: Describe__________________________
___Other: Describe_______________________________

Critical Period or Season

___Low Flow: ___Summer/Fall, ___Winter (freeze), ___Other
___High Flow: ___Winter/Spring, ___Other
___Storm Event: Describe__________________________
___Doesn't matter/anytime
___Other: Describe_______________________________

Parameter(s) of Concern or Problem Suspected

___Point Source Effluent

___NPDES regulated parameter:
- ___BOD, ___Temperature, ___pH
- ___TSS, ___Fecal coliform
- ___Residual Chlorine, ___NH_3,
- ___Metal(s):__________
- ___Oil and Grease, __Solids,
- ___Bioassay
- ___Other: Describe:_________

___Other parameter(s) of concern:
- ___Metals:__________
- ___Pesticides:__________
- ___PCBs
- ___Volatile Organics:__________
- ___Base neutrals:__________
- ___Acid extractables:__________
- ___TOX
- ___Nutrients
- ___Other:__________

___Non-Point Parameters:
- ___BOD, ___Temperature, ___pH,
- ___TSS, ___Fecal coliform/pathogens
- ___NH_3, ___Metals:__________
- ___Pesticides:__________
- ___PCBs
- ___Volatile Organics:__________
- ___Base neutrals:__________
- ___Acid extractables:__________
- ___TOX
- ___Nutrients
- ___Other:__________

General Problem:
- ___Near-field, ___Far-field
- ___Eutrophication
- ___Toxicity
- ___Water quality standard or criteria violation
- ___Habitat destruction
- ___Impairment of beneficial uses
- ___Drinking water contamination
- ___Problem unknown
- ___Other:____________________

Description:____________________

____

Media to Sample

___Water:	___Total,	___Dissolved,	___Particulate
___Effluent:	___Total,	___Dissolved,	___Particulate
___Sediment:	___Surficial,	___Deep	
___Tissue:	___Fish,	___Shellfish,	___Other:__________
___Ground Water			

___Other:______________________________

Report Considerations

___Full report

___Memorandum only

___"Quick and Dirty"

Date Due or Die:_______________

Appendix B. Example Project Proposal and Scope of Work

ENVIRONMENTAL INVESTIGATIONS AND LABORATORY SERVICES PROGRAM
SURFACE WATER INVESTIGATIONS SECTION

June 23, 1988

TO: Lynn Singleton

FROM: Will Kendra

SUBJECT: Proposed Fish Hatchery Effluent Study

Problem Description:
The freshwater fish rearing industry is rapidly expanding in Washington State, particularly in the private sector. To date, only the larger facilities have permitted wastewater discharges. However, many of the permits are outdated and require little or no treatment of food and fecal wastes. Receiving water impacts are unknown. The Water Quality Program (WQP) is currently developing guidance for writers of freshwater fish culture permits. In response to both program and regional requests, the Water Quality Investigations Section will study a number of public and private facilities statewide. The scope of work will allow investigation of several "problem" sites, as well as provide a technical database for use in guidance development.

Survey Objectives:

1. Characterize effluent quality at assorted freshwater fish culture operations statewide.
2. Assess receiving water impacts caused by wastewater discharge from several fish facilities during the summer low-flow period.
3. Compare discharge quality and receiving water effects to findings reported in the literature.
4. Evaluate dilution zone requirements for the fish culture industry.

Lead Person: Will Kendra

Tentative Completion Dates:		
	Field Work	- July to September 1988
	Lab Work	- October 1988
	Draft Report	- December 1988
	Final Report	- January 1989

Approximate Lab Costs: $12,000

Clients: Stan Springer/Bill Moore, WQP; Ron Devitt, NWRO; Greg Cloud, SWRO

cc:			
	Mike Morhous	Carl Nuechterlein	Harold Porath
	Jim Gearheard	Hal Michael	Sue Davis

Scope of Work

Field activities will be of two types:

1) Intensive Surveys - includes grab and composite sampling of influent and effluent; also upstream/downstream sampling of receiving water, sediment, and benthic macroinvertebrates.

2) Influent/Effluent Monitoring - grab sampling of influent and effluent only.

