FINAL DRAFT

KING COUNTY DEPARTMENT OF NATURAL RESOURCES
YEAR 2000 CSO PLAN UPDATE PROJECT
SEDIMENT MANAGEMENT PROGRAM

Sediment Impact and Recovery Zone Models Review and Development

Task 900
Technical Memorandum

Brown and Caldwell
and Associated Firms

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EXECUTIVE SUMMARY

This technical memorandum presents a review of sediment impact models used by King County, and a recommendation for a sediment impact and natural recovery model for King County's use. Models that have been used by King County include a version of SEDCAM (called METSED), PLUMES, and the Environmental Fluid Dynamics Code (EFDC) model, also referred to as the WQA model. Additional models that have been evaluated include CORMIX, Officer and Lynch, van Genuchten and Parker, and WASP.

For the County's Sediment Management Program, a combination of near-field and far-field models is recommended. Models that are currently used by the County are recommended, such as PLUMES for the near field and EFDC for the far field. The level of detail/degree of refinement to the existing PLUMES/EFDC models would be dependent on the resolution to which the contamination needs to be modeled. A flow chart describing the screening level modeling and subsequent refinements is included in Figure 3.

To provide some perspective on local source control characteristics and an overall view of the sediment impact modeling capabilities, King County provided results for the EFCD (far-field) and PLUMES (near-field) modeling conducted for the seven CSO sites. The preliminary far-field results suggest that regional discharges to the vicinity of the seven CSO sites are largely controlled. The near-field results suggest a potential for localized recontamination; this may need to be investigated further with model refinements.

The County provided reports describing the METSED and EFDC models that have been used to date. The METSED model is appropriate for an initial indication of whether CSO discharges may result in sediment contamination. However, as a stand-alone model, METSED cannot provide spatial resolution of the contamination area or the sediment impact zone. The EFDC model can be used to delineate the areal extent of sediment contamination and can include the effect of multiple discharges. However, the configuration that is currently used by the County would be computer resource intensive to model the spatial footprint of contamination of all the CSO sites.

INTRODUCTION

King County recently contracted with Brown & Caldwell and its subconsultants (Herrera Environmental Consultants and Anchor Environmental) to develop a Sediment Management Plan (SMP) for King County's Combined Sewer Overflow (CSO) Program. One of the initial tasks (Task 900) of this effort is to review sediment impact and natural recovery models that have been developed for the study area and recommend a model for King County's use. The study area consists of the regions near 7 CSO outfalls, located in the Duwamish River and Elliott Bay near Brandon Street, Chelan Street, Denny Way (nearshore and offshore), Duwamish/Diagonal, Hanford Street, King Street, and Lander Street.

This technical memorandum presents a recommendation for a model to be used by the County to address sediment contamination in the study area. Several models that have been developed and used by the County for this purpose have been reviewed, and additional models that have been used in the region are briefly discussed. A recommendation for a sediment impact and natural recovery model for the study area is provided at the end of this document.

BACKGROUND

Regulation of sediment contamination in the marine environment of Washington state typically falls under the authority of the Department of Ecology. The Sediment Management Standards (SMS) establish Sediment Quality Standards (SQS) for the long-term goals of contaminated sediments. When sediments with contaminant concentrations above the SQS are left in place, a sediment recovery zone may be appropriate if the sediments can be shown to recover naturally.

The SMS indicates a sediment impact zone (SIZ) may be granted for an authorized or permitted discharge that results in sediment contaminant concentrations that exceed the sediment quality standards after compliance with SIZ discharge requirements can be demonstrated. A sediment recovery zone is an area where the contaminant concentrations currently exceed sediment quality standards as a result of historical discharges, but is expected to be reduced to below these criteria as a result of natural processes.

Sediment impact zone modeling assists in evaluating the effect of continuing discharges on sediment quality. The predominant physical processes include momentum of the discharge, buoyancy effects, hydrodynamics, particle dynamics, background loading of suspended particles, partitioning equilibria, and sediment deposition, erosion, and transport.

To model the natural recovery of sediments, the predominant physical processes need to be included. Additionally, the sources of contamination need to be properly identified and represented. Recovery of the sediments results from natural and anthropogenic factors. Natural processes include the deposition of clean sediment over impacted sediment, chemical and biological degradation of contaminants within the sediment, dilution of contaminated sediment by mixing processes, and transport of impacted sediment out of the area. Anthropogenic processes include improved management practices (e.g., source controls) and the removal of "hotspot" sediments from the area to reduce the contaminant available for transport and/or mixing.

Additionally, the SMS requires that recontamination modeling be performed to verify that contaminant sources have been controlled sufficiently to prevent recontamination of the remediation area. The modeling should determine whether the sediment concentrations would exceed the SQS or CSL within a 10-year time frame.

PRELIMINARY MODEL RESULTS

The County provided model results for the seven CSO sites for review. Although these data were intended to assist in the sediment site prioritization process (Task 1100/1200), the results are included and briefly discussed below to provide some perspective on local source control characteristics and an overall view of the sediment impact modeling capabilities. Documentation for the County's model and results is provided in the Combined Sewer Overflow Water Quality Assessment for the Duwamish River and Elliott Bay (Duwamish River and Elliott Bay Water Quality Assessment Team 1998).

The County ran the EFDC (Environmental Fluid Dynamics Model) model and the PLUMES model for a 10-year period to simulate existing contaminant release loadings. These models are described in more detail in the sections that follow. The EFDC model output was provided for a grid cell (measuring approximately 250 m by 50 m) located near the CSO outfall (far-field). The PLUMES model output was provided for locations approximately 1 to 15 m from each CSO outfall (near-field). Output from these models included total cohesive suspended solids, particulate fraction, and total contaminant water concentration (in the layer above the sediments). The EFDC output also included contaminant concentrations in the accumulated bed sediments. Collectively, the County refers to these models as the Water Quality Assessment (WQA) model.

As part of the model run, contaminants were assumed to partition between the dissolved phase and cohesive particulates (Duwamish River and Elliott Bay Water Quality Assessment Team 1998). Initial and input total suspended solids and contaminant concentrations were based on field measurements. CSO, stormdrain, and river loadings were based on databases for the area and output from a separate regional stormwater runoff model.

Model results for year ten of the far-field simulations included contaminant concentrations of the cohesive suspended solids following extended inputs at current source levels. This screening-level modeling provided an estimation of baseline sediment inputs to each study area. The far-field results were provided every two days for the duration of year ten.

To summarize the far-field screening-level modeling results, the mean, maximum, and minimum values for the tenth year are provided. These particulate concentration values were compared to SQS values and are listed in Table 1. For all of the CSO sites, the predicted far-field sediment particulate concentrations were below SQS chemical criteria. For contaminants with the SQS chemical criteria expressed on a total organic carbon basis (i.e. mg/kg organic carbon), the average of the organic carbon content values for that CSO area was used. Two exceptions were the Lander and King sites; the organic carbon content for Hanford was used for Lander, and a value of 1.5% was used for King.

Table 1. Far-field Contaminant Concentrations of Suspended Sediments.

