WATERSHED WATER QUANTITY AND WATER QUALITY MODELING FOR SINCLAIR AND DYES INLET

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ABSTRACT: Nonpoint discharge Elimination System (NPDES) has become increasingly difficult. Regulatory guidance encourages a science-based quantitative approach for determining effluent discharge limitations by considering processes that govern the fate and transport of contaminants; such as, contaminant transport and dispersal, as well as bioavailability and assimilative capacity. One such area where a science-based approach to determining Total Maximum Daily Loads (TMDL) would be beneficial is the Puget Sound Naval Shipyard (PSNS) in Bremerton, Washington, and the surrounding water bodies. PSNS is a large industrial facility that provides support for ships and service craft and performs construction, conversion, overhaul, repair, alteration, dry docking, decommissioning, and outfitting of ships. The inlet is primarily a sub-basin of the Puget Sound estuary system. A team of scientists/engineers and environmental numerical modelers from Concurrent Technologies Corporation (*CTC*), the U.S. Space and Naval Warfare Systems Center, San Diego (SSC SD), and the U.S. Army Engineering Research and Development Center (ERDC) have been assembled to provide technical support for the Puget Sound Naval Shipyard (PSNS) Environmental Investment (ENVVEST) project. Their effort involves modeling the drainage areas of the inlets and performing the hydrodynamic modeling of the inlets themselves. The ENNVEST Modeling Group is presently developing a number of HSPF models to be used to compute both water quantity as well as water quality simulations that will ultimately be used as input for the CH3D/WASP model being developed for Sinclair and Dyes Inlets. This paper will focus on the watershed modeling efforts to date, the water quality constituents to be modeled, and the data collection activities currently underway to support the watershed modeling effort.

INTRODUCTION

Establishing the relationship between the quality of the receiving waters and the incoming contaminant loads is achieved by a watershed management approach which links contaminant fate and transport modeling with ecological risk assessment. The resulting watershed modeling framework integrates a number of contaminant loading models (EPA's HSPF), the 3-D hydrodynamic model (ERDC's CH3D), and the water quality model (EPA's WASP). Nonpoint source contaminant loads, which constitute the majority of the pollution entering Sinclair Inlet, are being computed using a number of HSPF models for the inlet drainage areas and these loads will serve as time-dependent spatially-varied boundary conditions for the CH3D model. At present, HSPF models are being developed for the Anderson Creek, Barker Creek, Blackjack Creek, Chico Creek, Clear Creek, Gorst Creek, and Strawberry Creek watersheds. Point source contaminant loads (i.e., publicly-owned treatment works and other sources) will also be taken into account and input to the CH3D model. Once the integrated watershed and hydrodynamic modeling system has been developed, calibrated, and validated, various loading scenarios can be simulated in order to assess the environmental impacts for the project study area.

STUDY AREA

The ENVVEST study area is located in Kitsap County, Washington. The study area consists of all of the drainage areas into and including Dyes Inlet and Sinclair Inlet, Figure 1. Within the study area there are both point source and nonpoint sources of pollution into the marine water bodies. The major urban areas, within the study area, are the City of Bremerton, the City of Port Orchard, and the City of Silverdale.

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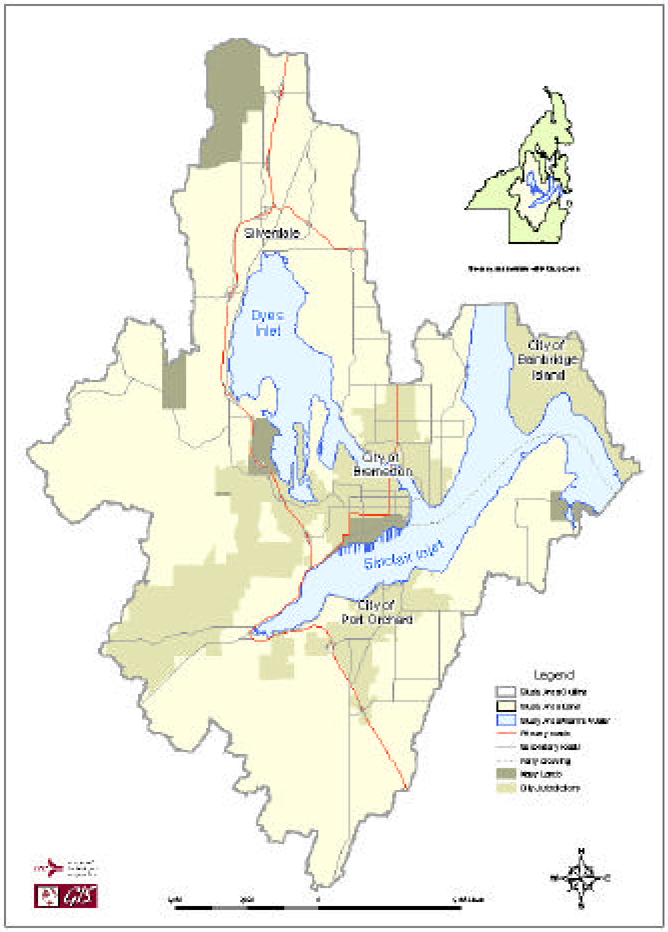

