PTI

ENVIRONMENTAL SERVICES

Puget Sound Contaminated Sediments Impact and Recovery Zones

WORKSHOP SUMMARY

For

Washington Department of Ecology
Sediment Management Unit
Olympia, Washington

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INTRODUCTION

The Washington Department of Ecology (Ecology) is mandated to adopt administrative rules that specify requirements for establishing sediment impact and recovery zones in Puget Sound. A sediment impact zone is a variance for a specific discharge activity to allow consideration of cost and technical feasibility in meeting sediment quality standards. Impact zones will be established based on the site-specific relationship between a point source discharge [controlled by all known, available and reasonable methods of treatment (AKART)], and the concentration and areal extent of contaminants in receiving water sediments. A sediment recovery zone is a variance for cleanup actions to allow consideration of cost and technical feasibility in meeting sediment quality standards. Recovery zones will take into account predictions of future sediment quality conditions in an area from the broader perspective of multiple contaminant sources and natural recovery processes.

Ecology requested PTI Environmental Services to organize and conduct an experts workshop on the development of preliminary models for establishing and managing contaminated sediment impact and recovery zones in Puget Sound. The general objectives of the workshop were to obtain expert opinion on sediment impact and recovery zone determinations, modeling of sediment contaminant transport, and recommendations for future activities.

The workshop was held on 23 June 1989 in three sections: a presentation of background information by representatives of Ecology, technical presentations by experts on sediment contaminant modeling, and a panel discussion of 16 questions and issues prepared prior to the workshop. The presentations and panel discussions formed the major focus of the workshop. In addition, time was provided during the workshop for questions and comments by agency personnel and interested parties. Attached to this report are a list of attendees (Attachment 1), copies of the workshop agenda (Attachment 2), and questions for panel discussion (Attachment 3).

Dr. Marc Lorenzen of PTI served as moderator for the workshop. Ecology representatives included Mr. Brett Betts and Mr. Keith Phillips of the Sediment Management Unit. The following individuals formed the experts panel:

- Dr. J.-D. Chiou, NUS Corporation (Pittsburgh, Pennsylvania)
- Dr. Nick Loux, U.S. Environmental Protection Agency (EPA) (Athens, Georgia)
- Dr. Steve McCutcheon, EPA (Athens, Georgia)
- Dr. Kevin Farley, Clemson University (Clemson, South Carolina)
- Mr. David Dykstra, SeaDyn Corporation (Pasadena, California)
- Dr. Steve Costa, CH2M HILL (Bellevue, Washington)
- Mr. Charles Boatman, URS Corporation (Seattle, Washington)
- Dr. Curtis Ebbesmeyer, Evans-Hamilton (Seattle, Washington)
- Dr. Ray Krone, University of California at Davis (Davis, California)

- Dr. Harold Mofjeld, National Oceanographic and Atmospheric Administration (Seattle, Washington)
- Dr. Nung Jane Shi, private consultant (Kirkland, Washington)
- Dr. Mills Soldate, Tetra Tech (Bellevue, Washington)
- Mr. William Yake, Ecology (Olympia, Washington).

The purpose of this report is to summarize topics discussed at the workshop and to provide a record of decisions and recommendations resulting from the discussions. The report is presented in two sections: a summary of preliminary comments and presentations by workshop experts, and the results of the panel discussions on prepared questions and issues.

BACKGROUND AND TECHNICAL PRESENTATIONS

BACKGROUND PRESENTATIONS

Dr. Lorenzen set forth the objectives for the contaminated sediments program and workshop. The program objective is to calculate sediment impact and recovery zones for given discharges and receiving environment conditions. It is anticipated that such zones will be necessary because source controls based on AKART may still result in sediment accumulations that exceed general sediment standards in the immediate vicinity of a discharge. The workshop objective is to obtain expert opinion and knowledge on the most appropriate quantitative method or methods to determine sediment impact and recovery zones.

Mr. Betts presented an overview of background information on contaminated sediment impact and recovery zone issues. The contaminated sediments and dredging program is outlined in the 1989 Puget Sound Water Quality Management Plan. The goal of the program is "to reduce and ultimately eliminate adverse effects on biological resources and humans from sediment contamination throughout the Sound by reducing or eliminating discharges of toxic contaminants and by capping, treating or removing contaminated sediments." The strategy for achieving this goal includes the following four elements. First, establish chemical and biological criteria for sediments, classify receiving water environments, and classify the sediments in a specific location. Second, control sources of toxic discharges. Third, develop rules (e.g., confined disposal standards) and establish sites for dredged material disposal. Fourth, conduct sediment cleanup actions.

Sediment quality standards (Element P-2) are currently being developed and are scheduled to be finalized in July 1990. These standards will include chemical and biological criteria, as well as provisions for the application of the criteria. The criteria will be protective of biological resources and reduce any significant risks to human health from direct or indirect exposure to contaminated sediments. Sediment quality standards will be used in municipal and industrial monitoring programs.

Policy Issues

The Sediment Advisory Group (SAG; a group of voluntary public advisors to Ecology) has raised several public issues that have been considered by Ecology in their development of rules. General issues raised by SAG include:

- How economic and risk analysis will be used as a basis for establishing sediment quality standards
- Whether multiple standards for sediment quality are necessary
- How sediment quality criteria will be implemented
- What are the legal implications of State Water Pollution Control Law, Revised Code of Washington (RCW) 90.48.520, which states that "in no event shall the discharge

of toxicants be allowed that would violate any water quality standard, including toxicant standards, sediment criteria, and dilution zone criteria".

An environmental impact statement (EIS) will address economic impacts (and environmental trade-offs) of sediment impact and recovery zone alternatives. These zones constitute a variance procedure for incorporating cost and technical feasibility in implementing sediment quality standards. Sediment quality standards will be used to assess ambient conditions of sediments outside the discharge and they will be considered during the review of available technology and as feedback during permit renewals and modifications. Sediment quality standards will be applicable only to "settled" sediments and not to effluent particles. RCW 90.48.520 does not limit Ecology's ability to use sediment impact and recovery zones. However, direct application of sediment quality standards to effluents is *not* intended by Ecology and is *not* required by RCW 90.48.520.

Several responses are possible if the monitoring of sediment impact and recovery zones shows problems. These responses include revising the definition of AKART for the facility, adding "beyond pipe" best management practices to AKART, altering the size of the sediment impact or recovery zone, requiring maintenance action, and requiring "unreasonable" technology (worst case).

Rule Development and Schedule

Key components of the rules being developed by Ecology include:

- Specific criteria for defining sediment impact and recovery zones
- Provisions for the management and maintenance of these zones
- Provisions for closure plans, where appropriate
- Provisions for "ratcheting" the zones, including reduction of the size of the impact or recovery zones, and the level of contamination within the zones.

Models to support the development or application of these rules will need to consider multiple discharge types and different receiving water and sediment scenarios. The models should identify and evaluate potential quantitative constraints for the zones, including their allowable areal extent and degree of contamination, recognizing that such zones are temporary variances from long-term goals for Puget Sound. Mr. Betts concluded with the following schedule for work products on sediment impact and recovery zone development:

- Work sessions and preparation and review of a draft technical report -- 7/89 to 1/15/90
- Final technical report -- 2/15/90
- Draft rule/EIS for public review -- 3/30/90.

TECHNICAL PRESENTATIONS

The following six summaries are based on presentations by sediment modeling experts.

Presenter: **Dr. J.-D. Chiou**
Title: **Model Review**

Dr. Chiou presented a review of procedures for selecting an appropriate mathematical model for water flow, and contaminant transport and accumulation as well as a list of contaminant transport and fate models that might be applicable for establishing sediment impact and recovery zones. A summary of this model review is included in this report (Attachment 4). Dr. Chiou began his presentation by defining general categories of mathematical models. These general categories included the following:

- Direct spatial definition based on source-receiving water characteristics
- Simple empirical models based on quantitative or statistical analysis of existing field data and source loading characteristics
- Simple deterministic models characterized by minimal data requirements, simplified processes, and few model variables
- Complex deterministic models involving many model variables, relatively complex transport processes, and relatively extensive data input.