	Brandon	Duwamish /Diagonal	Chelan	Hanford	Lander	King	Denny Offshore	Denny Nearshore
TOC	2.35%	3.31%	1.04%	3.30%	3.30%	1.50%	1.18%	1.18%
Copper (mg/kg)								
Mean	27.65	25.21	19.89	21.08	20.43	17.23	17.16	17.02
Max	48.76	45.12	38.93	55.29	44.49	24.24	29.70	28.19
Min	17.69	15.99	11.01	12.82	12.76	9.27	9.51	9.41
SQS, CSL = 390 mg/kg								
Lead (mg/kg)								
Mean	11.41	10.00	5.76	7.68	6.72	3.62	3.36	3.24
Max	32.19	24.42	18.35	49.79	34.31	6.85	6.08	6.43
Min	4.56	3.79	2.17	2.78	2.74	1.96	1.29	1.35
CSL = 530 mg/kg	SQS = 450 mg/kg							
1,4-Dichlorobenzene (mg/kg OC)								
Mean	0.0060	0.0035	0.0037	0.0031	0.0025	0.0012	0.0009	0.0009
Max	0.0189	0.0146	0.0123	0.0260	0.0283	0.0031	0.0032	0.0031
Min	0.0028	0.0013	0.0010	0.0013	0.0008	0.0005	0.0003	0.0003
CSL = 9 mg/kg OC	SQS = 3.1 mg/kg OC							
Polychlorinated biphenyls (mg/kg OC)								
Mean	0.0013	0.0009	0.0012	0.0003	0.0002	0.0003	0.0002	0.0002
Max	0.0128	0.0085	0.0091	0.0021	0.0026	0.0013	0.0018	0.0017
Min	0.0002	0.0001	0.0002	0.0001	0.0001	0.0001	0.0001	0.0001
CSL = 65 mg/kg OC	SQS = 12 mg/kg OC							
Chrysene (mg/kg OC)								
Mean	0.0546	0.0456	0.0313	0.0507	0.0227	0.0012	0.0010	0.0010
Max	0.5157	0.3887	0.6109	0.6618	0.5209	0.0087	0.0208	0.0155
Min	0.0171	0.0168	0.0028	0.0070	0.0029	0.0003	0.0000	0.0000
CSL = 460 mg/kg OC	SQS = 110 mg/kg OC							
Mercury (mg/kg)								
Mean	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004
Max	0.0006	0.0006	0.0004	0.0009	0.0009	0.0004	0.0004	0.0004
Min	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004
CSL = 0.59 mg/kg	SQS = 0.41 mg/kg							
Bis(2-ethylhexyl) phthalate (mg/kg OC)								
Mean	14.63	9.86	27.74	9.72	9.36	18.22	23.83	23.75
Max	24.00	19.95	34.67	27.18	27.98	19.66	25.59	25.34
Min	13.02	8.77	25.79	8.31	8.27	16.33	21.68	21.31
CSL = 78 mg/kg OC	SQS = 47 mg/kg OC							

NOTES:
CSL = Cleanup Screening Level
SQS = Sediment Quality Standard
OC = Organic Carbon
TOC = Total Organic Carbon

The year ten far-field results were also used to calculate the cumulative probabilities for the particulate contaminant concentrations. Plots of the cumulative probabilities for each contaminant are presented in Figures 1(a) through 1(g). Based on these results, none of the particulate contaminant concentrations are likely to exceed the SQS criteria. These preliminary data suggest that regional discharges to the vicinity of the seven CSO sites for the listed parameters are largely controlled.

The near-field screening level model results were provided for as long as the plume did not intersect the water surface or sediment bed. With the same 10-year run conditions used with the far-field model, the near-field model provided results whenever a discharge from that particular site occurred. The near-field total water contaminant concentrations and suspended solids concentrations for a year of model output were provided. These were used to calculate the cumulative probabilities for the particulate contaminant concentrations. Plots of the cumulative probabilities for each contaminant are presented in Figures 2(a) through 2(g).

The near-field screening level results indicate that certain chemicals, particularly bis(2-ethylhexyl) phthalate, have the potential to recontaminate sediments above CSL criteria within the immediate vicinity of the outfall (i.e., model results were developed for locations within 15 m from the outfalls). Additionally, Brandon shows the possibility of exceeding the SQS and CSL for lead, and all CSO sites exhibit the probability of exceeding the SQS for chrysene. Further evaluation of the nature and extent of the prospective sediment impact zones in this case may require significant model refinements (see below).