Four intensive surveys are planned, with influent/effluent monitoring scheduled for 12 additional facilities (others may be added to cover special circumstances - eg., a release event). Sampling at this many sites was deemed necessary given the variability in facility size and design, water supply and quality, fish species and age, feed types and rates, maintenance practices, and environments. Proposed sites are:

Intensive Surveys: Issaquah Salmon Hatchery (WDF), Yakima Trout Hatchery (WDW), Trout Springs Inc. (Tacoma), and Seafarms of Washington Inc./Global Aqua USA Inc. (Rochester).

Influent/Effluent Monitoring: WDF - Cowlitz Hatchery, McAllister Creek Hatchery, and Crisp Creek Rearing Pond; WDW Naches Hatchery, Spokane Hatchery, and Tokul Creek Hatchery and Rearing Pond; Private - Hurds Creek Fish Farm, Swecker Salmon Farm, Steelhammer Salmon Farm, Randle Trout Farm, Glenoma Trout Farm, and Cascade Mountain Trout Farm.

Field activities will be completed between July and September in order to coincide with the summer low-flow period and to enable the WQP to have a finished product by their target date of January 1989. A summer sampling schedule will not allow tracking of a single facility over time, but literature comparisons should adequately fill this void.

Field measurements will include flow, temperature, pH, conductivity, dissolved oxygen, solids (4), total suspended solids, settleable solids, nutrients (nitrate-nitrite, ammonia, total Kjeldahl nitrogen, and total phosphorus), chemical oxygen demand, and 5-day biochemical oxygen demand. Streambed sediments will be sampled for total organic carbon. Benthic macroinvertebrates will be sampled to assess the effects of organic/nutrient enrichment and intermittent discharge of chemicals used for disease treatment and cleaning purposes.

Appendix C. Equipment Check List

PROJECT ______________________

Instruments
- Batteries ___
- Benthos Sieve/Forceps ___
- Carpenter Square ___
- Chlorine Kit ___
- Compositors ___
- Conductance Meter ___
- Current Meter ___
- Deionized Water ___
- Drogues ___
- Dye ___
- Electrofisher ___
- Float Buoy w/ Anchor ___
- Hydrolab ___
- Kemmerer/Van Dorn ___
- Lead Fish ___
- Measuring Tape ___
- Messengers ___
- Oxygen Reagents ___
- pH Buffers ___
- pH Meter ___
- Ponar ___
- Preservative ___
- Salinometer ___
- Secchi Disk ___
- Sediment Pails/Spoons ___
- Seines/Nets ___
- Thermometer ___
- Top Setting Rod ___
- ______________ ___
- ______________ ___

Bottles
- 1 Gallon Glass Jar ___
- 1 L Bottles ___
- 1 L Cubitainers ___
- 1/2 Gallon Glass Jar ___
- 1/2 L Bottles ___
- 2 L Bottles ___
- 8 Oz. Sediment Jar ___
- Bacteria ___
- Bacteria - Thio. ___
- Biota Bottles ___
- Dissolved Oxygen ___
- Extra Bottles ___
- Nutrient Bottles ___
- Oil + Grease ___
- Rinse Bottle ___
- Sample Blanks ___
- TOC Bottles ___
- Twirl Paks ___
- Volatile Organics ___
- ______________ ___

Miscellaneous
- Binoculars ___
- Buckets ___
- Calculator ___
- Camera/Film ___
- Clip Board ___
- Compass ___
- Electrical Tape ___
- Equipment Manuals ___
- Field Notebook ___
- Flashlight ___
- Glass Tape ___
- Ice ___
- Ice Chests ___
- Knife ___
- Lab Manual/Forms ___
- Maps/Charts ___
- Pencils/Pens/Markers ___
- Project File ___
- Rags ___
- Rope/Twine ___
- Tags/Bands ___
- Tide Tables ___
- Tools ___
- Van Fuel ___
- Watch ___
- ______________ ___

Clothing
- Boots ___
- Chest Waders ___
- Full Clothing Change ___
- Gloves ___
- Hat/Cap ___
- Hip Waders ___
- Raingear ___
- Rubber Gloves ___
- Sunglasses ___
- Wader Socks ___
- ______________ ___