Dr. Chiou also defined model application constraints (e.g., shoreline configuration), key system processes (e.g., tidal vs. nontidal flow), and variables (e.g., specific contaminants). He discussed major considerations in selecting modeling approaches and summarized existing models (see matrices in Attachment 4). For example, surface water transport models were characterized by applicable water bodies, dimensions, time dependence, solution technique, sedimentation, degradation/transformation, availability, and technical support. Two modeling approaches that are applicable to estuarine systems, the Water Quality Analysis Simulation Program (WASP) and Chemical Transport Analysis Program (CTAP), were examined in detail as examples of models that would meet many of the specific needs of the contaminated sediments program. WASP is an EPA-maintained and supported model that includes the provision for a general modeling framework, interpretation of sediment and water contaminants, and the inclusion of multiple discharges. CTAP was developed in the early 1980s by HydroQual, Inc. for the Soap and Detergent Association as a management tool for siting production facilities and evaluating the discharge implications of new products introduced in existing plants.

Presenter: **Dr. Nick Loux**
Title: **Chemical Considerations**

Dr. Loux discussed important kinds of information that are necessary to evaluate the fate of chemical contaminants, including fundamental processes that control partitioning of contaminants between the water column and particles. Partitioning of contaminants is dependent on sediment characteristics, the specific element or organic compound (including possible chemical speciation for each contaminant), and in some cases, pH. The partitioning of neutral organic compounds as a function of organic carbon content is probably the best understood partitioning process. Metal partitioning is more complex and may depend on the particular metal speciation (which depends on pH conditions), organic carbon content, and inorganic complexing with iron and manganese oxides. Partitioning of ionizable organic compounds is least understood, but has been simulated for some compounds as a function of pH.

At EPA, Dr. Loux has been working on the application of a model to predicting metals contamination in freshwater aquifer soils. Measurements of actual conditions demonstrated that model predictions performed well. The model was conservative for low pH conditions, and therefore, approaches accuracy from the conservative direction. Dr. Loux indicated that the model should be applicable to marine systems provided that total organic carbon was less than 2 percent of the dry weight of sediment.

Presenter: **Dr. Steve McCutcheon**
Title: **Fate and Transport**

Based on his experience in various applications, Dr. McCutcheon recommended the MINTEQA2 and WASP4 model systems for contaminated sediment impact and recovery zone determinations. The MINTEQ system is not applicable for large bodies of water but could, for example, be used to identify important metals in Puget Sound. Subsequent work could then focus more efficiently on a subset of all metals.

EPA structured the WASP4 model to enable it to be used as a simple screening level tool. However, WASP4 contains subroutines that may be added to the system for multidimensional analyses of specific problems (e.g., consideration of food chain transfers). It is expected that a metals speciation module will be integrated with WASP4 within the next few months to 1.5 years.

As a screening step, Dr. McCutcheon recommended evaluation of the water column as a single-element and underlying sediments as a single-element. Based on results of the screening step, it would then be possible to subdivide an area into as many units as required to build complex modeling routines for a specific application. For analysis, Dr. McCutcheon recommended use of a hydrodynamic model (e.g., DYNHYD4 for large rivers and estuaries) coupled with a kinetic model (e.g., Tracer, EUTRO4, TOXI4), and post-processes printouts (e.g., tables, spreadsheet timeplots, and spatial plots). Other elements, for example a food chain model or food and gill exchange model, could be added as appropriate.

Dr. McCutcheon also discussed the EPA Center for Exposure Assessment Modeling. The center provides distribution, support, implementation, and training of interested scientists for available EPA mathematical models. The service for ongoing user support is provided at no charge.

Presenter: **Dr. Kevin Farley**
Title: **DECAL**

Dr. Farley presented a discussion of DECAL (Depositional Calculations), a model developed for the EPA 301h program for marine waivers from secondary sewage treatment. The DECAL model, which has been applied to Southern California Bight municipal wastewater outfalls, relates the discharge from a point source to sediment contaminant levels. This model is currently used to assess organic material accumulation in sediments. A major source of organic material considered by the model is coagulation and settling of material produced naturally by phytoplankton in the water column. Coagulation is considered to be a second-order process by the model.

Dr. Farley stated that in order to determine the level of accumulation of organic material in sediments, it is necessary to determine the influence of the processes that occur in the system (e.g., coastal transport, water column, and sediment fate processes). Time scales for these processes are estimated in the model in an attempt to simplify quantification of pertinent environmental processes. For example, all processes that occur in less than 1 day (e.g., plume entrainment, tidal oscillations) are considered to be instantaneous; such processes are averaged in the model over the daily cycle. All processes that occur over greater than a 10-day period (e.g., large scale circulation and resuspension) are assumed to be insignificant to the fate of outfall material over the distance of typical tidal excursion zones. Therefore, for water column calculations, time scales of one to several days are considered most important in describing particle dynamics and organic carbon cycles.

The water column is divided into two distinct layers in the DECAL model. It is assumed that each layer is well-mixed vertically and that there is a fast tidal motion. Such action would result in a rapid spread of organic solids over the tidal excursion zone.

In an initial verification study for southern California, the DECAL model agreed well with field data. Information needs for applying this model include effluent concentrations of contaminants and organic carbon, water flow, diffuser geometry, water column depth, depth of a lower layer of water, productivity rate, and tidal current measurements.

Presenter: **Mr. David Dykstra**
Title: **Initial Sedimentation**

Mr. Dykstra presented a general approach to sediment accumulation predictions. He discussed the objectives of the sediment impact and recovery zone modeling exercise, important contamination and sedimentation processes, and components that should be considered in modeling the transport and accumulation of sediment over time and space.

Objectives of the sediment impact and recovery zone model include practical application, technical defensibility, objective evaluation, and consistent guidelines. Important processes in the evaluation of modeling include contaminant source type and matrix (i.e., in solution or sorbed onto particles), and physical, chemical, and biological processes of sedimentation (Figure 1). Mr. Dykstra summarized the following information as important input variables for a sediment impact and recovery zone model:

- Particle size distribution
- Contaminant mass emission rates
- Temporal variations
- Initial dilution computations
- Turbulence parameters
- Coagulation/settling of particles
- Natural sedimentation rates