Figure 1(a). Farfield WQA results: Copper

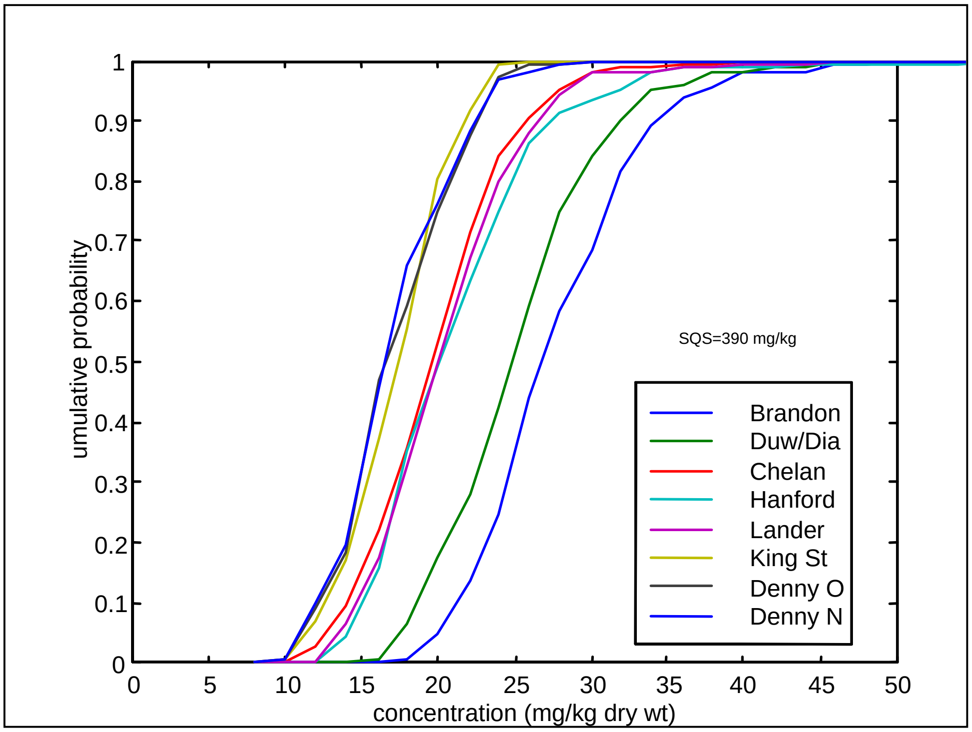


Figure 1(b). Farfield WQA results: Lead

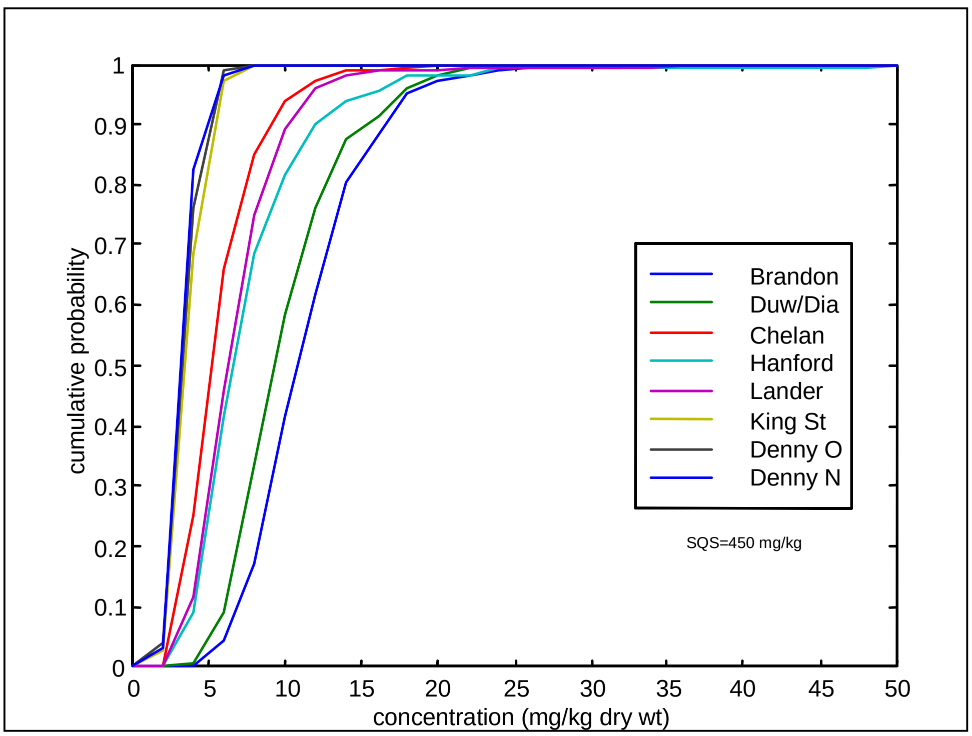


Figure 1(c). Farfield WQA results: 1,4-Dichlorobenzene

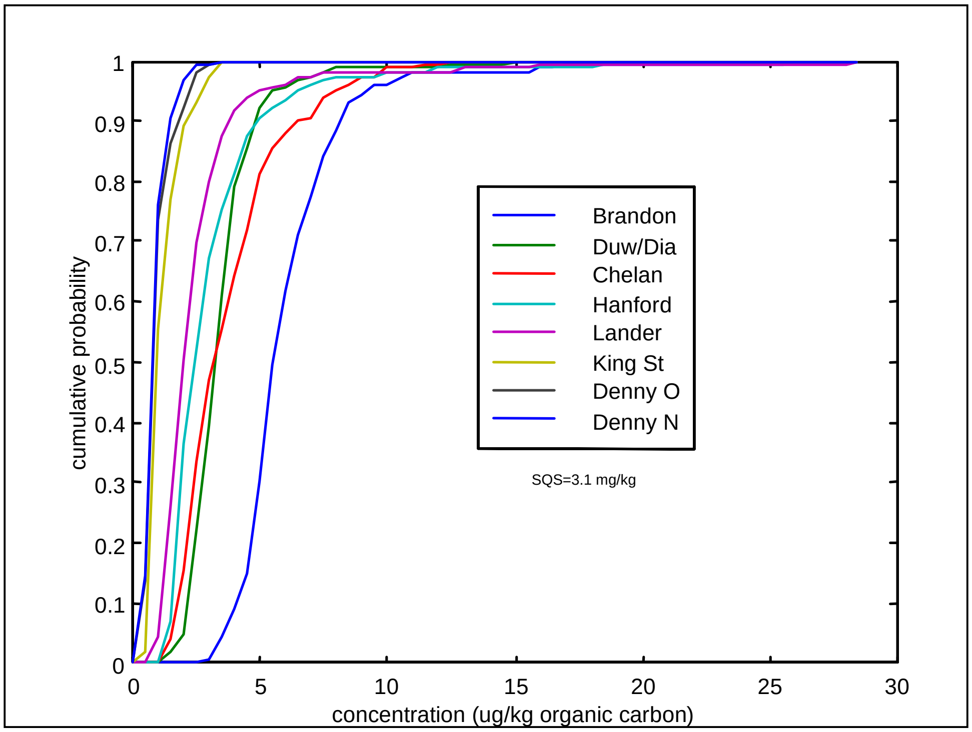


Figure 1(d). Farfield WQA results: Polychlorinated biphenyls

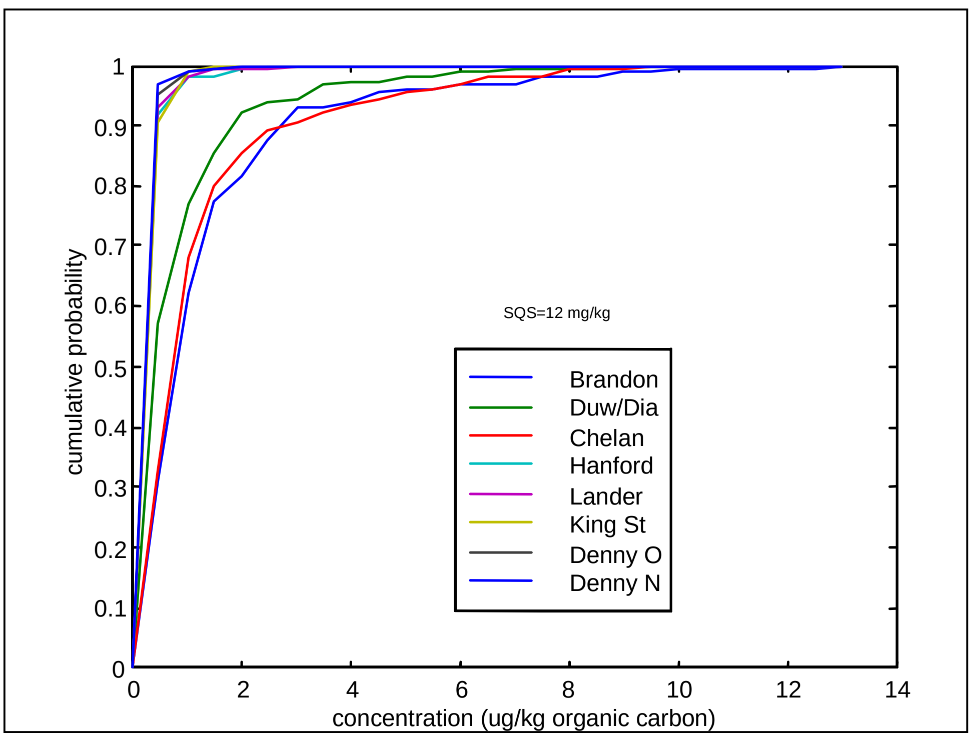


Figure 1(e). Farfield WQA results: Chrysene

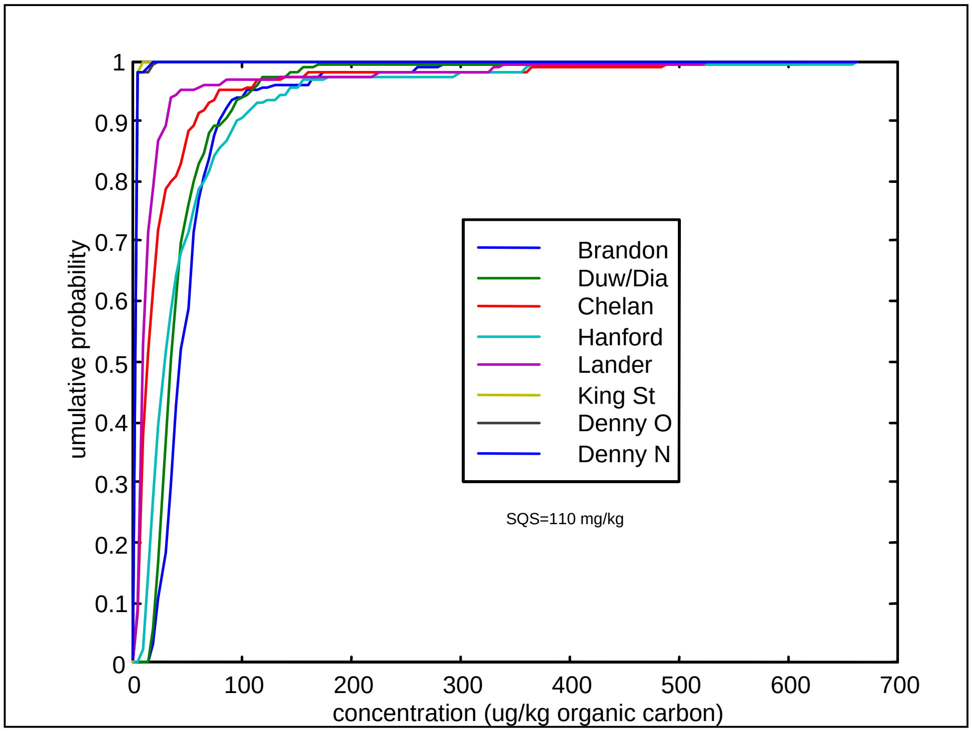


Figure 1(f). Farfield WQA results: Mercury

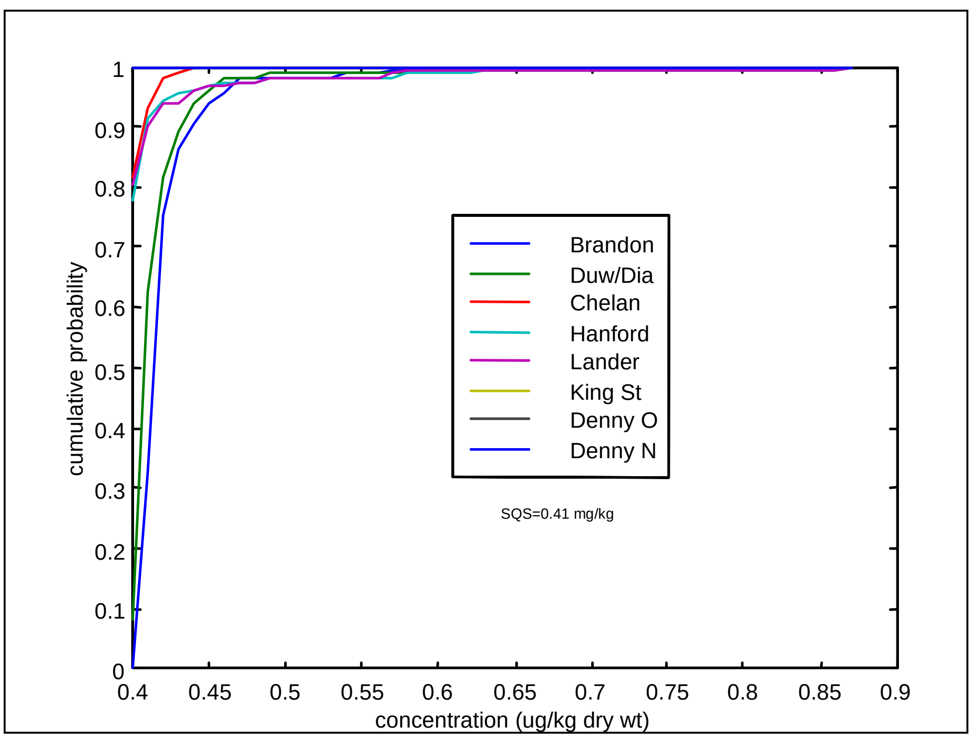


Figure 1(g). Farfield WQA results: Bis(2-ethylhexyl) phthalate

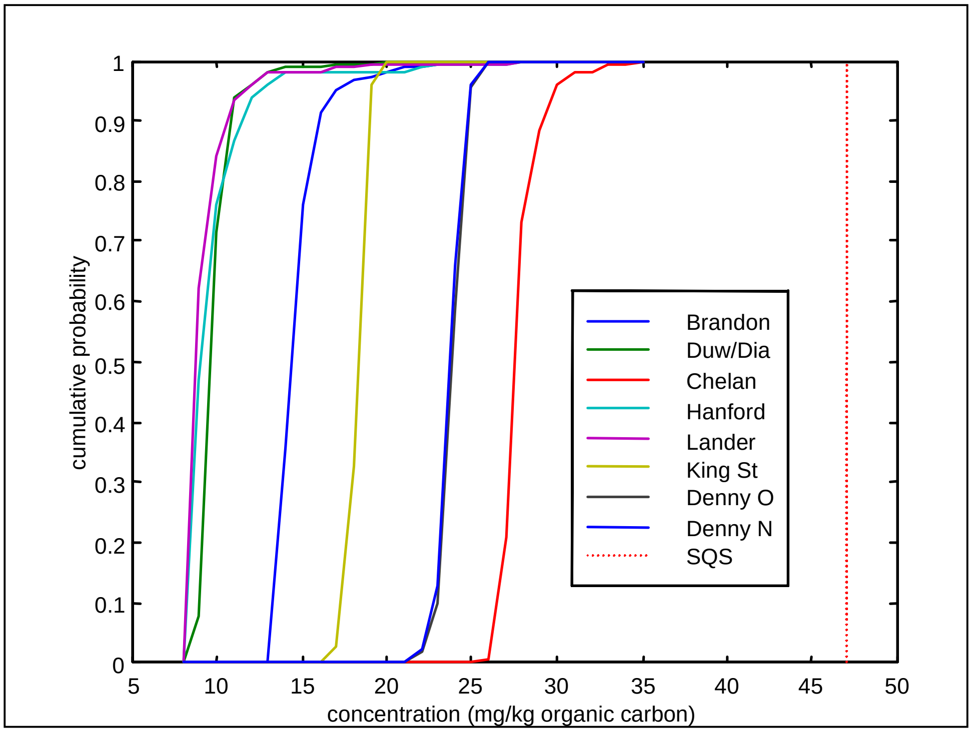


Figure 2(a). Nearfield PLUMES results: Copper

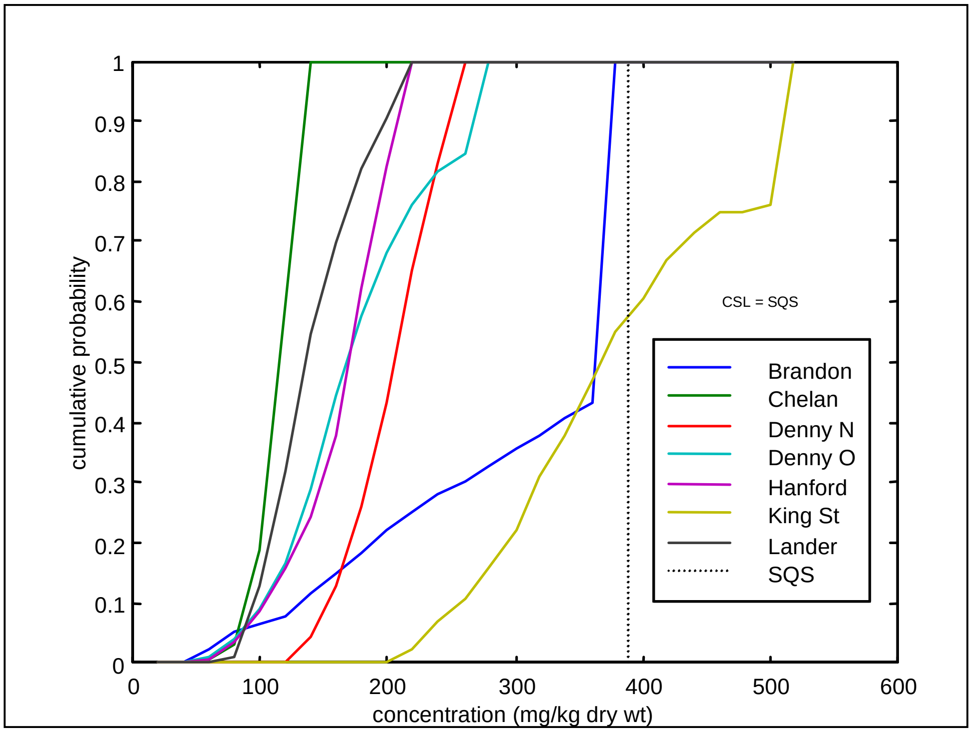


Figure 2(b). Nearfield PLUMES results: Lead

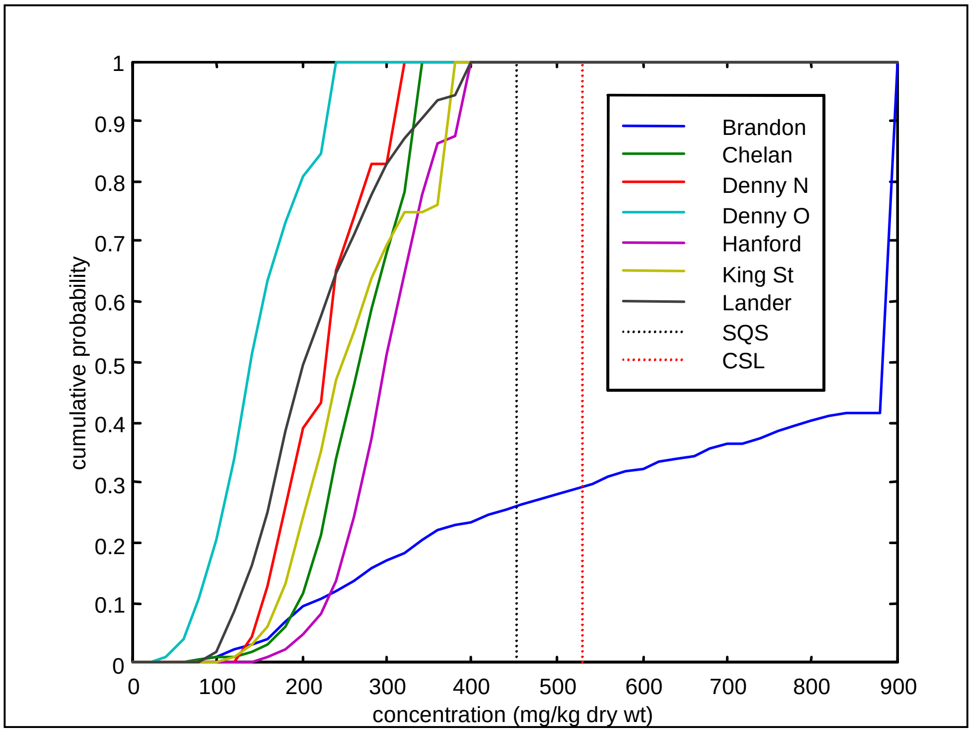


Figure 2(c). Nearfield PLUMES results: 1,4-Dichlorobenzene

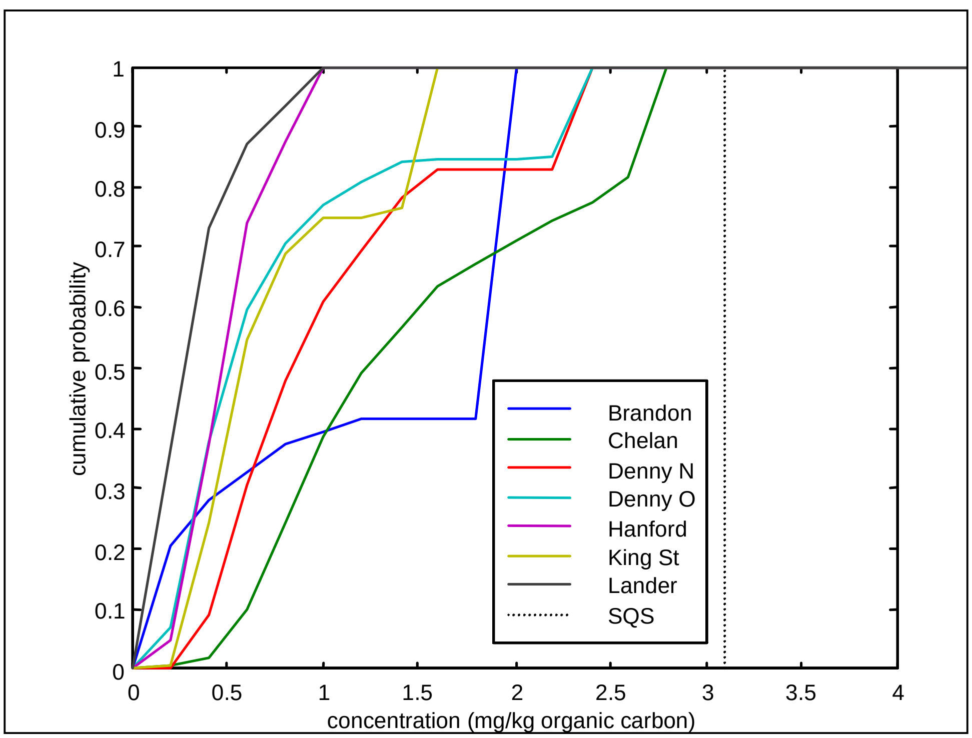


Figure 2(d). Nearfield PLUMES results: Polychlorinated biphenyls

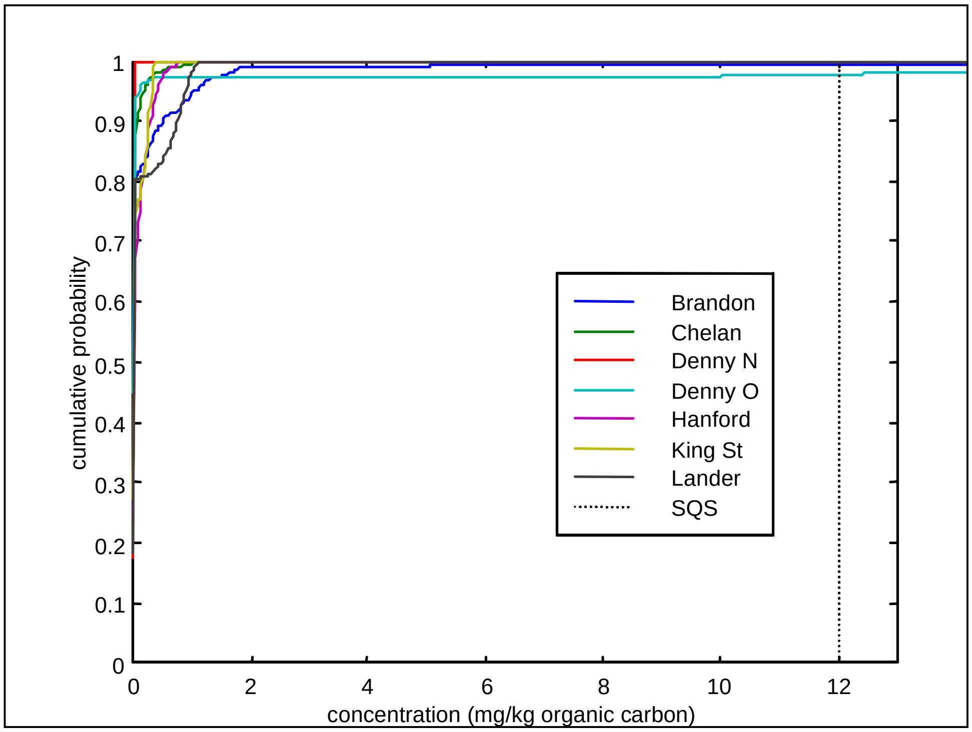


Figure 2(e). Nearfield PLUMES results: Chrysene

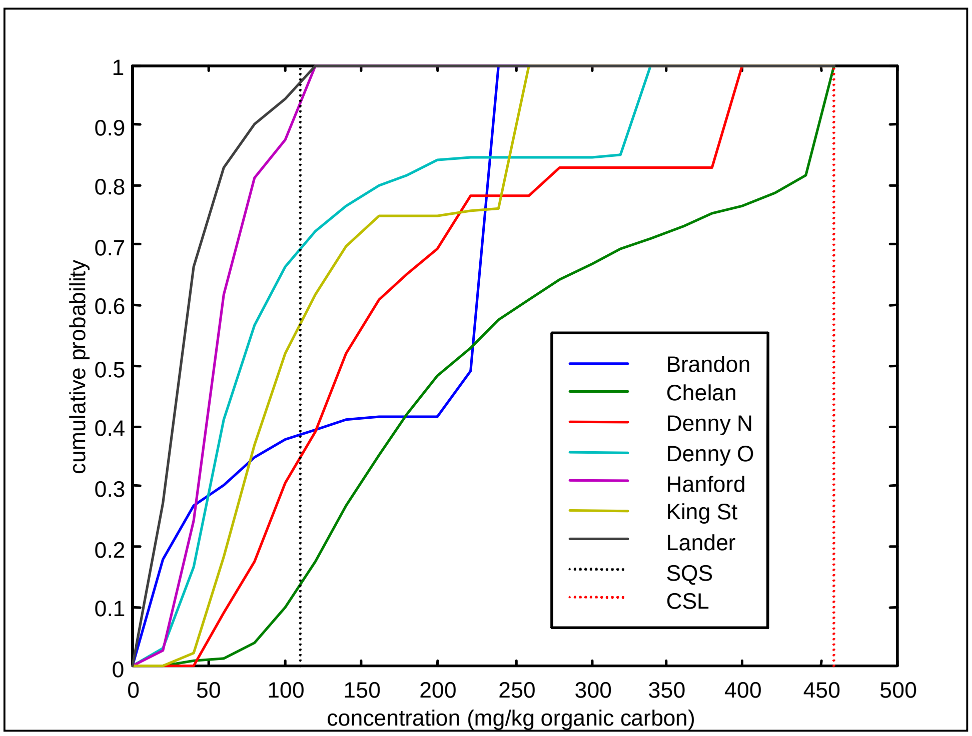


Figure 2(f). Nearfield PLUMES results: Mercury

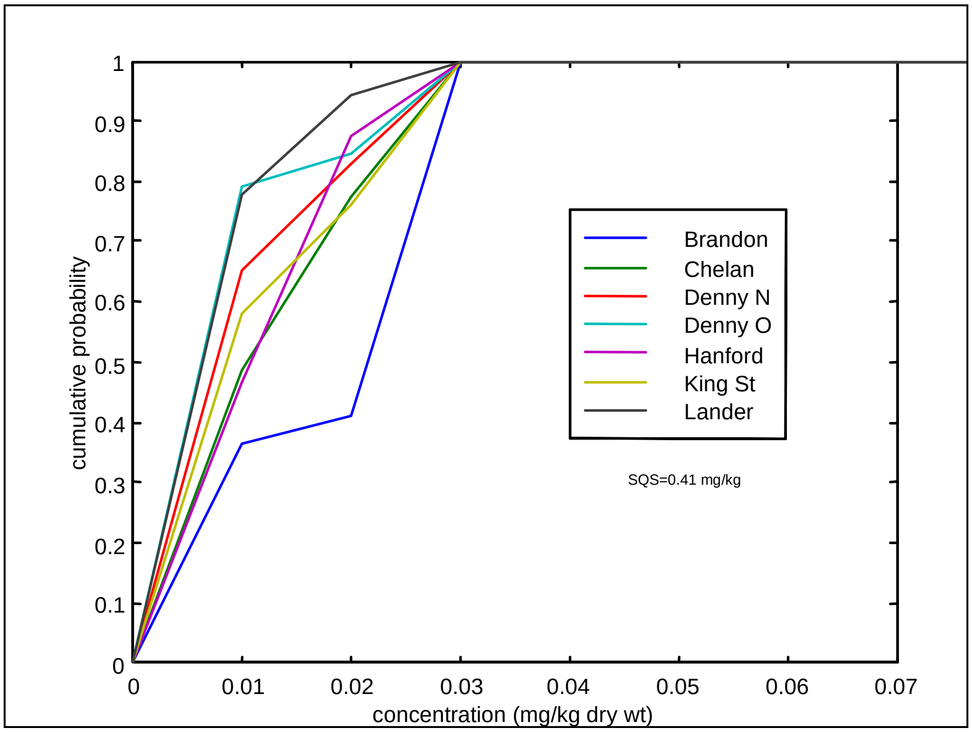
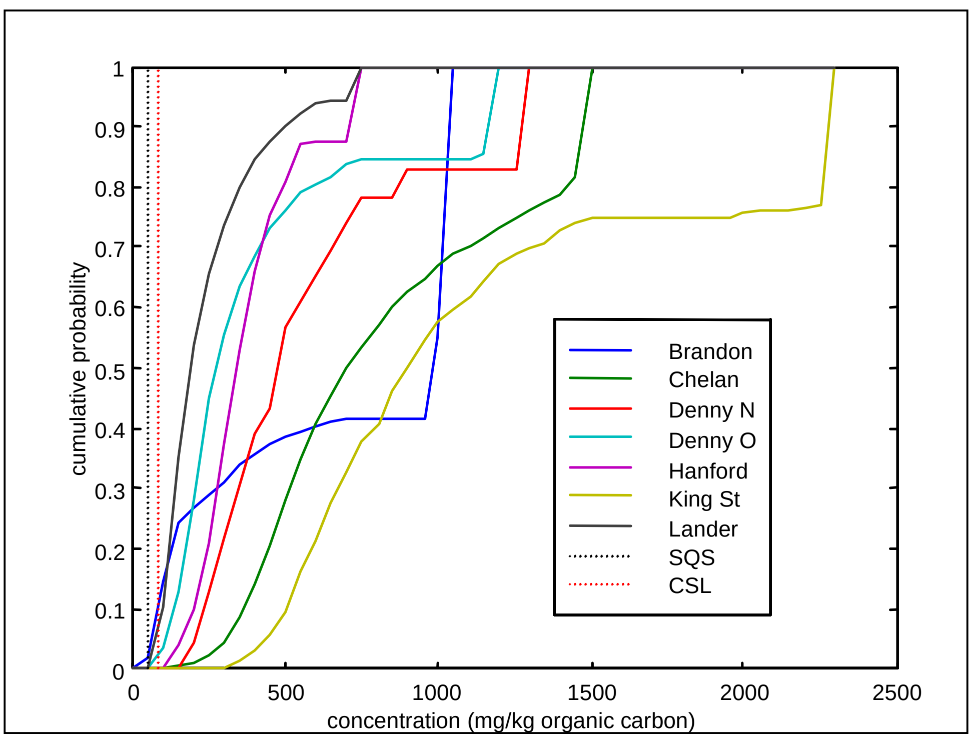


