A Watershed-Based Ecological Risk Assessment for Sinclair Inlet, Washington

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Abstract

The risk to ecological resources is being assessed at the watershed scale to develop and demonstrate an alternative strategy for protecting and improving the health of Sinclair and Dyes inlets. Through an agreement among the Puget Sound Naval Shipyard, the Environmental Protection Agency, and the Washington State Department of Ecology, the eco-risk process is being used to provide a unifying framework to focus data-gathering activities; develop and incorporate concerns of agencies, organizations, or individuals with a stake in the management of the watershed (stakeholders); foster partnering among stakeholders; and establish the technical and scientific basis to better protect and improve the health of the Inlets. The effects of stressors released from industrial and stormwater discharges, sewage treatment plants, and runoff from the surrounding watershed are being assessed by evaluating historical data, conducting studies to evaluate stressor sources and effects, and developing fate and transport models. The assessment will define the ecological state of the Inlets and surrounding watersheds, establish a link between stakeholder values and assessment criteria, define management endpoints, and develop a vision for the ecological health of the Inlets. Results from the assessment will help in addressing agency concerns and provide data to develop total maximum daily loading for priority constituents.

Introduction

On September 25, 2000, the U.S. Navy Puget Sound Naval Shipyard (PSNS), Region X of the U.S. Environmental Protection Agency (EPA), and the Washington State Department of Ecology (Ecology) signed a Final Project Agreement to initiate Phase I of the PSNS Project ENVironmental InVEStment. The PSNS ENVVEST project is part of EPA's eXcellence and Leadership program which was developed to give communities, state and local agencies, federal facilities, and industry the opportunity to propose cleaner, cheaper, and smarter ways of protecting the environment. The goal of the PSNS ENVVEST project is to protect and improve the health of surface waters of Sinclair and Dyes Inlets by developing a more environmentally protective strategy for managing pollutant sources in the Inlets than the regulatory framework that is currently in place (Navy, EPA, and Ecology 2000).

Protecting the health of the ecological systems within the watershed requires an understanding of what components of the ecosystem are at risk, where the sources of risk are coming from, and what is required to reduce or manage risk. There are issues that indicate the presence of risk to the ecological system of Sinclair and Dyes Inlets. Sinclair and Dyes Inlets are Impaired Waterbodies under the Clean Water Act; the 303(d) list includes listings for contaminants in the sediments and tissues from the Inlets and many stream segments within the watershed are identified on the 303(d) list for fecal coliforms and/or temperature (WDOE 1998). The 303(d) listing will require the development of a watershed clean-up plan or Total Maximum Daily Loading (TMDL) to establish limits on pollutants that can be discharged into the waterbodies

(WDOE 2001). Fecal coliform contamination is also an issue in the Inlets. Shellfish beds are closed because of concerns from contamination from Combined Sewer Overflows (CSOs). Currently, the City of Bremerton is constructing major improvements to the sewer system to separate sanitary wastes from stormwater (City of Bremerton 2001). Areas of Sinclair and Dyes Inlet have sediments contaminated with heavy metals and toxic organic compounds and clean up and dredging are currently being conducted by the Navy for areas adjacent to PSNS, Naval Station Bremerton (NSB and others 2000b), and the Naval Hospital at Jackson Park (NSB 2000a). At the Shipyard, permitted industrial discharges have stringent discharge limitations requiring costly treatment systems, yet they only account for a fraction of the loading coming into the Inlet (Johnson and others 1998). Eutrophication is also a concern. Low dissolved oxygen has been observed at head of Sinclair Inlet (Katz and others 1999), and algal blooms, red tides, and jellyfish blooms are also prevalent. In addition, important fish, wildlife, and habitat resources need to be protected and the Endangered Species Act requires protection of endangered or threatened species (e.g. salmon).

The Shipyard chose to pursue this pilot project because the Navy believes that the application of innovative ecological risk assessment tools at the watershed scale will improve TMDL development and result in a more environmentally protective strategy for managing pollutant sources in Sinclair and Dyes Inlets. The goal will be to redirect tax dollars currently spent meeting compliance requirements, to activities that will surpass current regulatory targets and greatly improve the health of the watershed.