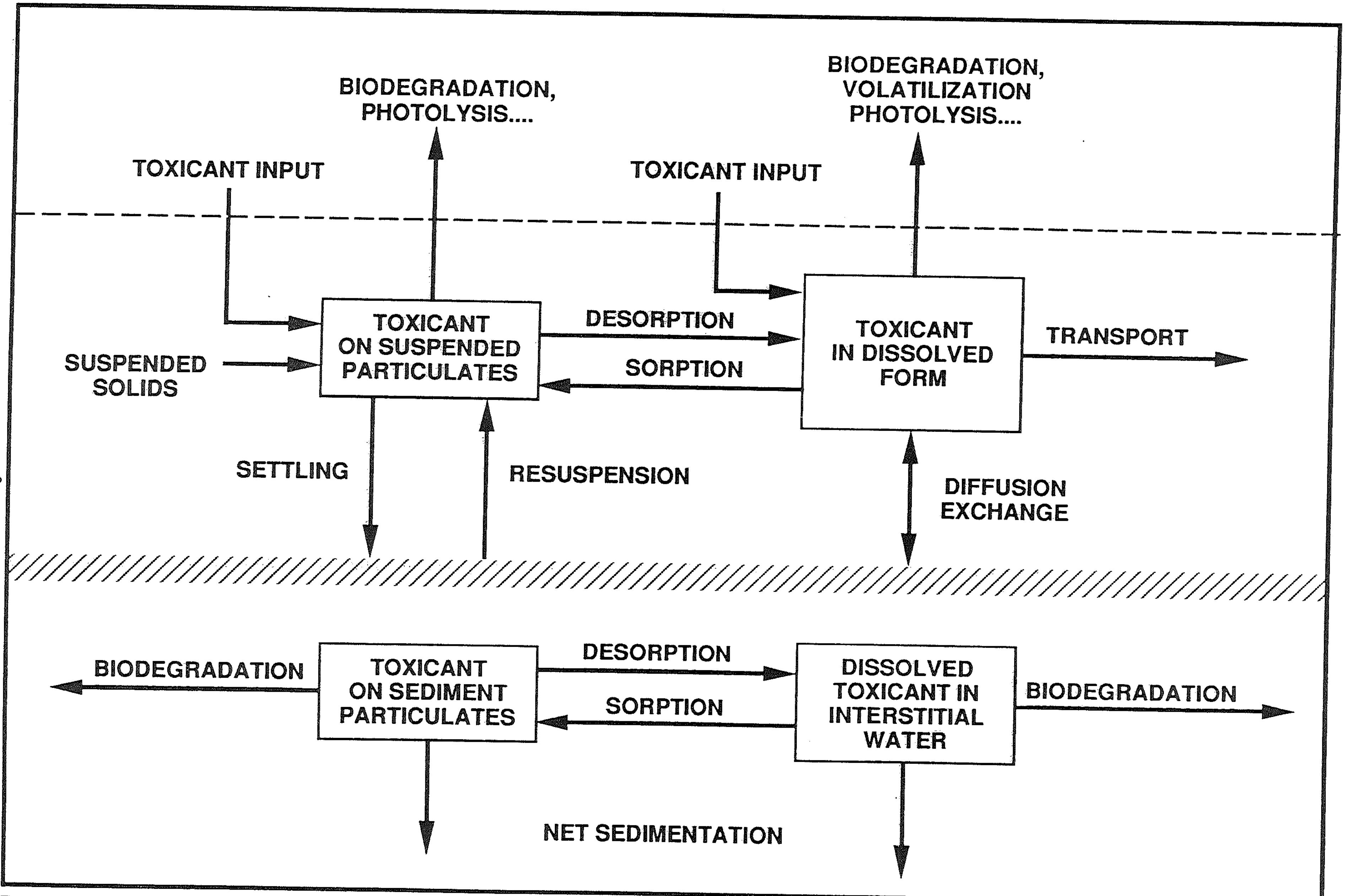

Figure 1. Schematic of principal features of the physical-chemical fate of toxic substances

- Shoreline configuration and bathymetry
- Mixed sediment layer thickness.

Mr. Dykstra observed that coagulation (see previous presentation on DECAL) may be less important at low concentrations of solids. By combining physical and chemical characteristics of a source and its receiving basin, predictions could be made of the sedimentation of discharged particles. This result, in combination with knowledge of natural sedimentation processes, could be used in a sediment processes model to describe the impact and recovery zones. The output of this model would document regions of sediment accumulation and predictions of concentrations of contaminants over time and space.

Presenter: **Dr. Steve Costa**
Title: **Eagle Harbor**

Dr. Costa presented the initial findings of a contaminant transport study performed on sediments from Eagle Harbor (Puget Sound), as part of a remedial investigation/feasibility study being conducted by EPA. Contaminants of concern are polycyclic aromatic hydrocarbons and metals.

An incremental modeling approach was used in this study to determine the location of areas of sediment deposition and erosion, bed transport, transportation pathways, and the overall sediment budget. A circulation model was used to assess tidal, wind, vessel, seiching (an oscillation of water caused by various physical processes), riverine, and thermohaline effects. A littoral model was used to assess the effects of wave energy, tidal flux, and longshore currents. The various models are executable on a mini computer, and result in a linear superposition of tidal, wind, vessel propeller, and current components. Dr. Costa described the approach as intermediate between a simple screening model and a complete numerical analysis.

Dr. Costa determined that an erosional area at the mouth of the harbor results in the net movement of intertidal material into the harbor. The remainder of the harbor appears to be depositional, although the sedimentation rate in the harbor is low. Prop wash from Washington state ferries while idling at the ferry terminal in Eagle Harbor resuspends contaminated sediments and relocates sediments to the southeast shoreline of the harbor.

PANEL DISCUSSION

The panel discussion format was comprised of the 16 questions presented below and in Attachment 3.

1. *Are the objectives clearly stated and realistic?*

Discussion concerning the appropriate response to this question focused on clarification of terminology. The term sediment is synonymous with the sediment environment. Ecology is ultimately interested in anything that affects the sediment environment. At present, the focus will be on point source discharges. Point source discharges include municipal and industrial sources, as well as in-water fish-rearing pens [currently defined by Ecology as point sources to be included in the National Pollutant Discharge Elimination System (NPDES) permit system]. A clarification of the difference between impact and recovery zones was also made by Ecology. An impact zone is the spatial zone allowed for discharges of ongoing contaminant sources. A recovery zone is an area of historical contamination. Overlaps of these two zones can occur.

Applications of sediment impact and recovery zone models could include assessment of new discharges with unknown impacts, identification of contaminated sediments around a discharge that may be subject to a reduction (ratcheting) in concentration, and prediction of changes in sediment concentrations resulting from proposed technological changes in source control. Other issues brought forth during this discussion included:

- The need to consider discharges at different depths (e.g., mid-water, intertidal)
- The method of addressing discharges with low levels of suspended solids or dissolved contaminants
- The applicability of using a model solely as one tool to site new industrial discharges in a previously uncontaminated area.

2. *What level of accuracy is appropriate for prediction of areas and concentrations of contaminants?*

This question was deferred; the panel observed that the appropriate level of accuracy depends on the magnitude of the sediment criterion relative to background concentrations.

3. What degree of accuracy can be reasonably expected for different models?

For a model to be used as a regulatory tool, it must be reproducible and consistently conservative but not overly simplistic. For example, fairly complex water quality models are typically used to apply criteria to thermal discharges. It was observed that the law allows complex models to demonstrate no effects at a site.

The accuracy of a sediment impact zone model will be tied to the magnitude and uncertainty of sediment quality criteria that are applied. It is important to estimate the uncertainty associated with sediment criteria and with any gradients of concentrations of contaminants in the field to assess the accuracy of a model. The ability to predict the distribution of contaminants with models is dependent on how well parameters are characterized before modeling begins. It is important to consider the constituents of concern (e.g., the contaminants having the greatest effect on biota) and the modes of constituent transport. Of primary concern are highly toxic contaminants that are widely dispersed. Sensitivity studies on models were recommended. Such studies would result in statistical distributions of the range of accuracies for models. A factor of 10 variability in system dynamics was not considered unusual. An estimate of representative values is often needed because of the expense and technical feasibility in determining hourly or daily estimates for many variables (e.g., sedimentation records can be used to infer an estimated sedimentation rate).

4. What are the primary factors affecting the accuracy of model predictions?

The accuracy of any model will be affected by the accuracy of the data used to develop that model. Also pertinent will be the particular factors considered in the model, and the relative detail or simplicity of those factors. Basic processes pertinent to the sediments must be included in the model (e.g., mixed layers that reflect the homogenization of contaminant accumulations over a decade).

5. Are three "application scenarios" appropriate for Puget Sound?

The following three major application scenarios were outlined by Dr. Lorenzen in his introduction as spanning a range of conditions to be modeled:

- A point source discharging into an enclosed waterway or inner harbor
- A point source discharging into a semi-enclosed, open embayment
- A point source discharging into an open shoreline (e.g., the main basin of Puget Sound).

Three additional scenarios were suggested by the panel and audience: net pens, intertidal, and riverine discharge. Mariculture net pens are considered a point source discharge and will be covered under the NPDES permit system. Sediment impact and recovery zone siting will need to be evaluated for these dischargers. The intertidal scenario would occur when an effluent is discharged on intertidal sediments. The riverine discharge scenario occurs when effluent is discharged to a freshwater environment with subsequent transport to an estuary.

Other issues mentioned during this discussion included:

- The presence or absence of a sediment impact zone in a specific location may be seasonally influenced
- The size of an impact zone in each scenario will determine the parameters to be considered for the model; there are no guidelines relating to areal extent established at this time.

6. *Can sediment "impact" zone models be uncoupled from recovery zone models?*

A recovery zone, as defined for historical contamination, would not consider new inputs of contaminants. An impact zone model, on the other hand, must take into account recovery. The panel observed that from Ecology's point of view, it would probably be protective to decouple impact zone models from recovery zone models. However, a discharger would probably want to include recovery in any impact zone model.

7. *What are important processes and variables that must be included?*

See question 15.

8. *Can processes and variables be ranked in order of importance?*

This question was deferred.