Figure 2(g). Nearfield PLUMES results: Bis(2-ethylhexyl) phthalate



REVIEW OF MODELS

The SMS outlines models that are approved for sediment impact zone modeling and sediment natural recovery predictions. In addition to those listed in the SMS, other models have been approved by the Department of Ecology as part of cleanup action alternatives and remedial actions. Table 2 lists some sediment impact and natural recovery models that have been used in the region and identifies those that have been used by the County.

Table 2. Sediment Impact and Natural Recovery Models

Model	Model Type, Approval, Use by County
CORMIX	SMS Sediment Impact Zone, Natural Recovery, used by County
PLUMES	SMS Sediment Impact Zone, Natural Recovery, used by County; recognized under the SMS for recontamination assessment in the near-field zone adjacent to outfalls
WASP	SMS Sediment Impact Zone, Natural Recovery; typically the preferred model under SMS for multiple source conditions and other complex sites
SEDCAM (METSED)	SMS Natural Recovery, used by County
Officer and Lynch	Natural Recovery (by Ecology approval)
Van Genuchten and Parker	Natural Recovery (by Ecology approval)
EFDC (WQA Model)	Sediment Impact Zone, Natural Recovery, used by County

The following documents describe sediment recovery and contaminant fate and transport models that have been applied to the study area.