Boating
- Anchor/Rope ___
- Boat Fuel ___
- Depth Sounder ___
- Flares ___
- Float Coats ___
- Foghorn ___
- Life Vests ___
- Oil ___
- Paddles ___
- Winch/Meter ___
- ______________ ___

Appendix D. Spreadsheets for Water Quality-based Permit Calculations

Spreadsheet Name	Function
AMMONIA	Calculates freshwater ammonia WQSs from temperature and pH
WQBP-CON	Calculates Water Quality-based Permit limits for specific chemicals
WQBP-TOX	Calculates Water Quality-based Permit limits for whole effluent toxicity
DOSAG	Streeter-Phelps D.O. sag equation
RIVPLUME	Simple dilution model for rivers
PH-MIX	Calculates pH of a mixture from temperature, pH, alkalinity, and discharge

USER INSTRUCTIONS

SPREADSHEET NAME: AMMONIA.WK1 (Lotus 1-2-3)

DESCRIPTION: This spreadsheet calculates the acute and chronic criteria for un-ionized and total ammonia for specified temperature and pH using the procedure described in the EPA Gold Book (EPA 440/5-86-001). It also calculates the amount of un-ionized ammonia present in a sample if total ammonia, temperature, and pH are known.

USER INSTRUCTIONS FOR INPUT SECTION:

Step 1: Specify the temperature of the sample or design condition for which un-ionized ammonia criteria or concentrations are to be estimated.

Step 2: Specify the pH of the sample or design condition for which un-ionized ammonia criteria or concentrations are to be estimated.

Step 3: Specify the sample total ammonia concentration if known. This value does not need to be specified to calculate the acute and chronic criteria. Entering a value here only affects Output Step 2 (calculation of un-ionized ammonia present in a sample).

Step 4: Specify "Acute TCAP" according to the Gold Book (enter 20 if salmonids are present; 25 if salmonids are absent).

Step 5: Specify "Chronic TCAP" according to the Gold Book (enter 15 if salmonids are present; 20 if salmonids are absent).

USER INSTRUCTIONS FOR THE OUTPUT SECTION:

The user should not enter or change any values or formulas in the Output Section. The spreadsheet calculates the amount of un-ionized ammonia present in a sample at Output Step 2 if the sample total ammonia was specified at Input Step 3. Output Step 3 provides the acute and chronic criteria for **un-ionized ammonia** expressed as μg N/L. Output Step 4 provides the acute and chronic criteria for **total ammonia** expressed as μg N/L.

Calculation Of Un-ionized Ammonia Concentration and Criteria.
Based on EPA Gold Book (EPA 400/5-86-001). Lotus File AMMONIA.WK1.

INPUT**

1. Sample Ambient Temperature (°C; 0<T<30) . . . . : 30.0

2. Sample Ambient pH (6.5<pH<9.0) . . . . : 9.00

3. Sample Total Ammonia (μg N/L) . . . . : 200.0

4. Acute TCAP (Salmonids present- 20; absent- 25) . . . . : 20

5. Chronic TCAP (Salmonids present- 15; absent- 20) . . . . : 15

OUTPUT***

1. Intermediate Calculations:

    Acute FT . . . . : 1.00
    Chronic FT . . . . : 1.41
    FPH . . . . : 1.00
    RATIO . . . . : 16
    pKa . . . . : 9.09
    Fraction Of Total Ammonia Present As Un-ionized . . . . : 44.6171%

2. Sample Un-ionized Ammonia Concentration (μg N/L) . . . . : 89.2

3. Un-ionized Ammonia Criteria:

    Acute (1-hour) Un-ionized Ammonia Criterion (μg N/L) . . . . . : 213.7
    Chronic (4-day) Un-ionized Ammonia Criterion (μg N/L) . . . . : 29.1

4. Total Ammonia Criteria:

    Acute Total Ammonia Criterion (μg N/L) . . . . : 479
    Chronic Total Ammonia Criterion (μg N/L) . . . . : 65

****

USER INSTRUCTIONS

SPREADSHEET NAME: WQBP-CON.WK1 (Lotus)

DESCRIPTION: This spreadsheet calculates water quality-based permit limits, including calculations of waste load allocations (WLAs) and permit limits incorporating effluent variability for specific chemical concentrations. The method used is documented in EPA-440/4-85-032 (Technical Support Document for Water Quality-based Toxics Control).