Study Area

The boundaries of the watershed include the receiving waters of Sinclair and Dyes Inlets extending out from the Inlets into the passages that connect them with the main reaches of the Puget Sound and the surrounding landscape that drains into the Inlets (Figure 1). The watershed scale is the proper scale to address the ecological issues because the issues are a result of the cumulative impacts of multiple interacting sources requiring a "place-based" approach for assessing risk (US EPA 2000). With a watershed-based approach, effects can be evaluated on different scales, hypothesis can be developed and tested, and the proper "environmental management unit[s]" can be defined (US EPA 2000). For example, environmental

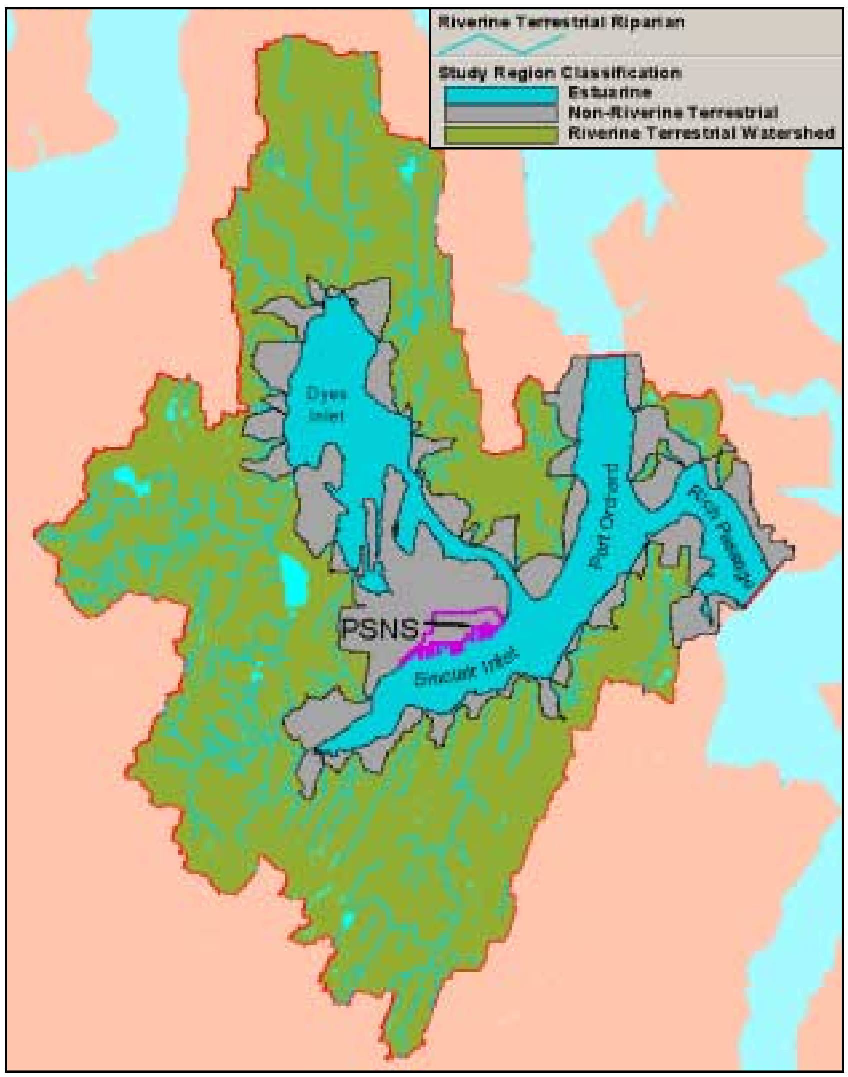

Figure 1. Study area for the PSNS ENVVEST Project.

problems at the Shipyard can only be interpreted within the context of Sinclair Inlet, while problems within the Inlet are related to problems within the receiving water system and the surrounding watershed. Central in this assessment is the idea that the quality of water draining into the Inlets is a function of the land use and discharge activities that are occurring within the watershed.