Figure 1 – ENVVEST Project Area

DATA COLLECTION ACTIVITIES

SSC SD has reviewed discharge data for 27 creeks in the watersheds of both Sinclair and Dyes Inlets. Out of these 27 creeks, flow discharges were available only for approximately 10 creeks. These flow discharges are daily means, covering different periods between 1990-2000. From this data review, watershed water quantity and limited amounts of quality from 1996-1999 was included (i.e., precipitation, fecal coliform, temperature, pH, dissolved oxygen, conductivity, turbidity, total dissolved solid, percent saturation, and flow). For the 20 streams that were provided by Kitsap Public Utility District (KPUD), a large portion of the streamflow data is for streams that are not in the study area related to this watershed modeling study. Figure 2 illustrates the gage locations that will be useful for watershed model calibration and verification activities for basins that drain into Dyes Inlet and Sinclair Inlet, respectively.

Precipitation and meteorological data are the primary forcing functions in the watershed HSPF model. The project team has received precipitation data from three different sources: (1) BASINS database; (2) Forecast Systems Laboratory (FSL) and the National Climatic Data Center (NCDC); and (3) local gages (i.e., *CTC*, City of Bremerton, etc.). The BASINS database incorporates precipitation and evapotranspiration data for the State of Washington on an hourly and a daily time scale for the period of 1970 to 1996. SSC SD provided hourly precipitation data for six rain gages, for the period of 1990 to 1998, which require some formatting before use. These data, of a regional scale, were obtained from the Hourly Precipitation Dataset, available on CD-ROM by the FSL and the NCDC. Precipitation data, as well

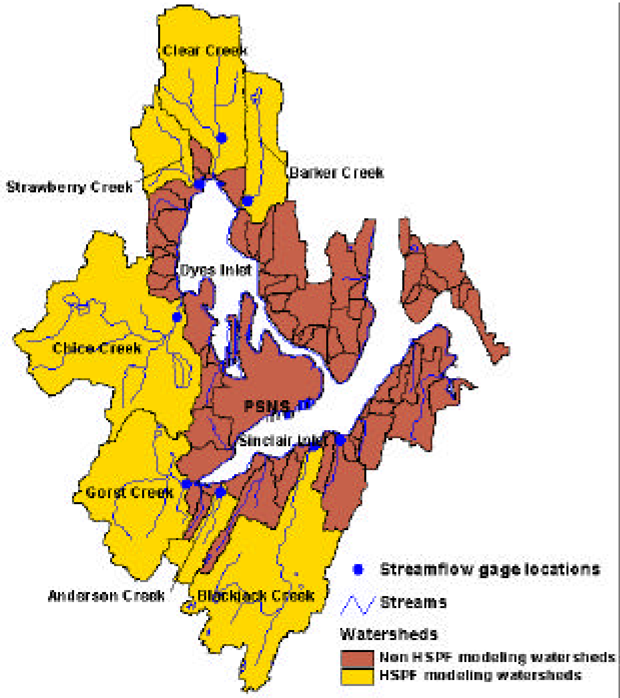

Figure 2. Streamflow Gage Locations for Basins
that Drain into Sinclair and Dyes Inlets.

as other meteorological data (temperature, humidity, wind speed, wind direction, high wind, and barometric pressure), were provided by *CTC*. These data sets were obtained from the weather station at the *CTC* office building on the waterfront in Bremerton, Washington. The period of record is 3/12/98 to 12/31/98, 02/01/99 to 12/30/99, and 01/03/00 to 08/14/00.