USER INSTRUCTIONS FOR INPUT SECTION:

Step 1: Specify water quality standards/criteria that apply to the receiving water. These include the acute and chronic concentration values (e.g., mg/L or μg/L) appropriate for the specific chemical of interest. The acute and chronic water quality criteria that apply to the conditions (e.g., hardness, pH, temperature) at the point of compliance (e.g., end-of-pipe or within the mixing zone for acute and 300 feet downstream from the discharge for chronic river) should be specified.

Step 2: Specify the upstream or background concentration of the parameter of interest in the receiving water for the acute and chronic evaluations (e.g., at river flow of 1Q10 for acute and 7Q10 for chronic).

Step 3: Enter the dilution factors that apply at the point of compliance for acute (e.g., end-of-pipe or about 30 feet downstream from a discharge to a river) and chronic (e.g., 300 feet downstream from a discharge to a river). Dilution factors (DF) in rivers should be defined as follows:

$$DF = (Qe + Qs)/Qe$$

where Qe is effluent flow (e.g., maximum permitted flow) and Qs is river discharge immediately above the plant outfall (e.g., 1Q10 for acute and 7Q10 for chronic. NOTE: To be consistent with current Ecology guidelines the value of Qs should not exceed 1.5% of 1Q10 for acute and 15% of 7Q10 for chronic design flows).

If actual dilution factors have been reliably estimated from tracer studies or plume modeling, then those values should be entered in the spreadsheet. If water quality criteria are required to be met at the end-of-pipe, then a dilution factor of 1 should be entered.

Step 4: Enter the coefficient of variation for the effluent concentration of the parameter of interest (e.g., use 0.6 if no data are available).

Step 5: Specify the number of days for the chronic average (EPA recommends using 4 days).

Step 6: Specify the number of samples per month that the permittee will be required to report to monitor compliance with the permit.

USER INSTRUCTIONS FOR THE OUTPUT SECTION:

The user does not need to enter or change any values or formulas in the Output Section. The spreadsheet calculates permit limits incorporating effluent variability using the method described in the EPA TSD. Estimated daily maximum and monthly average permit limits are calculated and displayed in the Output Section in the same concentration units used for water quality criteria.

If desired, the user may change the Z-statistics in the Output Section (consult the TSD for guidance). The Z-statistic values currently in the spreadsheet represent the latest guidance from EPA.

Water Quality Based Permits: Chemical Specific Permit Limits (based on EPA 440/4-85-032. LOTUS Worksheet WQBP-CON.WK1)

INPUT**

1. Water Quality Standards/Criteria (Concentration)

Acute (one-hour) Criteria	19.000
Chronic (n-day) Criteria	11.000

2. Upstream Receiving Water Concentration

Upstream Concentration for Acute Condition (1Q10)	0.000
Upstream Concentration for Chronic Condition (7Q10)	0.000

3. Dilution Factors (1/{Effluent Volume Fraction})

Acute Receiving Water Dilution Factor at 1Q10	1.000
Chronic Receiving Water Dilution Factor at 7Q10	1.000

4. Coefficient of Variation for Effluent Concentration

(use 0.6 if data are not available)	0.600

5. Number of days (n1) for chronic average

(usually four or seven; four is recommended)	4

6. Number of samples (n2) per month to base permit on 20

OUTPUT***

1. Z Statistics

LTA Derivation (99 percentile)	2.326
Daily Maximum Permit Limit (99 percentile)	2.326
Monthly Average Permit Limit (95 percentile)	1.645

2. Calculated Waste Load Allocations (WLA's)

Acute (one-hour) WLA	19.000
Chronic (n1-day) WLA	11.000

3. Back-Calculation of Long Term Averages (LTA's)

Sigma (same for acute and chronic)	0.5545
Mu for Acute WLA	1.6546
Mu-n1 for Chronic WLA	1.7151
Mu for Chronic WLA	1.6044
LTA for Acute (one-hour) WLA	6.1006
LTA for Chronic (n1-day) WLA	5.8018
Most Limiting LTA (minimum of acute and chronic)	5.8018