Ecorisk Process

Ecological risk is the likelihood that ecological impacts are occurring or will occur (US EPA 1992, 1998). Ecological risk assessment requires a firm understanding of the important ecological processes at work within the system (Figure 2). These processes include how water moves from rain to streams and creeks into the tidally dominated estuary (hydrology); the interaction among plants and animals, soils and groundwater, sediments and water column, and the uptake of nutrients and the assimilation of wastes (biogeochemistry); the sources of stress on the natural systems and effects to components of the ecosystem (ecotoxicology); and how components of the system interact (dynamics). From the knowledge of key ecological processes a conceptual model or “picture” of how the system works is developed. The conceptual model provides the basis for formulating the risk assessment and guides the development of specific ecological studies and evaluations needed to assess risk. Exposure and Effects Characterization will require data on stressor levels in the environment, the ecological health and condition of ecological resources, and toxicological information from the literature to help relate exposure levels to ecological effects.

The ecological risk assessment process (Figure 2) will develop the problem formulation (What are the questions being asked?), identify the assessment endpoints (What should be protected?) and exposure pathways (How can ecological resources be harmed?), characterize stress (Measure pollution levels), char acterize ecological effects (Measure toxicity and ecological effects), and characterize risk by weighing the lines of evidence and developing conclusions about risk. The risk assessment will also provide important feedback on the conceptual model and the understanding of how the system works. The conclusions about risk will be used to develop effective risk management and alterative regulatory strategies aimed at reducing and eliminating ecological risk. Follow up monitoring will verify the risk assessment and evaluate the success of alternatives for reducing risk.

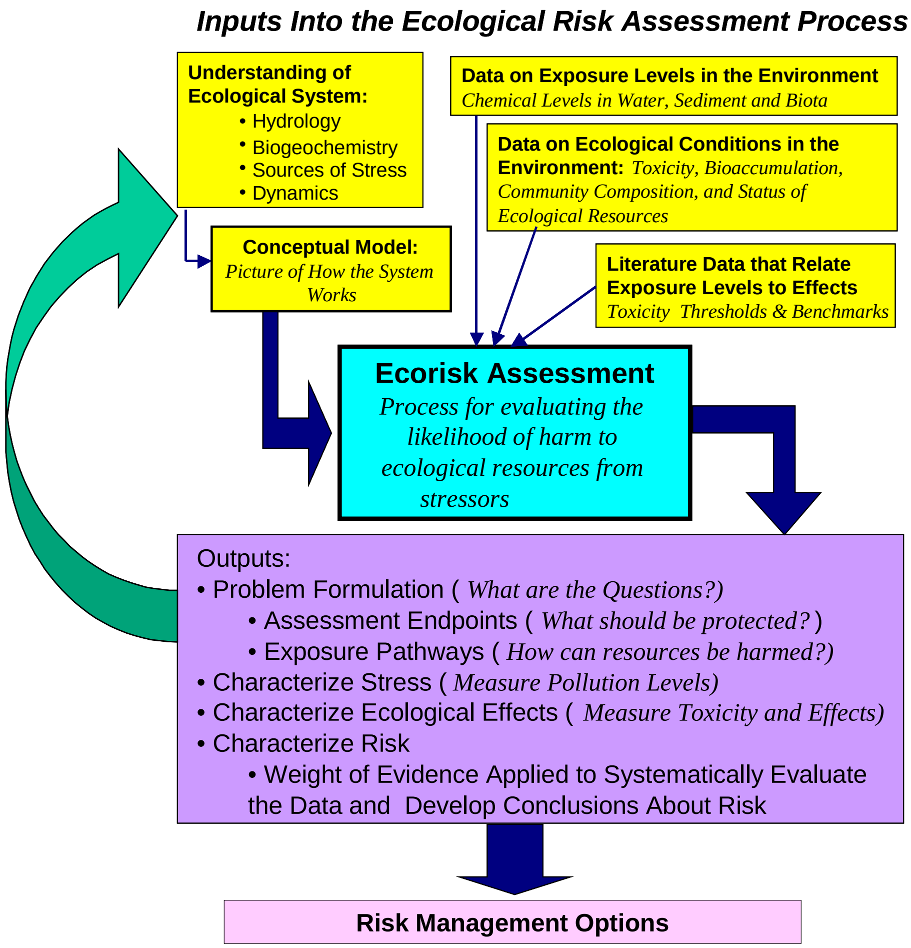

Figure 2. The Ecological Risk Assessment Process.