9. *What degree of hydrodynamic complexity is needed?*

Water movement will determine particle and dissolved material movements. It is also important to know if a particle will remain where it is initially deposited. A 1-month measure of tidal currents using a current meter at the location of interest will probably give adequate information on water movement. (Current meters are influenced by ship traffic and non-tidal currents but a one month current measurement is acceptable for court defense.) Dr. Mofjeld stated that the 1-month current meter survey was probably adequate for Commencement Bay and Elliott Bay. The cost of a one meter, 1-month survey is between $5,000 and $10,000. Surveys of this type are available for much of Puget Sound and cover the last 50 years.

Wind may also influence water movement and contaminant dispersion, especially in shallow areas. Seasonal effects such as storm events may also affect the distribution of contaminants.

10. Are detailed chemistry calculations for water column or sediment interactions needed to reasonably predict sediment accumulation?

The need for detailed chemistry calculations is dependent on a number of factors:

- Most of the chemical reactions will occur during the first 5 parts per thousand change in salinity. The effluent could be premixed with seawater before the analysis is applied.
- The amount of suspended solids in the effluent will affect the location (i.e., water column, sediments) of chemical changes. For effluent with high suspended solids, settling may occur before chemical reactions are complete.
- Chemistry within the sediments can also be important. If detailed chemistry will not be performed for the entire aquatic system, then measurements should at least be made of contaminant concentrations in the sediment layer.
- As sediment impact zones become smaller in size the importance of localized chemical effects increases, thus it is more important to perform detailed chemistry calculations on smaller as opposed to larger impact zones, the boundaries of which can be predicted based on more generalized processes.

11. Which additional models or approaches should be considered?

The additional models mentioned during this discussion were EPA's SEDACCUM1, U.S. Army Corps of Engineers' STUVH, NOAA's Tidal Harmonics Model, and various radionuclide deposition models. No model will be sufficient by itself. A tiered approach is necessary to address concerns of transport, deposition, and ultimate fate.

12. To what level of accuracy must "background" sedimentation rates be known?

See question 13.

13. How can sediment trap data be appropriately used?

Sediment coring and dating will provide background sedimentation rate information while sediment traps provide qualitative and quantitative source information. It was noted that sediment traps can be disturbed in busy industrialized waterways, which limits their use (radionuclide analysis of sediments was recommended as a substitute for estimating sedimentation rates in these situations). Background sedimentation rates can influence concentrations of dissolved constituents as well as the distribution of contaminants around an outfall. High background sedimentation rates can result in low levels of dissolved constituents and reduce the concentration of contaminants around an outfall.

14. Can we explicitly recognize uncertainty in calculations?

Not discussed at this time.

15. Are there sufficient data to develop an empirical approach for Puget Sound (for the three "application scenarios")?

The general consensus from this discussion was that field data would have to be collected at any proposed impact zone to apply an empirical approach. Sampling could be expensive. An approach that combines empirical data collection with modeling will develop an adequate picture of conditions at a site while reducing some of the sampling costs.

Extrapolation of empirical results was not recommended. It is possible to over- or under-regulate by applying too general a model. Also, the more a site differs from sites used to develop empirical results, the greater the uncertainty.

An engineering approach was recommended to determine objectively the factors to be considered. The following is a list of the primary variables to be measured:

- Discharge rate
- Total suspended solids
- Dissolved contaminant concentrations
- Sorbed contaminant concentrations
- Velocity of flow (current measurements)
- Depth to sediments
- Settling velocity
- Sediment core data (Pb^{210} dating)
- Sediment trap data (as appropriate to the site)
- Distribution/partitioning coefficients.

Using these variables it is possible to perform a simple dilution calculation to prepare a mass balance and define the extent of the impact zone.

16. What is the most appropriate approach(es) to meet study objectives?

For existing outfalls, it is necessary to gather information at the outfall by measurement. A skeleton approach for modeling of proposed outfalls is presented below:

- Determine transport processes (i.e., examine sediments that are present at the site, measure currents and waves, determine the importance of erosion)
- Determine what waste constituents will be present at the site and in what form
- Select the most important waste constituents (i.e., those having the most profound or greatest effect on the system)
- Perform time and spatial scale simulations
- Model existing outfalls to gain experience with the chosen models.

Some of the discussion focused on who should be developing the models. It was suggested that the state set standards to be used by private industry for guidance in the development of specific models. It was also suggested that the state require field sampling to supplement modeling. A general model specified by the state could be used to assess more complicated approaches developed by private industry. Information essential to any approach includes sediment geochemistry, water temperature, other conventional variables, and calculations for partition (K_D) values for Puget Sound.

SUMMARY

Dr. Thomas Ginn of PTI concluded the workshop by summarizing the areas of consensus and conclusions reached by the panel. The summary presentation was formatted in accordance with the same set of questions addressed in the panel discussion. During the conclusion, panel members were given the opportunity to clarify or correct any of the summary statements.

WORKSHOP OBJECTIVES

Workshop objectives were found to be realistic and comprehensible as originally stated. The objectives were clarified emphasizing that the primary focus of the workshop was on sediment impact zone models that address processes that occur after release from a discharge pipe to sediment deposition. Such models could be used as tools to select monitoring locations, distinguishing historical from ongoing sources, and for specifying sediment impact zones as part of the permitting process.

MODEL ACCURACY

No consensus was reached concerning the appropriate or expected accuracy of available models in predicting sediment contamination. However, there was valuable discussion and input on the variables and processes that are important in determining the overall accuracy of any predictive model. It was agreed that the keys to successful model development and application are to identify and characterize the critical processes that determine overall model accuracy. Identified examples of important sediment processes included flocculation/coagulation, bioturbation, and sediment and water partitioning.

MODEL APPLICATION SCENARIOS

The three application scenarios were generally found to be acceptable. It was recommended, however, that special situations such as areas adjacent to major riverine inputs and intertidal habitats be evaluated either for their applicability to existing model scenarios or for the development of additional application areas.

SEDIMENT IMPACT ZONE VERSUS RECOVERY ZONE MODELS

It was concluded that the two general model types and associated processes could be uncoupled for purposes of regulatory tool development, especially for refractory substances.

IMPORTANT PROCESSES AND VARIABLES

Prior to identification of important processes, it was recommended that an evaluation of time and space scales be conducted, similar to the one conducted during DECAL development. As a general category, hydrodynamic processes were identified as extremely important, especially in relation to adequate characterization of temporal changes.

HYDRODYNAMIC COMPLEXITY

A 1-month current record was recommended as generally appropriate for representing tidal current regimes in Puget Sound. However, it will be important to evaluate time scales of tidal excursions relative to settling times in candidate application areas.

NEED FOR DETAILED CHEMISTRY

The need for detailed chemistry was found to depend on the model process. In the water column, especially during dilution, detailed chemistry is probably not required for metals and neutral organic substances. Alternatively, it was recommended that important processes occurring in bottom sediments require detailed chemistry following sediment deposition.

ADDITIONAL MODELS OR APPROACHES

SEDACCUM1 and STUVH were identified as potentially applicable to the development of sediment impact zones. The National Oceanic and Atmospheric Administration's Tidal Harmonic Model and Sediment Deposition Model were identified as possible ancillary tools.

BACKGROUND SEDIMENTATION RATES AND USE OF SEDIMENT TRAPS

The use of long-term sediment records (by isotope analysis of cores) was identified as a valuable method to estimate natural sedimentation rates. Sediment trap data may provide valuable additional information on source inputs and seasonal variations in sediment quality.

USE OF AN EMPIRICAL APPROACH

The development of an empirical approach was not supported by the experts panel. The primary limitations of an empirical approach were identified as the high initial costs of data collection, and extreme site-specific nature of important transport processes (especially localized hydrodynamic conditions).

RECOMMENDED APPROACH TO MEET STUDY OBJECTIVES

No available model was recommended for direct application in its present form to meet the study needs. Two models were identified as potentially applicable tools that may require modification:

Model	Advantages
WASP4	Availability, flexibility, ongoing support by EPA
DECAL	Simplicity, personal computer version

In lieu of a single recommended model at this time, the panel supported a five-step process leading to tool development and refinement:

- Determine important transport processes
- Determine waste constituents requiring characterization
- Select important waste constituents for simulation
- Determine time scales for simulation
- Apply candidate models to existing discharge for sensitivity analysis and initial validation.

It was recognized that potential model applications may range from relatively simple mass balance approaches to more complex deterministic methods. The following site-specific data would be important for any model application:

- Current data (preferably a 1-month record)
- Nearby sediment deposition rate
- Effluent characteristics (waste constituents, solid concentrations, and particle setting velocity)
- Receiving water data (salinity, density stratification, temperature, major elements).