- “Norfolk Recontamination Modeling Report,” prepared for the Elliott Bay/Duwamish Restoration Program Panel by Kevin Schock and Randy Shuman, 1996.
- “Predesign Letter Report on Duwamish River Sediment Quality Modeling,” by ENSR, HDR Engineering, 1998.
- “Predesign Letter Report on Performance Modeling of the Tunnel Alternative,” by ENSR, HDR Engineering, 1998.

- “King County Combined Sewer Overflow Water Quality Assessment for the Duwamish River and Elliott Bay. Draft Volume IV: Hydrodynamic and Fate and Transport Numerical Model for the Duwamish River and Elliott Bay,” by the Duwamish River and Elliott Bay Water Quality Assessment Team, 1998.

- “Proposal for Evaluation of Potential Recontamination and Completion of Duwamish Site Assessment Report,” by EcoChem, 1998.

METSED Model

The METSED model is a modified form of the SEDCAM sediment recovery model. SEDCAM was developed for the Commencement Bay Nearshore/Tideflats Feasibility Study and Record of Decision, and is listed as an approved method to estimate sediment recovery under the SMS program. SEDCAM incorporates the effects of sedimentation, biodegradation, and diffusion processes (Tetra Tech, 1988). The model assumes a well-mixed system and allows for the continual input of contaminants with sedimentation.

Several versions of METSED were created, with each successive version augmenting various aspects of the SEDCAM model. The first version of METSED applied SEDCAM over a series of discrete time periods to allow for a time-varying loading of contaminant into the sediments. Chemical discharge concentrations were based on analytical results of field samples collected (for both the sediments and CSO discharges); total suspended solids concentrations (TSS) for the river were estimated by an empirical relationship; contaminant partition coefficients were based on literature values; and CSO inflow values were based on representative CSO loading hydrographs for the area. The dilution of CSO inflow was a length-based factor, estimated by the extent of existing contamination, the whole river width, and the momentum of the CSO effluent entering the flowing river. The METSED model was configured to solve the SEDCAM equation over a series of one-week intervals; the estimated concentration from the preceding interval would become the input concentration for the successive interval. Contaminant inputs from the CSO and stormdrains were included to evaluate the effect that CSO source elimination would have on sediment concentrations.