Conceptual Model

The conceptual model identifies the major components of the system (Figure 3). Sources of stress enter the system through industrial discharges, outflows from sewage treatment plants, storm water drains, combined sewer overflows, and streams. The water quality of the industrial and treatment plant outfalls are a function of the wastewater treatment systems in place and the permissible discharge allowed by National Pollution Discharge Elimination System permits. The water quality of the storm water and the streams is a function of the landscape from which the water drains and spills which may enter the drainage system. Once released into receiving the water system, the discharges are mixed and transported by complicated currents that are driven by the tides, winds, and weather events. Residual contamination within the system from past releases shows up as pockets of contaminated sediments and elevated concentrations of contaminants in the tissues of fish and shellfish. Currently, major efforts are underway by the Navy to clean up contaminated areas identified near PSNS in Sinclair Inlet (NSB and others 2000b) and Jackson Park (NSB and others 2000a) in Dyes Inlet and by the City of Bremerton to eliminate and control CSO releases in the Port Washington Narrows (City of Bremerton 2000).

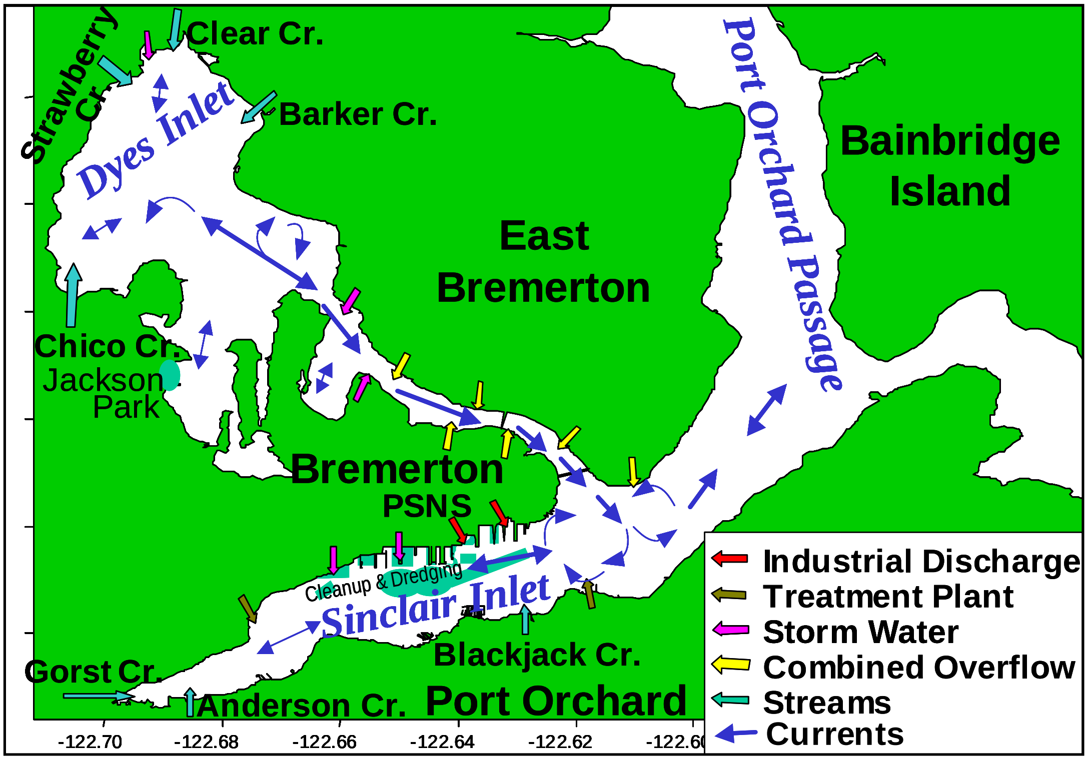

Figure 3. Conceptual model of major processes within the watershed.