4. Derivation of Permit Limits From Limiting LTA

Mu for daily maximum permit limit	1.6044
Mu-n2 for monthly average permit limit	1.7492
Sigma^2-n for monthly avg permit limit	0.0178
Daily Maximum Permit Limit	18.069
Monthly Average Permit Limit	7.163

****

USER INSTRUCTIONS

SPREADSHEET NAME: WQBP-TOX.WK1 (Lotus)

DESCRIPTION: This spreadsheet calculates water quality-based permit limits, including calculation of waste load allocations (WLAs) and permit limits incorporating effluent variability for whole effluent toxicity. The method used is documented in EPA-440/4-85-032 (Technical Support Document for Water Quality-based Toxics Control).

USER INSTRUCTIONS FOR INPUT SECTION:

Step 1: Specify water quality standards/criteria that apply to the receiving water. These include the acute and chronic values. EPA recommends using 0.3 TUa for acute and 1.0 TUc for the chronic criteria.

Step 2: Specify the assumed acute (TUa) and chronic (TUc) toxicity of the upstream or background in the receiving water for the acute and chronic evaluations (e.g., at river flow of 1Q10 for acute and 7Q10 for chronic).

Step 3: Enter the dilution factors that apply at the point of compliance for acute (e.g., end-of-pipe or about 30 feet downstream from a discharge to a river) and chronic (e.g., 300 feet downstream from a discharge to a river). Dilution factors (DF) in rivers should be defined as follows:

$$DF = (Qe + Qs)/Qe$$

Where Qe is effluent flow (e.g., maximum permitted flow) and Qs is river discharge immediately above the plant outfall (e.g., 1Q10 for acute and 7Q10 for chronic. NOTE: To be consistent with current Ecology guidelines the value of Qs should not exceed 1.5% of 1Q10 for acute and 15% of 7Q10 for chronic design flows).

If dilution factors have been estimated from tracer studies or plume modeling, then those values can be entered in the spreadsheet. If water quality criteria are required to be met at the end-of-pipe, then a dilution factor of 1 should be entered.

Step 4: Enter the Acute-Chronic Ratio (ACR). EPA recommends using a value of 10 for the ACR if no data are available.

Step 5: Enter the coefficient of variation for the effluent concentration of the parameter of interest (e.g., use 0.6 if no data are available).

Step 6: Specify the number of days for the chronic average (EPA recommends using 4 days).

Step 7: Specify the number of samples per month that the permittee will be required to report to monitor compliance with the permit.

USER INSTRUCTIONS FOR THE OUTPUT SECTION:

The user does not need to enter or change any values or formulas in the Output Section. The spreadsheet calculates permit limits incorporating effluent variability using the method described in the EPA TSD. Estimated daily maximum and monthly average permit limits are calculated and displayed in the Output Section in the units of TUc.

If desired, the user may change the Z-statistics in the Output Section (consult the TSD for guidance). The Z-statistic values currently in the spreadsheet represent the latest guidance from EPA.

Water Quality Based Permits: Whole Effluent Toxicity Permit Limits (based on EPA 440/4-85-032. LOTUS Worksheet WQBP-TOX.WK1)

INPUT ***

1. Water Quality Standards/Criteria

Acute (one-hour) toxicity criteria (TUa)	0.300
Chronic (n-day) toxicity criteria (TUc)	1.000

2. Upstream Receiving Water Toxicity

Upstream Acute Toxicity (TUa)	0.000
Upstream Chronic Toxicity (TUc)	0.000

3. Dilution Factors (1/{Effluent Volume Fraction})

Acute Receiving Water Dilution Factor at 1Q10	1.000
Chronic Receiving Water Dilution Factor at 7Q10	1.000

4. Acute-Chronic Ratio (use 10 if data are not available) . . . 10.000

5. Coefficient of Variation for Effluent Toxicity (use 0.6 if data are not available) . . . 0.600

6. Number of days (n1) for chronic average (usually four or seven; four is recommended) . . . 4

7. Number of samples (n2) per month to base permit on . . . 4

OUTPUT **

1. Z Statistics

LTA Derivation (99 percentile)	2.326
Daily Maximum Permit Limit (99 percentile)	2.326
Monthly Average Permit Limit (95 percentile)	1.645