The second version of METSED incorporated better estimates for the dilution of the CSO and stormdrain discharges with the river flow. CORMIX3, the Cornell Mixing Zone Expert System (see below), was applied to estimate the dilution from the CSO and stormdrain discharge. Additionally, improved partitioning coefficients were applied for the chemical constituents. The sediment recovery predictive equation was solved in a series of one-week interval inputs, as in the original version of METSED.

The third version of METSED modified the time intervals between input values. Storm events were discretized with a 10-minute time interval, and non-storm events were discretized with an hours- to days- time interval. As with the second version, CORMIX3 was used to estimate the dilution of the CSO and stormdrain effluent with the river. The resulting predicted concentrations were promising enough to prompt a further reduction of the time interval to a constant value of 0.01 day. Under this configuration, the

METSED model was applied to predict the necessary dilution of the stormdrain input that resulted in sediment concentrations below the SQS values.

In applying the METSED model, estimated values to describe the sediment matrix and mixing process were used. The mixed layer depth was assumed to be 5 cm, an average sediment specific gravity of 2.5 was used, a sediment porosity of 0.6 was applied, and the sediment accumulation rate was based on the fall velocity of the average sediment particle (medium sized silts). The net sediment accumulation rate, a value that is based on field measurements, incorporated sediment accumulation and resuspension for a particular area.

The METSED model is appropriate for an initial indication of whether CSO discharges may result in sediment contamination. However, as a stand-alone model, METSED cannot provide spatial resolution of the contamination area or the sediment impact zone.

EFDC

The Environmental Fluid Dynamics Code (EFDC) model is a three-dimensional circulation and transport model that is used for estuarine simulations. EFDC incorporates the effects of tides, river hydraulics, and density-driven flows to predict the circulation and hydrodynamics of an estuarine system. EFDC includes sediment transport processes, and allows for the tracking of contaminant fate between the dissolved and sorbed states (Hamrick and Wu). EFDC may be applied to model sediment impact zones and sediment natural recovery. The County has used the EFDC model with the objective of estimating other source loads (sources other than CSOs) into the Duwamish estuary, and assessing how the removal of CSO source loads affects the contaminant concentrations in the water and sediments.

The computational domain for the Duwamish estuary included Elliott Bay, the Duwamish River, and the Green River up to the intersection with I-405. The areal extent of the estuary was discretized into 512 finite difference cells. In the areas of sediment contamination (near the CSO outfalls), the cell size was approximately 250 m by 50 m. Vertically, the water column was divided into 10 layers, with the layer width based on the density stratification. The bottom sediments were treated as one continuous layer. The hydrodynamic and contaminant fate and transport components were calibrated to the Duwamish Estuary.

A field sampling program was implemented to augment water concentration and sediment concentration data for the EFDC modeling input. The Elliott Bay boundary, the Duwamish boundary, and the CSOs were monitored for contaminant concentrations. Sediment concentrations and characteristics within Elliott Bay and the Duwamish River were obtained from a database. Suspended solids input at the Green River boundary was estimated with an empirical relationship based on a database of suspended solids concentrations and flow rate. The County's Runoff and Transport Model used historical rainfall data to estimate stormwater runoff hydrographs. Partition coefficients for metals were computed for each sample site; partition coefficients for organics were obtained from literature references.

The EFDC model could be used to delineate the areal extent of sediment contamination. However, the configuration that is currently used by the County would be computer resource intensive to model the spatial footprint of contamination of all the CSO sites.

Officer and Lynch

The Officer and Lynch (1989) model is a one-dimensional sediment natural recovery model. It incorporates the burying of contaminated sediments, the mixing of cleaner sediments to the surface by benthic organisms, and the exchanges between the bottom sediments and water column. The model also allows for non-advective concentrate exchange due to periodic and episodic resuspension of bottom sediments and exchanges across the bottom boundary layer. In the Officer and Lynch model, the bioturbation effects are represented by a constant diffusion coefficient applied over the mixed layer interval. Beneath the mixed layer, the sediments are treated as a non-diffusive medium.

The Officer and Lynch model is based on the concentrate continuity equations for a system that includes advective and diffusive processes (Officer and Lynch, 1982). Sedimentation is represented by an advection process, and bioturbation is represented as a diffusive process. The model uses the one-dimensional equation for advection and diffusion processes, applying a continuity of flux boundary condition at the sediment: water interface and a continuity of flux and concentrate at the limit of the mixing zone boundary. The Officer and Lynch model also allows for compaction effects in the sediment media and the variation of porosity with depth.

Parameters that need to be properly represented include the mixed layer depth, the net sediment accumulation rate, the bioturbation rate, the sediment specific gravity and porosity, and the interface concentrate exchange rate. The values of these parameters are generally based on field samples, sediment trap data, bathymetry surveys, and radiochemical sediment analysis. The Officer and Lynch model has been applied to predict sediment natural recovery for Sitcum Waterway Operable Unit, other Commencement Bay Nearshore/Tideflats Site areas, Bellingham Bay, and other areas of Puget Sound.

Van Genuchten and Parker

The van Genuchten and Parker (1984) model is based on the same governing equations as the Officer and Lynch model. The van Genuchten and Parker model includes sediment burial, sediment mixing, and sediment-water exchanges.

In the van Genuchten and Parker model, the concentrate continuity equation for a system with advective and diffusive processes is represented in a partial differential equation. As with the Officer and Lynch model, a continuity of flux boundary condition is applied at the sediment water interface. A continuity of flux and concentrate boundary condition at the limit of the mixing zone boundary would result in the same solution as described in the Officer and Lynch model; however, the van Genuchten and Parker model has been configured with a semi-infinite boundary condition of a zero concentration gradient at infinite sediment depth. This implies that the accumulating sediments are allowed to mix throughout the sediment column, that mixing is not limited to the upper portion of the column.

As with the Officer and Lynch model, the net sediment accumulation rate, the bioturbation rate, the sediment specific gravity and porosity values need to be properly represented. The van Genuchten and Parker model has been applied to predict sediment natural recovery in the Hylebos Waterway of the Commencement Bay Nearshore/Tideflats Site.

CORMIX and PLUMES

The Cornell Mixing Zone Expert System (CORMIX) was designed to model pollutant discharges into waterways. The CORMIX system consists of three separate modules to analyze submerged single port discharges, multiport diffuser discharges, and surface discharges from pipes or channels. CORMIX incorporates buoyant effects of the discharge with the stratified flow of the waterway to predict dilution and plume migration and mixing. CORMIX focuses on the near-field mixing zone (Jirka et al. 1996).

CORMIX represents the receiving waterway with average values. While appropriate on a small scale basis, this model is limited to the extent of the discharged plume. CORMIX can be used as a near-field mixing model, when the buoyancy effects of the discharged effluent and momentum effects of the receiving waterway are important.

PLUMES models pollutant discharges and mixing in a manner similar to CORMIX. PLUMES is an EPA model that has obtained regulatory approval for modeling submerged port and multiport diffuser discharges, and is also commonly applied at SMS sites for outfall-related recontamination evaluations.

WASP

WASP (the Water Quality Analysis Simulation Program) consists of a set of two separate modules to model the hydrodynamics and fate and transport of contaminants (both within the water system and sediment system). WASP is listed here because it is identified in the Sediment Management Standards as a sediment impact zone model and as a model to predict the effects of natural recovery. A model such as WASP is particularly appropriate in relatively complex receiving water/sediment environments.

With regard to the governing equations and physical processes, WASP is similar to the EFDC model. Additionally, both WASP and EFDC can be used to model the effect of multiple discharges. Differences between the two models arise in numerical algorithms, how sediment resuspension is handled, and the ability to incorporate sediment layering. The EFDC model treats the sediment as a single layer but can dynamically model sediment resuspension; the WASP model can incorporate multiple sediment layers, but can not dynamically model sediment resuspension.

The WASP system is comprised of two separate models, DYNHYD, a hydrodynamic model, and WASP, a water quality program. With the hydrodynamic solution, the WASP program solves sediment transport and chemical kinetic relationships to predict the contaminant transport. For WASP simulations, the DYNHYD program is the most compatible one that estimates the hydrodynamic conditions. Other linked programs are also available for application to WASP.