Project Structure

The project management structure for the project consists of the Project Management Team, a Technical Steering Committee, and Technical Working Groups formed to address specific technical areas and issues (Figure 4). The project management team consists of one representative from each of the signatory agencies. The role of the project management team is to guide project development through both Phase I and II of the ENVVEST/XL project. The Navy is providing funding for the PSNS ENVVEST Project and the PSNS and Navy Region Northwest are the Navy Resource Sponsors for the project. The Technical Steering Committee is made of the technical leads from the PSNS technical team and the technical leads from EPA and Ecology. The Technical Steering Committee will oversee the development of a technical master plan (PSNS ENVVEST 2001) and will assure that the technical master plan will meet the goals and milestones defined by the Project Management Team. The Technical Steering Committee will periodically review and update the technical master plan, identify issues and concerns that need to be addressed by the Project Management Team, assist with reviewing and interpreting technical results, and evaluating the implications of technical accomplishments in meeting project goals, milestones, and objectives. The Technical Steering Committee will also provide technical direction and guidance to the technical team and Technical Working Groups in conducting specific technical tasks.

The Technical Working Groups are made up of representatives of the technical team and technical representatives of stakeholders and agencies who have an interest or stake in the technical issues being addressed. The Technical Working Groups will assist the technical team in conducting data gathering and analysis activities to develop the technical data and information needed for the project. The Technical Working Groups will provide a forum for evaluating, recommending, and documenting technical decisions and plans, appraising the status and direction of the work, and help develop a consensus on technical issues. The Technical Working Groups will also assist in identifying specific issues for consideration by the Project Management Team. The Technical Working Groups will provide an important opportunity for stakeholder input and involvement in developing and implementing the technical approach for the project. The Technical Working Groups will be organized according to the schedules and objectives defined in the technical master plan and are open to participation by members of the technical team, stakeholder technical representatives, regulatory representatives, and members of the science advisory panel.