2. Calculated Waste Load Allocations (WLA's)

Acute (one-hour) WLA (TUa)	0.300
Acute (one-hour) WLA (TUc)	3.000
Chronic (n1-day) WLA (TUc)	1.000

3. Back-Calculation of Long Term Averages (LTA's)

Sigma (same for acute and chronic)	0.5545
Mu for Acute WLA	-0.1912
Mu-n1 for Chronic WLA	-0.6828
Mu for Chronic WLA	-0.7935
LTA for Acute (one-hour) WLA	0.9632
LTA for Chronic (n1-day) WLA	0.5274
Most limiting LTA (minimum of acute and chronic)	0.5274

4. Derivation of Permit Limits From Limiting LTA

Mu for daily maximum permit limit	-0.7935
Mu-n2 for monthly average permit limit	-0.6828
Sigma^2-n for monthly avg permit limit	0.0862
Daily Maximum Permit Limit (TUc)	1.643
Monthly Average Permit Limit (TUc)	0.819

****

USER INSTRUCTIONS

SPREADSHEET NAME: DOSAG.WK1 (Lotus)

DESCRIPTION: This spreadsheet calculates the critical dissolved oxygen sag and concentration downstream from a point source load of BOD in a river using the Streeter-Phelps equations. The method used is documented in EPA/600/6-85/002a (Water Quality Assessment: A Screening Procedure for Toxic and Conventional Pollutants in Surface and Ground Water).

USER INSTRUCTIONS FOR THE INPUT SECTION:

Step 1: Enter the permittees effluent characteristics, including permitted discharge and maximum (e.g, weekly) 5-day BOD (referred to as $CBOD_5$ for "carbonaceous" 5-day BOD). Nitrogenous BOD (NBOD) may also be entered if known. NBOD can be estimated as:

$$NBOD = 4.57 * (Ammonia\ N + Organic\ N)$$

where concentrations of NBOD, ammonia N and organic N are expressed in mg/L. Effluent temperature and dissolved oxygen for the analysis are also entered at this step.

Step 2: Enter receiving water characteristics. These will generally be conditions at the 7Q10 discharge. Upstream $CBOD_5$, NBOD, dissolved oxygen and temperature at the design river flow (e.g., 7Q10) should be entered. The local channel elevation and channel slope (e.g., from USGS topographic maps) downstream should also be entered. Downstream average channel depth and velocity at the design flow should be entered also.

Step 3: Enter the reaeration rate (base e) at 20°C. Calculated values using empirical equations referenced in EPA/600/6-85/002a are given in the input section for guidance in selecting an appropriate value. If the calculated values are used, select the most appropriate equation based on applicable depth and velocity (e.g., if depth is $<$ 1 to 2 feet, then use the value shown from the Tsivoglou-Wallace equation).

Step 4: Enter the BOD decay rate (base e) at 20 degrees C. A calculated value based on the Wright and McDonnell equation referenced in EPA/600/6-85/002a is provided and may be entered at Step 4 if desired.

USER INSTRUCTIONS FOR THE OUTPUT SECTION:

The user does not need to change or enter any values or formulas in the Output Section. The travel time and distance to critical sag, deficit at critical sag, and dissolved oxygen concentration at critical sag are displayed in the Output Section.

Streeter-Phelps analysis of critical Dissolved Oxygen Sag (DOSAG.WK1).

INPUT ***

1. Effluent Characteristics

Discharge (cfs)	1.86
$CBOD_5$ (mg/L)	100
NBOD (mg/L)	2.6
Dissolved Oxygen (mg/L)	2
Temperature (°C)	20.7

2. Receiving Water Characteristics

UpsDischarge (cfs)	16
Upstream $CBOD_5$ (mg/L)	1.5
Upstream NBOD (mg/L)	0.2
Upstream Dissolved Oxygen (mg/L)	8.32
Upstream Temperature (°C)	20.7
Elevation (ft NGVD)	1540
Downstream Average Channel Slope (ft/ft)	0.00088
Downstream Average Channel Depth (ft)	0.46
Downstream Average Channel Velocity (fps)	0.98