ATTACHMENTS

ATTACHMENT 1

REGISTRATION LIST

PUGET SOUND CONTAMINATED SEDIMENTS IMPACT/RECOVERY ZONE MODELING WORKSHOP

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Goldberg, Jennie	Seattle Drainage & Wastewater Utility	(206) 684-7597
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ATTACHMENT 2

WORKSHOP AGENDA

PUGET SOUND CONTAMINATED SEDIMENTS IMPACT/RECOVERY ZONE MODELING WORKSHOP

23 June 1989

8:30 - 8:50	Introduction	M. Lorenzen
8:50 - 9:10	Background	B. Betts/K. Phillips
9:10 - 9:30	Model Review	J.-D. Chiou
9:30 - 9:55	Chemical Considerations	N. Loux
9:55 - 10:20	Fate & Transport	S. McCutcheon
10:20 - 10:35	Break	
10:35 - 10:55	DECAL	K. Farley
10:55 - 11:15	Initial Sedimentation	D. Dykstra
11:15 - 11:40	Eagle Harbor	S. Costa
11:40 - 12:00	Audience Questions/Comments	
12:00 - 1:00	Lunch	
1:00 - 3:00	Panel Discussion	
3:00 - 3:15	Break	
3:15 - 4:15	Panel Discussion	
4:15 - 4:30	Audience Questions/Comments	
4:30 - 5:00	Wrap-up	T. Ginn

ATTACHMENT 3

QUESTIONS FOR PANEL DISCUSSION

PUGET SOUND CONTAMINATED SEDIMENTS IMPACT/RECOVERY ZONE MODELING WORKSHOP

23 June 1989

1. Are the objectives clearly stated and realistic?
2. What level of accuracy is appropriate for prediction of areas and concentrations of contaminants?
3. What degree of accuracy can be reasonably expected for different models?
4. What are the primary factors affecting the accuracy of model predictions?
5. Are three "application scenarios" appropriate for Puget Sound?
6. Can sediment "impact" zone models be uncoupled from recovery zone models?
7. What are important processes and variables that must be included?
8. Can processes and variables be ranked in order of importance?
9. What degree of hydrodynamic complexity is needed?
10. Are detailed chemistry calculations for water column or sediment interactions needed to reasonably predict sediment accumulation?
11. Which additional models or approaches should be considered?
12. To what level of accuracy must "background" sedimentation rates be known?
13. How can sediment trap data be appropriately used?
14. Can we explicitly recognize uncertainty in calculations?
15. Are there sufficient data to develop an empirical approach for Puget Sound (for the three "application scenarios")?
16. What is the most appropriate approach(es) to meet study objectives?
    a) What is the level of effort required for site specific application?
    b) What degree of accuracy can be expected?

ATTACHMENT 4

MODEL REVIEW

INTRODUCTION

As a starting point to select a suitable modeling approach for this project, two strategies will be used. First, important issues of the project will be discussed. Second, existing models will be reviewed to determine which ones can best resolve these issues.

CATEGORIES OF MATHEMATICAL MODELS

A number of modeling approaches can be used to quantitatively define the contaminant source-sediment relationships in effect in the Puget Sound Area. These approaches can be divided into four categories which can increase in complexity. They are as follows: Direct Spatial Definitions, Simple Empirical Models, Simple Deterministic Models, and Complex Deterministic Models.

Direct spatial definitions are based on contaminant source and receiving water characteristics, such as discharge rates and water depth. Simple empirical models are supported by quantitative or statistical analysis of existing field data and source loading characteristics. Simple deterministic models are characterized by minimal data requirements, simplified processes, and few model variables. Complex deterministic models involve many model variables, relatively complex transport processes, and relatively extensive data inputs.

MAJOR ISSUES

The major issues for selecting a suitable modeling approach can be divided into technical and non-technical areas. The technical areas cover the definition of model application constraints. The non-technical areas involve important considerations that each modeler must examine.

Technical Areas

To apply one or more than one modeling approach, the contaminant source-sediment characteristics of the Puget Sound Area must be considered. Hence, the constraints of a model's application must be defined in terms of the natural system's key processes and variables. The usefulness of a model can be judged on its ability to simulate contaminant source types and characteristics, the shoreline configuration, sediment characteristics, contaminant types, and sedimentation processes.

For this project, the model should characterize the effects of contaminant discharges on the Puget Sound Area. The types of discharges that the model should describe include industrial point sources, combined sewer overflows, and storm drains. The properties of the pollutants that must be accounted for include dissolved, suspended, or settling characteristics.

The Area's shoreline configuration must be simulated, since the type of configuration (e.g., narrow waterways, main basins, and confined embayments) could affect contaminant concentrations. Likewise, the hydrographic regimes (e.g., tidal vs. nontidal flows, riverine transport, and static conditions) must be accounted for, since they can affect the properties of the pollutants.

Characteristics of sediments in the environment should be represented, since they can concentrate or dilute the effects of the contaminants. Low sedimentation areas would intensify the effects of any contamination, while high sedimentation environments, near river mouths and semierosional shorelines, would decrease contaminant levels. A model should also define physical/chemical phenomena which can occur in the ecosystem such as "contaminant loss" due to biodegradation, volatilization, and photolysis as well as "contaminant gain" due to biochemical and chemical reactions. At least five types of physical/chemical phenomena would have to be characterized in the Puget Sound Area water column and sediments. They are as follows: 1) Sorption/desorption between dissolved and particulate forms; 2) settling and resuspenison mechanisms of particulates; 3) diffusive exchange between the sediment and water column; 4) transport of toxicants due to advective flow transportand dispersive mixing; and 5) net deposition and loss of chemicals to deep sediments. See Figure 1 for a schematic of the interaction between these physical/chemical processes

Non-Technical Areas

Generally, a model should be chosen on the basis of five major considerations that directly apply to the project goals. The usefulness of a model can be measured by these following considerations:

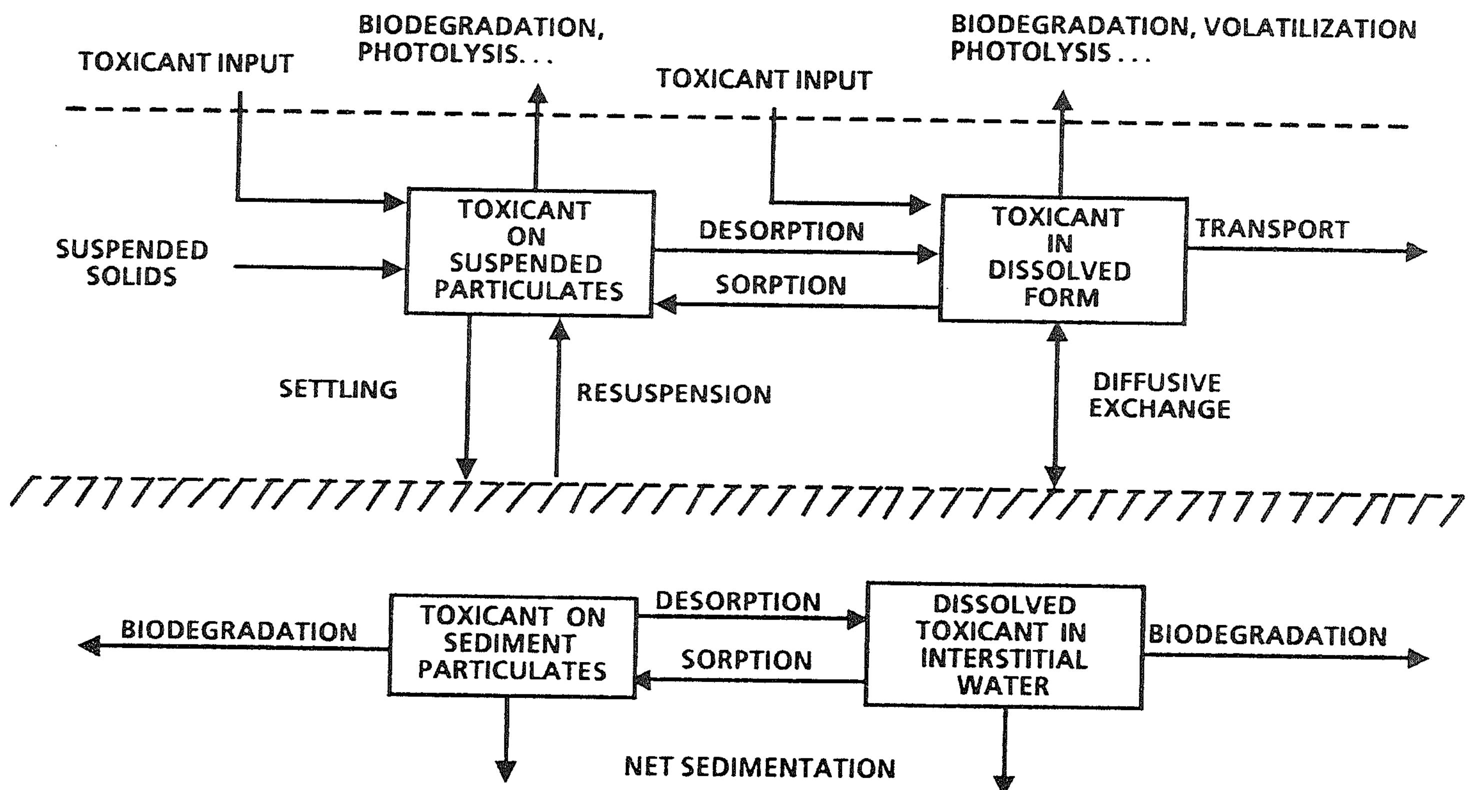
1) Applicability to study objectives. For example, a model used for a screening study would be less complex than a model utilized to simulate a detailed investigation.