WASP requires a computational domain discretized in a manner similar to the domain for the EFDC simulation of the Duwamish estuary. Since EFDC can dynamically model sediment resuspension, it would be more appropriate for situations that include irregular, varying flow conditions. However, the flow field from an EFDC model run can be used with the WASP model.

DISCUSSION

For screening-level analysis, the SEDCAM/METSED model has been applied to some King County sites to evaluate the potential to recontaminate the sediments. The METSED model cannot provide a delineation of the contaminant area, but can be used as an initial tool to indicate whether more detailed modeling should be conducted.

Contaminant fate and transport models, such as EFDC and WASP, are more detailed and can be used to identify the contaminant area. These finite difference models typically require that the extent of the estuary be discretized to model the hydrodynamics of the system. The resolution of spatial discretization affects the computational intensiveness of the model (and the time required for model execution). To keep the computations of the hydrodynamic solution manageable, the discretization may be greater than the contaminated area to be modeled. However, the hydrodynamics and contaminant transport are important processes that contribute to sediment impact and natural recovery processes.

The contaminant fate and transport models can be decoupled from the hydrodynamics; this would enable different grid resolutions between the hydrodynamic solution and the contaminant fate and transport solution. For example, the hydrodynamic solution for a representative time frame (large grid resolution) can be used to run the contaminant fate and transport model (fine grid resolution). A representative time frame could be a tidal cycle with average annual CSO and river inflow conditions.

A means to incorporate local mixing of the CSO inflow is to use a near-field model (such as CORMIX or PLUMES) coupled with the far-field model (such as EFDC or WASP). For an initial screening, the near-field model can be used to assess whether recontamination in the area surrounding the CSO requires further investigation. Should that be the case, the near-field model can be used to help establish the cell size for subsequent contaminant transport model runs.

A sediment mixing model (such as Officer and Lynch) can be applied with the results of the near-field/far-field coupled model. Using a separate sediment recovery model has the advantage that the near-field results can be applied for the local area around the CSO outfall. The Officer and Lynch model is more refined than the SEDCAM model; it has been used to predict the natural recovery for other contaminated sediment sites in the Puget Sound area and in the alternatives decision process for these sites. Use of the Officer and Lynch model requires site specific parameters based on field measurements. This model includes sediment resuspension, but does not track the movement of the resuspended sediment. The Officer and Lynch model represents more of the physical processes behind natural recovery.

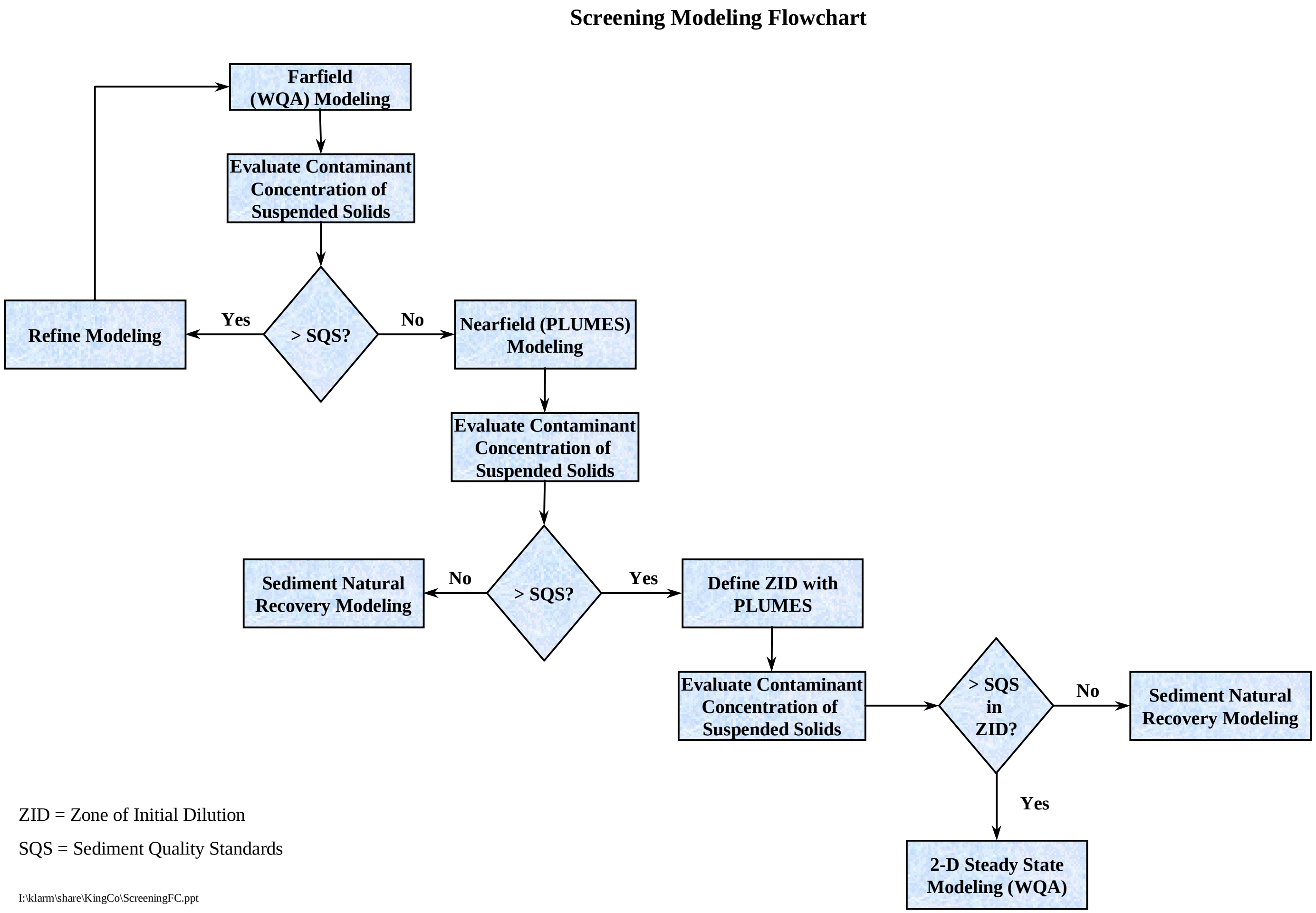
RECOMMENDATION

For the County's Sediment Management Program, a combination of near-field and far-field models is recommended. The discharge model PLUMES is currently used and maintained by the County and is an appropriate model for near-field effects. The hydrodynamic and transport model EFDC is also used by the County and can be applied to predict far-field effects. For sediment impact zone modeling, this coupled combination of models can predict the influence that continuing discharges will produce in the estuarine system. Additionally, the EFDC model results can be used to predict the natural recovery of an area once sources have been controlled. For more detailed representation of the sediments, the sediment deposition and resuspension from EFDC can be used with a sediment recovery model such as the Officer and Lynch model to more accurately represent the sediment mixing process.

The level of detail and refinement to the existing EFDC/PLUMES model currently used would be dependent on the resolution to which the contamination needs to be modeled. For screening level modeling, a flowchart of this recommendation is provided in Figure 3. Using the far-field model (EFDC) as it is currently configured, the contaminant concentration of the suspended solids can be evaluated and compared to the SQS values. Should the model predict concentrations greater than the SQS, then the far-field model could be refined - either in spatial discretization, input concentrations, or flow conditions, to provide a more accurate assessment of the nature and extent of sediment recontamination potential. In addition, the near-field model (PLUMES) results could be evaluated and compared to the SQS values. (Many of these steps in the process have already been completed, and are discussed in the Preliminary Model Results section.)

Should the near-field model results exceed the SQS, then the PLUMES model can be used to define the zone of initial dilution; that can be used as the minimum cell size for further refinements to the near-field modeling. The refined PLUMES runs can then be used to evaluate whether the contaminant concentrations of suspended solids exceed the SQS in the zone of initial dilution. Should that be the case, then the modeling can be refined, either with a steady state approximation using the EFDC model (as it is configured), or using the WASP contaminant transport model (with a hydrodynamic solution of a representative long-term average condition). These refinements would enable a finer grid resolution to better define contaminant extent with subsequent modeling runs.

Figure 3. Screening Modeling Flowchart



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