Another source of local precipitation data is the City of Bremerton, which has been collecting rainfall data at two gage sites. The period of record is from 1994 to the present. These data sets have been reformatted into 15-minute intervals and have been disseminated to the project team. The installation of additional rain gages within the project area has been recommended.

Contaminants of concern include the following:

- Copper.
- PCBs.
- Mercury.
- Dissolved oxygen.
- Nutrients (NH_3, NO_2/NO_3, total nitrogen [N], total phosphorus [P]).
- Fecal coliform.
- Other PSNS related contaminants of concern.

Table 1 lists the contaminant loading sources for Sinclair and Dyes Inlets. The loads for copper , dissolved oxygen, and nutrients are included. Loads for PCBs and mercury are not included, because characteristics and sources for these two contaminants are quite different from those for the other contaminants. Therefore, PCBs and mercury will be treated separately. Loads and knowledge for fecal coliform will be investigated separately in the ongoing combined sewer overflow (CSO)/Dyes Inlet modeling study.

Table 1. Contaminant Loading Sources for Sinclair and Dyes Inlets

Loading Sources	***Sinclair Inlet and Dyes Inlets***									
	Nitrogen Load (Load should in the form of N-species; if not, total-N needs to be available)				*Phosphorus Load (Load should in the form of two P-species; if not, total-P needs to be available)*			*Cu*	*BOD*	*TSS*
	NH_3	*NO_3*	*Org-N*	*Tot-N*	*OPO_4*	*Org-P*	*Tot-P*			
[a] *Atmospheric*	?	?	?	?	?	?	?	?	?	---
[b] *POTWs*	?*	?*	?*	?*	?*	?*	?*	?*	?*	?*
[c] *Groundwater*	?	?	?	?	?	?	?	?	?	---
PSNS	?*	?*	?*	?*	?*	?*	?*	?*	?*	?*
CSO	?/	?/	?/	?/	?/	?/	?/	?/	?/	?/
[d] *Nonpoint Source*	Ö	Ö	Ö	Ö	Ö	Ö	Ö	Ö	Ö	Ö
[e] *Sediment Flux*	Ö	Ö	Ö	Ö	Ö	Ö	Ö	Ö	Ö	Ö

Notes:

[a] Contaminant sources from atmospheric are unknown, but potentially these loading sources may be important for certain contaminants of concern.

[b] Bremerton and Port Orchard WWTPs are two major sources. Detailed information on these sources is available in Tetra Tech, Inc. 1988.

[c] Contaminant sources from groundwater are unknown, but potentially these loading sources may be important for certain contaminants of concern.

[d] HSPF models under development will provide nonpoint source loading

[e] Benthic flux measurement conducted by SPAWAR in March 2000 will provide contaminant sediment flux data.

? No data is known to exist.

? Partial data is available.*

?/ Data search for CSO loading is underway in the CSO/Dyes Inlet fecal coliform plume dispersion modeling study. Unknown so far.

Ö Data is available or will be available.

POTW: publicly-owned treatment works

MODELING METHODOLOGY

The Hydrologic Simulation Program-FORTRAN (HSPF) model was developed for the U.S. Environmental Protection Agency (USEPA) and is a combination and improvement of three other models: the Agricultural Runoff Management (ARM) model, the NonPoint Source (NPS) runoff model, and the Hydrologic Simulation Program (HSP). HSPF is a comprehensive model of watershed hydrology and water quality that allows the integrated simulation of runoff processes with in-stream hydraulic, sediment, and chemical interactions. HSPF was first released publicly in 1980, as version 5. Currently, version 11 of HSPF is available as public domain software that can be downloaded from USEPA and U.S. Geological Survey (USGS) web sites. User support, code maintenance, and further refinement and enhancement of the HSPF model are ongoing. Since its original development, the HSPF model has been applied throughout North America and numerous countries and climatic regions around the world.