2) Adaptability and ease of use. The model should be easy to use for maximum access and easily modified to meet changing project conditions.

3) Data requirements for sources and receiving waters. A model should accommodate the types of data needed along with the amount of information available for successful completion of the study.

FIGURE 1

SCHEMATIC OF PRINCIPAL FEATURES OF THE PHYSICAL-CHEMICAL FATE OF TOXIC SUBSTANCES



4) Expected accuracy and major uncertainties. The model should be somehow characterized in these areas.

5) Estimated costs and schedule for adaptation and/or development. These economic and temporal variables must be known in a model so that its users can anticipate any adaptations and/or further developments that may take place.

MODEL SELECTION PROCESS

The following model selection process has been suggested by the United States Environmental Protection Agency (EPA). The models that will be compared in this process have also been used in previous EPA projects. Because natural sedimentation, hydrodynamics, and contaminant transport may all be involved in this study, a model or models must be chosen that can encompass all three aspects. Therefore, the actual process must be conducted in four stages: 1) initial analysis; 2) selection of a nonpoint source runoff model; 3) surface water flow simulation; and 4) surface water contaminant transport analysis. In terms of information and data gathering, each stage is dependent on the previous one. A modeler must have this methodical approach to objectively screen many models to provide a pool of desirable candidates for further consideration.

Initial Analysis

In the initial analysis, the modeler must clearly define the work that he or she wants to accomplish in the project. Problems coming from the contaminant sources must also be clearly defined. Lastly, by a review of sampling and analytical data, a modeler must identify the physical and chemical properties of the contaminants.

Nonpoint Source Runoff Models

To compare the features of nonpoint source runoff models, a modeler must keep in mind a number of requirements. First, the models should simulate the type and use of the land area (e.g., urban, agricultural, or forest). Secondly, the time characteristics necessary for the study must also be determined. For example, these temporal properties can include annual/seasonal, single event, or continuous simulation. Thirdly, the model must address the spatial characteristics of the area. These properties can cover single catchment, small catchment, large catchment, and multiple catchment areas. Lastly, the model should be able to simulate the important physical, chemical, and biological processes occurring in the ecosystem. These processes include hydrologic processes (i.e., surface runoff, snow melt, flow routing, and storage) and water quality processes (i.e., sediment-erosion, adsorption, and the effects of conventional pollutants and pesticides). Table 1 summarizes the capabilities and characteristics of the nonpoint source runoff models which were reviewed.

Surface Water Flow Models

In choosing a model that adequately covers the aspects of a system's surface water flow, a modeler must ensure that potentially useful models continue to meet the requirements of the project. These requirements include: identifying the applicable water bodies as rivers, lakes, or estuaries; characterizing the water body as stratified or well-mixed; determining if a steady-state or transient analysis is necessary to describe the system's time dependence; and determining if a 1-, 2-, or 3-dimensional analysis is applicable. See Table 2 for additional characteristics of the surface water flow models reviewed.

Surface Water Contaminant Transport Models

A successful surface water contaminant transport model must simulate the discharges of contaminated sediments or waters to surface waters. Before using a particular model, the modeler should considert the answers to the following questions: 1) Are there point or nonpoint sources? 2) Is steady-state or transient analysis necessary? 3) Is a one-, two-, or three-dimensional analysis needed? 4) What are the dominant mixing and transport processes? 5) Are sediment contaminant interactions important? 6) What biological, chemical, and physical reactions need to be incorporated?

The surface water contaminant transport models being reviewed have many of the simulation characteristics of previous models (e.g., applicable water bodies, dimensions, time dependence, solution techniques, availability, and support). In addition, they have the capabilities to characterize forms of sedimentation (i.e., settling, exchanging bed, transport, and scour/deposition) and degradation/transformation (e.g., decay, photolysis, hydrolysis, oxidation, biodegradation, volatilization, sorption, and daughter products). A modeler should, again, select from the pool of desirable surface water models those that best describe the effects of contaminants according to the site-specific conditions. Important features of each model should be compared along with their capabilities and characteristics (see Table 3).

Because of the nature of this project (e.g., contaminant transport), the surface water contaminant transport group is the most important group of models which is under examination. Since these models are the most complex ones available for this study, their data requirements are much more extensive than the other two groups of models. To assist a modeler in focusing on the complex needs

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TABLE 1
SUMMARY MATRIX OF NONPOINT SOURCE RUNOFF MODELS

CAPABILITIES AND CHARACTERISTICS	MODEL NAME									
	USLE	MRI	HSPF	NPS	ARM-II	AGRUN	ACTMO	CREAMS	SWMM	STORM
APPLICABLE LAND AREAS										
URBAN			X	X					X	X
AGRICULTURAL	X	X	X	X	X	X	X	X	X	X
FOREST	X	X	X	X	X					
SPATIAL PROPERTIES										
SINGLE CATCHMENT	X	X		X	X		X	X		
SMALL	X	X		X	X		X	X		
LARGE										
MULTIPLE CATCHMENTS			X			X			X	X
TEMPORAL PROPERTIES										
ANNUAL/SEASONAL	X	X								
SINGLE EVENT			X	X	X	X	X	X	X	X
CONTINUOUS SIMULATION			X	X	X	X	X	X	X	X
HYDROLOGIC PROCESSES										
SURFACE RUNOFF			X	X	X	X	X	X	X	X
SUBSURFACE PROCESSES			X	X	X	X		X		
SNOW MELT			X	X	X		X		X	X
FLOW ROUTING			X			X		X	X	X
STORAGE			X					X	X	
WATER QUALITY PROCESSES										
SEDIMENT-EROSION	X	X	X	X	X	X	X	X	X	X
ADSORPTION		X	X		X		X	X		
CONVENTIONAL POLLUTANTS		X	X			X		X	X	X
PESTICIDES		X	X		X		X	X		
CONSERVATIVE SUBSTANCES		X	X		X		X		X	
NONCONSERVATIVE SUBSTANCES		X	X		X		X			

TABLE 2
SUMMARY MATRIX OF SURFACE WATER FLOW MODELS

CHARACTERISTICS	MODEL NAME											
	HEC-2	CHMHYD	HEC-6	SEDONE	HSPF	DWOPER	DYNHYD3	EXPLORE-1	CAFE	WATFLO	Leender-tse-2D	Leender-tse-3D
APPLICABLE WATER BODIES												
RIVER	X	X	X	X	X	X	X	X	X	X	X	X
LAKE												
ESTUARY		X		X			X	X	X	X	X	X
DIMENSIONS												
1-DIMENSIONAL	1L	1L	1L	1L	1L	1L	1L	1L				
2-DIMENSIONAL							Q2	Q2	2H		2H	
3-DIMENSIONAL												X
TIME DEPENDENCE												
STEADY-STATE	X											
TRANSIENT		X	X	X	X	X	X	X	X	X	X	X
SOLUTION TECHNIQUE												
NUMERICAL	FD	FD	FD	FD	FD	FD	FD	FD	FE	FD	FD	FD
AVAILABILITY												
PUBLIC DOMAIN	X	X	X	X	X	X	X	X	X		X	X
PROPRIETARY										X		
SUPPORT												
UNKNOWN		X		X				X	X		X	X
HEC	X		X									
U.S. EPA					X		X					
NOAA						X						
CONTRACTUAL										X		