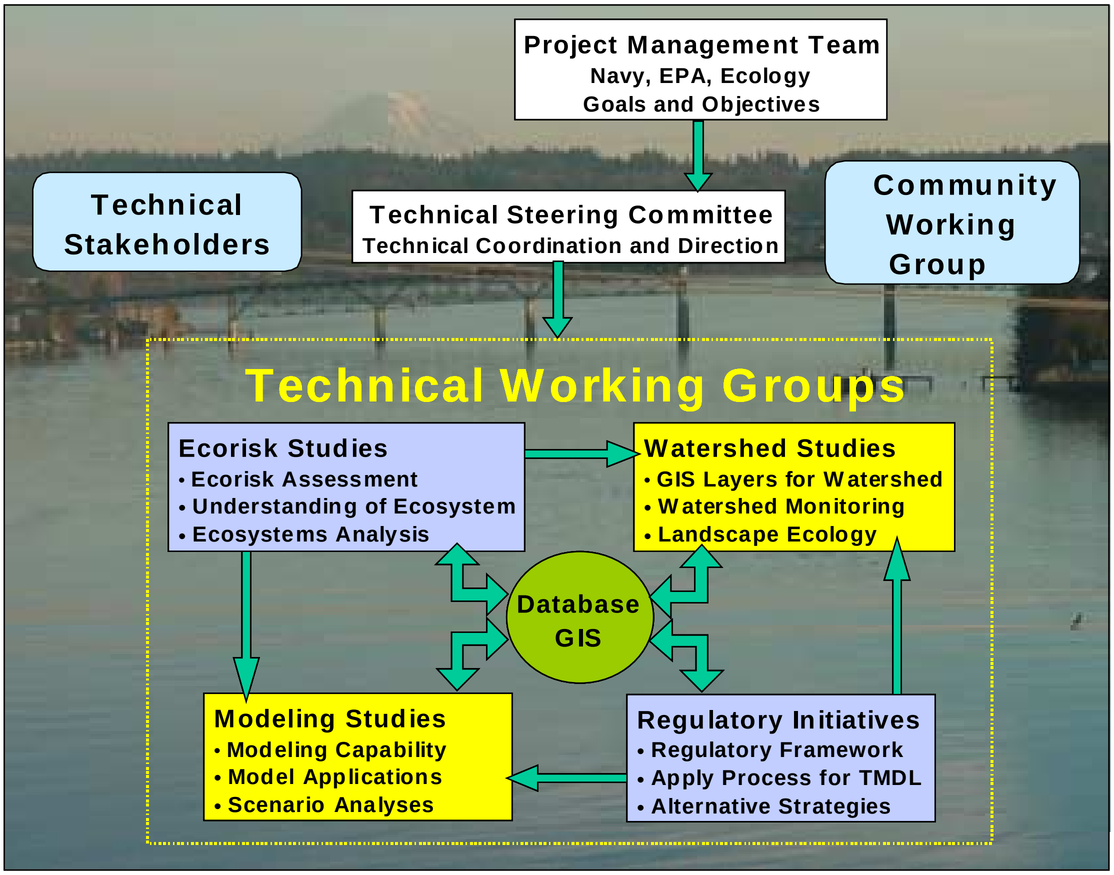

Figure 4. Project management structure for the PSNS ENVVEST Project.

The Science Advisory Panel is composed of recognized scientific experts in disciplines directly applicable to the scientific issues being addressed by the PSNS ENVVEST project. The scientific advisory panel will be available to advise the Project Management Team, Technical Steering Committee, and Technical Working Groups on scientific issues of importance to the PSNS ENVVEST project. The Scientific Advisory Panel will also assist in peer reviewing the technical reports and products produced during the project.

Results and information developed by the Technical Working Groups will also be presented and made available to the Community Working Group. A Community Working Group has been formed to provide a forum to foster openness and trust, help in conveying information about the project to the community, help in identifying community concerns, help in obtaining a diversity of viewpoints, and provide feedback on proposed decisions. The Community Working Group will meet periodically to discuss progress and status of the project, represent community interests, and weigh in on issues of concern to the community.

Technical Approach

The technical approach is to develop tools for conducting the assessment and performing specific studies and evaluations to identify relationships among sources of stress and impacts to ecological resources (US EPA 2000). Technical objectives are being developed for the following focus areas:

(1) Ecological Studies and Risk Assessment
(2) Modeling Studies
(3) Watershed Studies
(4) Regulatory Studies

In addition, core capabilities for data base management, geographic information system (GIS) analyses, and web-enabled project documentation and reporting are defined that will be required for successful implementation of the project (Figure 4).

Ecorisk Studies

The objectives for the Ecorisk Studies working group are to conduct an ecological risk assessment for the watershed, develop a better understanding of how the ecosystem works, and perform ecosystems analysis with the aim of relating management options to potential ecological responses. The questions to be addressed by the risk assessment are: Is there unacceptable risk to ecological resources in the watershed? If so, which ecological resources are most threatened? Which stressors are most likely to be causing risk (risk drivers)? Where are the potential sources of stress coming from? And what are the options for reducing risk? Risk management and policy options for reducing and avoiding risk include cleaning up sources of contamination, developing TMDLs and implementing appropriate point and nonpoint source controls, restoring and rehabilitating damaged habitat, enhancing existing habitat, and monitoring natural attenuation.

Risk assessment tasks are defined to formulate the problem, conduct a screening level risk assessment, and prepare a baseline risk assessment for the receiving waters and streams within the watershed. Ecological studies are planned to fill critical data and information gaps necessary to perform the risk assessment. The objectives of problem formulation are to develop the conceptual model that will be used to guide the risk assessment process, identify the assessment endpoints, the exposure pathways, and the stressors of concern. The problem formulation for the watershed needs to include both the receiving water system (Inlets) as well as the streams. The problem formulation will also incorporate stakeholder inputs and be understandable to nontechnical reviewers and the general public. Recently, water quality surveys (NRaD 1995b, SSC 1998b) in the Inlets were conducted to provide baseline data on circulation, hydrography, and water quality for dry and wet weather conditions (Katz and others 1999), Benthic Flux Sampling Devices (NRaD 1995a, SSC 1998a, Hampton and Chadwick 2000) were deployed in April/May 2000 to make direct measurements of the flux of contaminants from the sediment and measure sediment oxygen demand at nine sites within Sinclair and Dyes Inlets (Davidson and others 2001), and selected stream segments have been sampled for macroinvertebrates.