3. Reaeration Rate (Base e) at 20 °C (day^-1) 3.57

Reference	Applic. Vel (fps)	Applic. Dep (ft)	Suggest Value
Churchill	1.5 - 6	2 - 50	41.70
O'Connor and Dobbins	.1 - 1.5	2 - 50	41.12
Owens	.1 - 6	1 - 2	89.63
Tsivoglou-Wallace	.1 - 6	.1 - 2	3.57

4. BOD Decay Rate (Base e) at 20 °C (day^-1) 2.51

Reference	Suggest Value
Wright and McDonnell, 1979	2.51

OUTPUT***

1. Initial Mixed River Condition

$CBOD_5$ (mg/L)	11.8
NBOD (mg/L)	0.4
Dissolved Oxygen (mg/L)	7.7
Temperature (°C)	20.7

2. Temperature Adjusted Rate Constants (Base e)

Reaeration (day^-1)	3.63
BOD Decay (day^-1)	2.59

3. Calculated Initial Ultimate CBODU and Total BODU

Initial Mixed CBODU (mg/L)	17.3
Initial Mixed Total BODU (CBODU + NBOD, mg/L)	17.7

4. Initial Dissolved Oxygen Deficit

Saturation Dissolved Oxygen (mg/L)	8.41
Initial Deficit (mg/L)	0.75

5. Travel Time to Critical D.O. Concentration (days) 0.31
6. Distance to Critical D.O. Concentration (miles) 4.94
7. Critical D.O. Deficit (mg/L) 5.70
8. Critical D.O. Concentration (mg/L) 2.71

****

USER INSTRUCTIONS

SPREADSHEET NAME: RIVPLUME.WK1 (Lotus)

DESCRIPTION: This spreadsheet calculates dilution at a specified point of interest downstream from a point discharge to a river. The procedure used is described in Fisher *et al.*, 1979 (Mixing in Inland and Coastal Waters, Academic Press) and referenced in EPA-440/4-85-032 (TSD for WQ-based Toxics Control). The calculation for dilution factors incorporates the boundary effect of shorelines (Fisher *et al.*, equation 5.9) using the method of superposition.

USER INSTRUCTIONS FOR THE INPUT SECTION:

Step 1: Enter the effluent discharge rate (e.g., maximum permitted discharge or plant design flow).

Step 2: Specify the receiving water characteristics, including average channel depth, velocity and width downstream from the discharge at the design flow (e.g, at 1Q10 for acute criteria evaluation and 7Q10 for chronic. NOTE: The product of depth*width*velocity should equal the receiving water discharge rate downstream from the discharge). Also enter the channel slope downstream from the discharge (e.g., as measured from a USGS topographic map).

Step 3: Enter the distance between the diffuser midpoint and the nearest shoreline of the river (e.g., for a sidebank discharge enter 0).

Step 4: Enter the location of the downstream point at which dilution factors will be estimated, including the distance downstream from the diffuser and the distance from the nearest shoreline. The "point of interest" is the location at which dilution factors will be estimated in the Output Section. The highest concentration of effluent downstream from the outfall will be the same distance from shore as the diffuser midpoint. Therefore, the distance from shore for the point of interest should be the same as for the diffuser midpoint in Step 3 for a worst case. However, the dilution at any point downstream may be estimated using any combination of distances downstream and from shore for the "point of interest."

USER INSTRUCTIONS FOR THE OUTPUT SECTION:

The user does not need to enter or change any values or formulas in the Output Section. The plume characteristics incorporating the shoreline effect are displayed at Step 5 of the Output Section, including the approximate distance downstream to complete mix, theoretical maximum available dilution at complete mix of effluent with the receiving water, and the calculated dilution factor at the specified point of interest downstream from the discharge.

Spread of a plume from a point source in a river with and without boundary effects from the shoreline (Fischer *et al.*, 1979).