TABLE 2
SUMMARY MATRIX OF SURFACE WATER FLOW MODELS
PAGE TWO

CHARACTERISTICS	MODEL NAME											
	HEC-2	CHMHYD	HEC-6	SEDONE	HSPF	DWOPER	DYNHYD3	EXPLORE-1	CAFE	WATFLO	Leender-tse-2D	Leender-tse-3D
OTHER												
SEDIMENTATION			X	X	X							
WATER QUALITY CAPABILITIES					X		X				X	
COMPATIBILITY WITH SPECIFIC TRANSPORT MODEL							X	X	X	X		
AUTOCALIBRATION						X						

LEGEND: 1L = 1-DIMENSIONAL LONGITUDINAL; Q2 = QUASI-TWO-DIMENSIONAL, LINK NODE, HORIZONTAL PLANE; 2H = TWO-DIMENSIONAL, HORIZONTAL PLANE; FD = FINITE DIFFERENCE; FE = FINITE ELEMENT

TABLE 3
SUMMARY MARIX OF SURFACE WATER CONTAMINANT TRANSPORT MODELS

CHARACTERISTICS	MODEL NAME											
	WQAM	SLSA	MICHRIV	CATP	EXAMS	MEXAMS	WASTOX	TOXIWASP	CHNTRN	HSPF	FETRA	SERATRA
APPLICABLE WATER BODIES												
RIVER	X	X	X	X	X	X	X	X	X	X	X	X
LAKE	X	X		X	X	X	X	X		X		
ESTUARY	X						X	X	X		X	
DIMENSIONS												
1-DIMENSIONAL	B	B	X	C	C	C	C	C	X	X		
2-DIMENSIONAL				C	C	C	C	C			2H	2V
3-DIMENSIONAL				C	C	C	C	C				
TIME DEPENDENCE												
STEADY-STATE	X	X	X	X	X	X						
TRANSIENT							X	X	X	X	X	X
SOLUTION TECHNIQUE												
ANALYTICAL	X	X	X									
NUMERICAL				FD	FD	FD	FD	FD	FD	FD	FE	FE
SEDIMENTATION												
SETTLING	X	X	X	X		X	X	X	X	X	X	X
EXCHANGING BED		X	X	X	X	X	X	X	X	X	X	X
TRANSPORT				X			X	X	X	X	X	X
SCOUR/DEPOSITION				X			X	X	X	X	X	X
DEGRADATION/TRANSFORMATION												
FIRST-ORDER DECAY	X	X	X	X	X		X	X	X	X	X	X
PHOTOLYSIS					X		X	X	X	X		X
HYDROLYSIS					X		X	X	X	X		X
OXIDATION					X		X	X	X	X		X
BIODEGRADATION					X		X	X	X	X		X
VOLATILIZATION					X		X	X	X	X		X
SORPTION	X	X	X	X	X	X	X	X	X	X	X	X
DAUGHTER PRODUCTS					X					X	X	

TABLE 3
SUMMARY MATRIX OF SURFACE WATER CONTAMINANT TRANSPORT MODELS
PAGE TWO

CHARACTERISTICS	MODEL NAME											
	WQAM	SLSA	MICHRIV	CATP	EXAMS	MEXAMS	WASTOX	TOXIWASP	CHNTRN	HSPF	FETRA	SERATRA
AVAILABILITY												
PUBLIC DOMAIN	X		X		X	X	X	X	X	X	X	X
PROPRIETARY		X		X								
SUPPORT												
UNKNOWN		X		X			X		X		X	X
U.S.EPA	X		X		X	X		X		X		

LEGEND: B = BOX MODEL, ONE-DIMENSIONAL FOR RIVERS, ZERO-DIMENSIONAL FOR LAKES; C = COMPARTMENT MODEL; 2H = TWO-DIMENSIONAL, HORIZONTAL PLANE; 2V = TWO-DIMENSIONAL, VERTICAL PLANE; FD = FINITE DIFFERENCE; FE = FINITE ELEMENT of the transport group, Tables 4, 5, and 6 will provide information on their features, data requirements, resource requirements, and references.

RECOMMENDED MODELS

From the transport group, two programs were selected that best fit the specific requirements necessary to model the interactions between sediments and water columns in the Puget Sound Area. The models were found to include components that covered most of the natural processes happening in the Puget Sound Area. They were also found to be very flexible, with effective uses in screening studies as well as in-depth investigations.

The first model, or Water Quality Analysis Simulation Program (WASP), can be used as a generalized modeling framework for contaminant fate and transport in surface waters. It is multidimensional, allows for the interaction between the sediment bed and the overlying water column, and permits multiple discharges, tributary flows, and incremental inflows and withdrawals. WASP includes components that describe a system's toxicity, eutrophication, and hydrodynamics. In addition, it has the advantage of a strong support system from the EPA.

The second model, or Chemical Transport Analysis Program (CTAP), can be utilized as a management tool to assist in the siting of new production facilities and the introduction of new products at an already existing plant. CTAP's modeling framework can be applied to 1-, 2-, or 3-dimensional water bodies. It also allows for the interaction between the sediment bed and the overlying water column and permits multiple discharges, tributary flows, and incremental inflows and withdrawals. In addition, it provides for a "moving bed" computation; permits system-dependent transport structures; and simulates a steady state condition and first-order decay rates. CTAP is developed by Hydro Qual, Inc. and is maintained by The Soap and Detergent Association.

TABLE 4
FEATURES OF SURFACE WATER FATE MODELS

	WQAM	SLSA	MICHRIV	CTAP	EXAMS II	MINTEQA 1	HSPF	TODAM	CHNTRN	FETRA	SERATRA	WASP 4	SARAH
Streams/Rivers	●	●	●	●	●	●	●	●	●	●	●	●	●
Impoundments	●	●		●	●	●	●		●	●	●	●	
Estuaries/Tidal	●			●				●	●	●		●	
1-Dimensional	●	●	●		●		●	●	●	●		●	●
Multi-dimensional				●	●					●	●	●	
Accounts for Dispersion				●	●			●	●	●	●	●	●
Accounts for Degradation	●	●	●	●	●		●	●	●	●	●	●	●
Accounts for Physical Removal	●	●	●	●	●		●	●	●	●	●	●	●
Accounts for Stratification	●			●	●				●		●	●	
Handles Varying Release Rates		●			●		●	●	●	●	●	●	
Handles Dynamic Water Flow							●	●	●	●	●	●	
Steady State	●	●	●	●	●	●							●
Point Source	●	●	●	●	●		●	●	●	●	●	●	●
Non-Point Source	●				●		●	●	●	●	●	●	●
Organic Pollutants	●	●	●	●	●		●	●	●	●	●	●	●
Metals/Inorganics	●	●	●	●		●	●	●		●	●		●
Particulate Pollutants	●	●	●	●	●	●	●	●	●	●	●		●
Predicts Contaminant Concentration as a Function of Distance From Source	●	●	●	●	●		●	●	●	●	●	●	●
Predicts Metal Speciation						●			●				
Predicts Bioconcentration Levels of Contaminants					●								●
Predicts Long-Term Average Ambient Concentrations at Receptors	●	●	●	●	●		●	●	●	●	●	●	●
Predicts Short-Term Maximum Concentrations at Receptors		●			●		●	●	●	●	●	●	●
Predicts Persistence of Contaminant Following Termination of Release		●			●		●	●	●	●	●	●	