HSPF is a mathematical model that simulates water quantity and quality processes on a continuous basis in natural and man-made water systems. The HSPF model, which requires calibration for the specific watershed to be studied, can be run at time steps of 15 minutes to one hour. HSPF uses meteorological input data and parameters related to land use patterns, soil characteristics, and agricultural practices to simulate the water quantity and quality processes that occur within a watershed. The HSPF model is generally classified as a lumped parameter model; however, the spatial variability in a watershed can be simulated if the basin is appropriately divided into land segments, which are generally hydrologically homogeneous. Several potential applications and uses of the HSPF model:

- Flood control planning and operations.
- Hydropower studies.
- River basin and watershed planning.
- Storm drainage analyses.
- Water quality planning and management.
- Point and nonpoint source pollution analyses.
- Soil erosion and sediment transport studies.
- Evaluation of urban and agricultural best management practices (BMPs).
- Fate, transport, exposure assessment, and control of pesticides, nutrients, and toxic substances.
- Time-series data storage, analysis, and display.

PRESENT MODEL DEVELOPMENT

To date, HSPF models have been developed for Anderson Creek, Blackjack Creek, Gorst Creek, Chico Creek, Barker Creek, Clear Creek, and Strawberry Creek, as shown in Figure 2. The water quantity components have been set up and simulations have been made, however, the water quality components have not been developed to date. Some calibration, of water quantity, has been done on the watershed models, as shown in Figure 3 for Barker Creek. However, KPUD is collecting flow and precipitation data that will be used to further calibrate and verify the HSPF models. PSNS is currently developing a water quality monitoring plan that will be used to collect observed data for the purpose of calibrating and verifying the HSPF models.

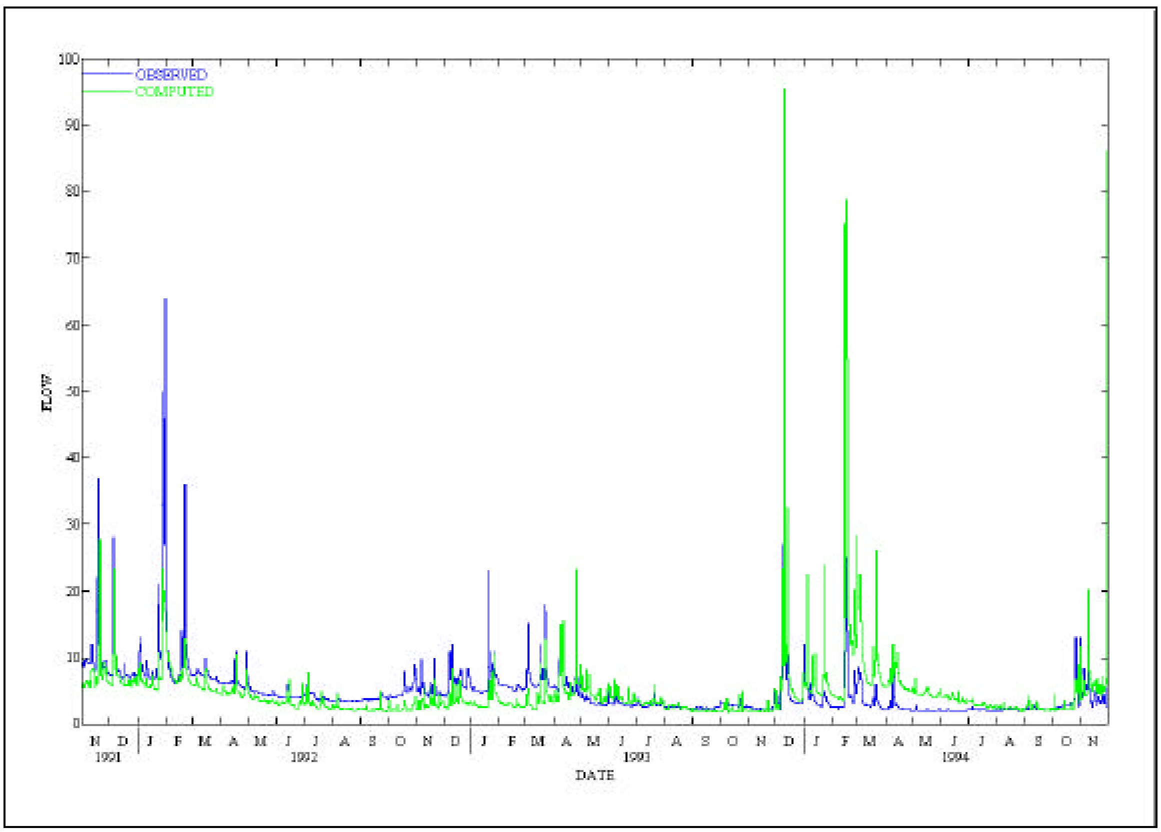

Figure 3 - Simulated and observed flows for Barker Creek.