Modeling Studies

The modeling studies have two thrusts (1) developing a capability to model the watershed and receiving waters and (2) applying the models to answer specific Ecorisk, TMDL, and other regulatory questions. An integrated modeling system is being developed that will include the surrounding watershed and hydrodynamic and contaminant transport within the receiving waters of the Inlets. The modeling studies consist of a series of tasks to develop the integrated modeling capability and conduct specific model applications to support risk analysis, watershed studies, regulatory studies, and respond to stakeholder input. The final modeling product will provide the capability to simulate various risk management and policy alternatives. The models selected for this portion of the project are Hydrological Simulation Program Fortran (HSPF) for the watershed and Curvilinear Hydrodynamics in 3-dimensions (CH3D) and Water Analysis Simulation Program (WASP) for the receiving waters. Although HSPF is a lumped parameter model, it is the only public-domain model currently available that can simulate both hydrologic and water quality parameters at the watershed scale. The HSPF model has been widely used, it has a large user group, and it is a commonly accepted regulatory tool (US EPA 2001).

Originally developed by the Army Corps of Engineers for the Chesapeake Bay estuarine system, CH3D calculates time-varying 3-dimensional numerical flow fields for water surface, velocity, salinity, and temperature to simulate vertical and horizontal mixing (Johnson and others 1991). The CH3D model uses curvilinear boundary-fitted numerical grids in the horizontal plane. The gridding in the vertical direction is z-grid, which divides the water column into many layers of equal thickness, with number of layers varying from several layers for deeper regions to one layer for extremely shallow regions (< 3m). CH3D is capable of handling a variety of external forcing functions, including tides, winds, tributary flows, point and non-point sources, as well as baroclinic effects due to density differences between freshwater inflows and saline Inlet water (Johnson and others 1991, Wang and Richter 1999, Wang 2001). Its open code, flexibility in defining model grids, and process-based numerical scheme makes CH3D very versatile in developing applications for coastal and estuarine systems. Presently, CH3D models are being used to simulate a variety of Navy harbors including Sinclair/Dyes Inlet, Norfolk/Hampton Roads, VA, Little Creek, VA, and Pearl Harbor, HI (P.F. Wang, SSC, personal communication).

The Water Analysis Simulation Program (WASP) is supported and distributed by the U.S. EPA Center For Exposure Assessment Modeling (CEAM). WASP "is a generalized framework for modeling contaminant fate and transport in surface waters. Based on the flexible compartment modeling approach, it can be applied in one, two or three dimensions and is designed to permit easy substitution of user-written routines into program structure. Problems studied using WASP framework include biochemical oxygen demand and dissolved oxygen dynamics nutrients and eutrophication, bacterial contamination, and organic chemical and heavy metal contamination" (US EPA CEAM 2001).

There are two components to WASP: (1) Toxics, TOXI5, which combines chemical kinetic subroutines with the WASP transport structure and simple sediment balance algorithms to predict dissolved and sorbed chemical concentrations in the bed and overlying waters; and (2) Dissolved Oxygen (DO)/Eutrophication, EUTRO5, which combines eutrophication kinetic subroutines within the WASP transport structure to predict DO and phytoplankton dynamics affected by nutrients and organic material.

In June of 2000, a Modeling Sub-Working Group of Stakeholders came together address the issue of fecal coliform contamination of shellfish beds in Dyes Inlet from combined sewer overflows in the Port Washington Narrows. Participants in the working group included the Suquamish Tribe, Washington State Department of Health, City of Bremerton, Kitsap County, CTC, PSNS, and SSC. The working group determined that shellfish beds in upper Dyes Inlet remain closed mainly due to uncertainty about CSO overflows in the Port Washington Narrows. A modeling study was proposed to model a "typical" CSO overflow event on incoming tide. Key issues identified included the lack of knowledge on current and transport patterns in upper Dyes Inlet, the need for data on CSO events and discharge parameters, and data needed to support the modeling approach. The Navy and Stakeholder Team planned and cooperatively executed a drogue and current meter study for Dyes Inlet in the fall of 2000. The study provided data to address the key issues identified by the working group and are currently being used to calibrate the CH3D model for the Inlets.