LOTUS FILE RIVPLUME.WK1

INPUT **

1. Effluent Discharge Rate (cfs) 16.58

2. Receiving Water Characteristics Downstream From Waste Input
   Stream Depth (ft) 2.15
   Stream Velocity (fps) 1.95
   Channel Width (ft) 206.00
   Stream Slope (ft/ft) 5.61e-04

3. Discharge Distance From Nearest Shoreline (ft) 0.00

4. Location of Point of Interest to Estimate Dilution
   Distance Downstream to Point of Interest (ft) 300.00
   Distance From Nearest Shoreline (ft) 0.00

OUTPUT **

1. Source Conservative Mass Input Rate
   Concentration of Conservative Substance (%) 100.00
   Source Conservative Mass Input Rate (cfs*%) 1,658.00

2. Shear Velocity (fps) 0.197

3. Transverse Mixing Coefficient (ft2/sec) 0.254

4. Plume Characteristics Assuming No Shoreline Effect
   Unbounded Plume Width at Point of Interest (ft) 35.378
   Concentration at Point of Interest (Fischer Eqn 5.7) . . . . 1.78e+01

5. Plume Characteristics Accounting for Shoreline Effect
   Co . . . . 1.92E+00
   x' 9.22E-04
   y'o . . . . 0.00E+00
   y' at point of interest . . . . 0.00E+00
   Solution using superposition equation (Fischer eqn 5.9)
      Term for n= -2 . . . . 0.00E+00
      Term for n= -1 . . . . 0.00E+00
      Term for n= 0 . . . . 2.00E+00
      Term for n= 1 . . . . 0.00E+00
      Term for n= 2 . . . . 0.00E+00
   C/Co (dimensionless) . . . . 1.86E+01

   Concentration at Point of Interest (Fischer Eqn 5.9) . . . . 3.57E+01

   Approximate Downstream Distance to Complete Mix (ft) 130,200

   Theoretical Dilution Factor at Complete Mix 52.090

   Calculated Dilution Factor at Point of Interest 2.803

****

USER INSTRUCTIONS

SPREADSHEET NAME: PH-MIX.WK1 (Lotus)

DESCRIPTION: This spreadsheet calculates the pH of a mixture of two flows using the procedure in EPA's DESCON program (EPA, 1988. Technical Guidance on Supplementary Stream Design Conditions for Steady State Modeling. EPA Office of Water, Washington D.C.). The major form of alkalinity is assumed to be carbonate alkalinity. Also, alkalinity and total inorganic carbon are assumed to be conservative.

USER INSTRUCTIONS FOR THE INPUT SECTION:

Step 1: Specify the upstream characteristics, including discharge, temperature, pH, and alkalinity.

Step 2: Specify the effluent characteristics, including discharge, temperature, pH, and alkalinity.

USER INSTRUCTION FOR THE OUTPUT SECTION:

The user does not need to enter or change any values or formulas in the Output Section. The spreadsheet calculates and displays the pH of the mixture.

Calculation of pH of a mixture of two flows. Lotus File PH-MIX.WK1 based on the procedure in EPA's DESCON program (EPA, 1988. Technical Guidance on Supplementary Stream Design Conditions for Steady State Modeling. USEPA Office of Water, Washington D.C.)

INPUT **

1. UPSTREAM CHARACTERISTICS
   - Upstream Discharge (cfs) 3.00
   - Upstream Temperature (°C) 20.00
   - Upstream pH 7.50
   - Upstream Alkalinity (mg $CaCO_3$/L) 50.00

2. EFFLUENT CHARACTERISTICS
   - Effluent Discharge (cfs) 3.85
   - Effluent Temperature (°C) 20.00
   - Effluent pH 7.20
   - Effluent Alkalinity (mg $CaCO_3$/L) 150.00

OUTPUT **

1. IONIZATION CONSTANTS
   - Upstream pKa 6.38
   - Effluent pKa 6.38

2. IONIZATION FRACTIONS
   - Upstream Ionization Fraction 0.93
   - Effluent Ionization Fraction 0.87

3. TOTAL INORGANIC CARBON
   - Upstream Total Inorganic Carbon (mg $CaCO_3$/L) 53.81
   - Effluent Total Inorganic Carbon (mg $CaCO_3$/L) 172.81

4. DOWNSTREAM MIXED FLOW CONDITIONS
   - Mixture Temperature (°C) 20.00
   - Mixture Alkalinity (mg $CaCO_3$/L) 106.22
   - Mixture Total Inorganic Carbon (mg $CaCO_3$/L) 120.71
   - Mixture pKa 6.38

   pH of Mixture 7.25

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Appendix E. Example Table of Contents for SWIS Reports

TABLE OF CONTENTS