The modeling team has collaborated on an Inter-Calibration Study, on Anderson Creek, with the intent to determine common data sets as well as a common modeling methodology that all of the watershed modelers will use in developing, calibrating, and verifying their respective watersheds. One example, from this effort, can be seen in Figure 4.

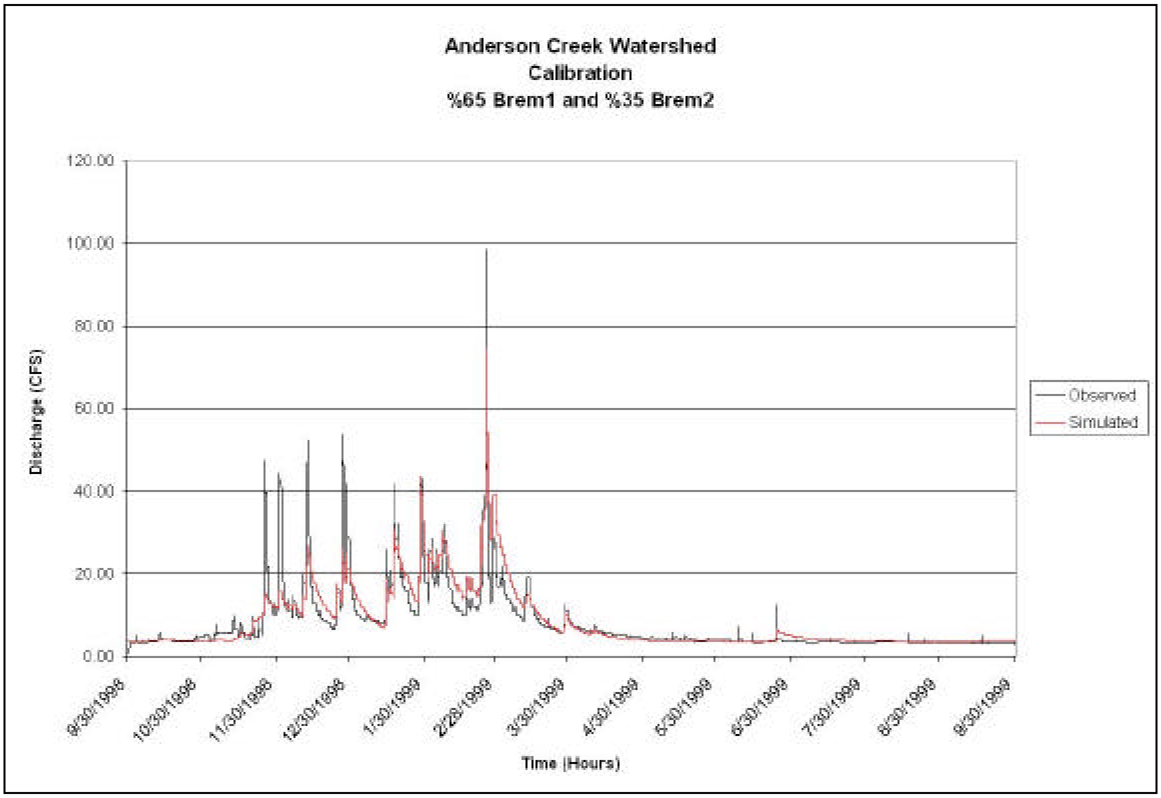

Figure 4 – Simulated and observed flows related for Anderson Creek

FUTURE MODEL DEVELOPMENT

Once the Inter-Calibration Study is completed, then the modeling team will revisit the various HSPF models in order to make sure that they conform to the agreed upon methodology and use the appropriate data sets. The modeling team will continue to calibrate and verify the models as more observed water quantity data becomes available. Once the observed water quality data becomes available, then the modeling team will develop the necessary water quality components, within HSPF, such that calibration and verification simulations can be done. As the HSPF models are calibrated and verified for both water quantity and water quality, the watershed modeling team will work with the hydrodynamic modeling team and the risk assessment team in order to determine the effects that the non-point source and point source pollution has on the water bodies.

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