Source: U.S. EPA, 1985h; Delos et al., 1984

TABLE 5
DATA REQUIREMENTS FOR SURFACE WATER MODELS

	WQAM	SLSA	MICHRIV	CTAP	EXAMS II	MINTEQA 1	HSPF	TODAM	CHNTRN	FETRA	SERATRA	WASP 4	SARAH
Water Body Physiography	●	●	●	●	●		●	●	●	●	●	●	
Flow Rates	●	●	●	●	●		●	●	●	●	●	●	●
Watershed Land Use/Characteristics	●						●						
Climatic Data					●		●		●			●	●
Water Body Biological Parameters					●		●		●			●	●
Water Physical Properties (e.g., Temperature, etc.)					●	●	●		●			●	●
Water Chemical Properties					●	●	●		●			●	●
Estuary Salinity Profiles	●												
Sedimentation/Presuspension Velocities		●		●			●	●	●	●	●	●	
Sediment Bed Depths		●		●	●		●					●	
Sediment Size or Content Parameters				●	●		●	●	●	●	●	●	
Overall Aquatic Half-Life Values	●				●		●		●			●	●
Dispersion Coefficients				●	●			●	●	●	●	●	●
Substance Physical/Chemical Properties	●				●	●	●	●	●			●	●
Chemical Partition Coefficients	●	●	●	●	●	●	●	●	●	●	●	●	●
Water Column Degradation Coefficients	●	●	●	●	●		●	●	●	●	●	●	●
Bed Sediment Degradation Coefficients		●	●	●	●		●	●	●	●	●	●	
Average Release Rates	●	●	●	●	●	●	●	●	●	●	●	●	●
Dynamic Release Patterns					●		●	●	●	●	●	●	

Source: U.S. EPA, 1985h; Delos et al., 1984

TABLE 6
RESOURCE REQUIREMENTS AND INFORMATION SOURCES: SURFACE WATER FATE MODELS

MODEL	DESCRIPTION	RESOURCE REQUIREMENTS, COMMENTS	REFERENCES, SOURCES OF DOCUMENTATION, SOFTWARE
Water Quality Assessment Methodology (WQAM)	• Steady-state, 1-dimensional model • Requires only desktop calculations • Provides canonical information • Models lakes, rivers, and estuaries	• Easy to set up and use • No computer programming needed; requires only hand calculator • Recommended if time, costs, or information are restrictive	*Reference*: Mills, et al. 1982 *Documentation*: ORD Publications USEPA, Cincinnati, Ohio 45288 (513) 684-7562
Simplified Lake/ Stream Analysis (SLSA)	• Steady-state, 1-dimensional model • Solution either by desktop calculations or simple FORTRAN program • Suitable for simplified lake and river systems	• Easy to set up and use • Computer programming not necessary; if used, only 280 bytes are required; suitable for microcomputers • Well-documented and suggested for use before utilization of a more sophisticated model • May be used with hand calculator	*Reference*: HydroQual 1982 *Documentation*: William Gulledge 2581 M Street, N.W. Washington, DC 20037 (202) 887-1183
Chemical Transport and Analysis Program (CTAP)	• Steady-state, 3-dimensional compartmental model • FORTRAN IV program suitable for numerous computers • Similar to SLSA, except more sophisticated; each CTAP compartment is equivalent to one SLSA "lake" • Models streams, stratified rivers, lakes, estuaries, and coastal embayments	• Requires extensive data input • FORTRAN program - Suitable for IBM 360/370, UNIVAC 108, CDC 6600 mainframe computers • Microcomputer version available requiring 32 K bytes storage • One of the better-documented models, which may make it more desirable than other complex models	*Reference*: HydroQual 1982 *Documentation*: William Gulledge Chemical Manufacturers Association 2581 M Street, N.W. Washington, DC 20037 (202) 887-1183

TABLE 6
RESOURCE REQUIREMENTS AND INFORMATION SOURCES: SURFACE WATER FATE MODELS
PAGE TWO

MODEL	DESCRIPTION	RESOURCE REQUIREMENTS, COMMENTS	REFERENCES, SOURCES OF DOCUMENTATION, SOFTWARE
Metals Exposure Analysis Modeling System (MINTEQA1)	• Steady-state, 3-dimensional compartmental model • Complex computer program • Designed for modeling of metal loadings • Suitable for freshwater, non-tidal aquatic systems	• Complex metal dynamics requiring extensive data input • Can be used with mainframe or small (e.g., PCP 11/70 or HP 3000) computers • Interactive format • Contains data base with thermodynamic properties of 7 metals	*Further information*: Yasuo Onishi Battelle Pacific Northwest Laboratories Richland, WA 99352 (509) 376-8302
Transient One-Dimensional Degradation and Migration Model (TODAM)	• Time-varying, 1-dimensional model • Second-order decay mechanisms • Models river and estuarine systems • Requires exterior hydrodynamic model (e.g., EXPLORE) to provide channel and flow velocities to TODAM	• Requires extensive data input • Complex FORTRAN program, written in the preprocessor language FLECS or in FORTRAN IV • Applicable to VAX or PDP 11/70 computers (batch mode) • TODAM has been applied; however, documentation is currently under review; release date unknown	*Reference*: Onishi, et al. 1982 *Further information*: Yasuo Onishi Battelle Pacific Northwest Laboratories Richland, WA 99352 (509) 376-8302

TABLE 6
RESOURCE REQUIREMENTS AND INFORMATION SOURCES: SURFACE WATER FATE MODELS
PAGE THREE

MODEL	DESCRIPTION	RESOURCE REQUIREMENTS, COMMENTS	REFERENCES, SOURCES OF DOCUMENTATION, SOFTWARE
Channel Transport Model (CHNTRN)	• Time-varying, 1-dimensional model • Models organic pollutants • Second-order decay mechanisms • Models rivers, lakes, estuaries, and coastal waters • Can be coupled with a hydrodynamic model, CHNHYD, to estimate flow dynamics where such data are not available	• Requires extensive data input, and extensive setup time • Has not been field-tested, and documentation is currently under review • FORTRAN IV program language • Applicable to IBM 3933 computer, and others	*Reference*: Yeh 1982 *Documentation*: Dr. G. T. Yeh Environmental Sciences Division Oak Ridge National Laboratory P.O. Box X Oak Ridge, TN 37830 (615) 574-7285
Finite Element Transport Model (FETRA)	• Time-varying, 2-dimensional model (longitudinal and lateral) • Second-order decay mechanisms for organic pollutants • Models rivers, estuaries, coastal systems, and completely mixed lakes • Can be coupled with EXPLORE hydrodynamic model to generate flow velocities where these are unknown	• Input data requirements are extensive • Computer program written in FORTRAN IV • Can be used on IBM, VAX, or CDC 7600 computers • Has been field-validated • Setup and execution time requirements are extensive	*Reference*: Onishi 1981 *Further information*: Yasuo Onishi Battelle Pacific Northwest Laboratories Richland, WA 99352 (509) 376-8302

TABLE 6
RESOURCE REQUIREMENTS AND INFORMATION SOURCES: SURFACE WATER FATE MODELS
PAGE FOUR

MODEL	DESCRIPTION	RESOURCE REQUIREMENTS, COMMENTS	REFERENCES, SOURCES OF DOCUMENTATION, SOFTWARE
Estuary and Stream Quality Model (WASP4)	• Time-varying, 3-dimensional model • Sophisticated second-order organic decay kinetics • Models rivers, lakes, and estuaries	• Very data-intensive model • User must provide hydrodynamic flows between model compartments • Applicable to IBM 370 or PDP 11/70 systems, IBM PC • FORTRAN IV program requires 64 K bytes memory • Requires 150-300 man-hours for setup	*Documentation and Software*: Dr. John Connolly Environmental Engineering and Science Manhattan College Bronx, NY 10471 (212) 920-0276; or Dr. Parmely H. Prichard Environmental Research Laboratory Gulf Breeze, FL 32561 (904) 932-5311 Robert Ambrose Center for Water Quality Modeling USEPA Athens, GA 30613 (404) 546-3546

REFERENCES

If more detailed information is required, please refer to the following documents:

1) "Selection Criteria for Mathematical Models Used In Exposure Assessments, Surface Water Models," EPA/600/8-87/042, July 1987.

2) "Superfund Exposure Assessment Manual," EPA/540/1-88/001, April 1988.

3) Principles of Surface Water Quality Modeling and Control. R. Thomann and J. Mueller. Manhattan College. Harper & Row Publishers. New York. 1987.