For the Inlets, a WASP box model has been setup to run long-term simulations (years to decades) and the kinetic subroutines from WASP have been linked directly to CH3D so that short-term dynamic simulations (days to months) can be calculated. The grid for CH3D has been refined and a Lagrangian particle tracking model within CH3D is being calibrated with the drogue study data to simulate CSO releases. The beta version of software to animate CH3D results is undergoing final testing and updates to CH3D manual are being incorporated into the electronic users manual. For the watershed model, hydrologic properties of the study area have been defined, major subbasins within the watershed have been identified, data available on topography, soils, landuse, stream flow, and water quality have been catalogued and evaluated, the initial watershed development training class has been completed, and the hydrologic components for models of Gorst, Blackjack, Chico, Clear, Strawberry, and Barker Creeks (Figure 2) have been set up.

Watershed Studies

Watershed studies are being conducted to define the environmental setting of the landscape, identify sources and volumes of runoff, evaluate the contribution of contaminants and water quality from the landscape, and identify sources of stress and impact on the ecological system. The GIS layers to be developed consist of: natural features including soils, topography, steep slopes, vegetative cover, forest, shrub, and grass; manmade features including land use, urban, industrial, commercial, institutional, high density suburban, medium density suburban, low density suburban, rural residential, agricultural, and military; estimates of imperviousness using land use-based conversion factors; estimates for roads (types), road-density, and stormwater infrastructure; delineation of surface and riparian corridors including streams, wetlands, lakes, estuaries, and near shore areas; and the lateral extent (10/30/50/100 meter analysis bands), longitudinal continuity/fragmentation (breaks/km), vegetation quality (mature or young forest/wetlands/developed) of riparian corridors.

Watershed monitoring will consist of hydrological, meteorological, water quality, and biological effects monitoring. In consultation with the Project Copartners and Technical Stakeholders a watershed monitoring program will be developed to provide input to the Ecorisk, Modeling, and Regulatory Working Groups. Landscape ecology analyses, utilizing GIS tools, will be conducted to determine the major sources of stream flow into the Inlets and evaluate whether relative stream flows based on historical data can be used to estimate stream flows for periods where there are hiatuses in the data record. Estimates of water quality as a function of lan duse will also be developed. This will consist of a GIS analysis using default values for loadings (US EPA 1983) to assess which areas of the watershed will have the highest potential for contaminant loading. Initially, the results from the analysis will be used to prioritize streams and stormwater flows that need to be monitored. The default values will be updated with empirical relationships between land use and runoff developed from the watershed monitoring data.

Regulatory Initiatives

This work area addresses studies and analyses that will be conducted to define and satisfy existing regulatory requirements, leading to a better understanding of the regulatory process and needs (what's driving the regulations? public opinion? court decisions? legislative mandates?…) and the development of a better way to accomplish the same goals. Regulatory studies will be focused on defining the regulatory framework for the watershed and working with Copartners and project participants to prepare a Water Cleanup Plan for the Watershed (WDOE 1999). The Water Cleanup Plan will define the plans goals and affected parties, identify cooperative efforts, design the technical study, detail the modeling and watershed studies that need to be conducted, and prepare the technical study project plan for external review. This task will also develop a process for addressing Clean Water Act Section 303(d)-listed contaminants of concern for the watershed. This task will involve working with Copartners, stakeholders, and the community to develop a process for addressing 303(d)-listed contaminants of concern to remove the "impaired water body" status for Sinclair and Dyes Inlets and the contributing watershed.

Obtaining Flexibility

Based on the results of the Phase I studies of the watershed, recommendations for alternative strategies will be developed. The studies and research conducted would result in recommendations for implementation and define the evaluation criteria that will used to monitor performance and determine if there are measurable improvements in environmental quality (Figure 5). The information gained from Phase I will be used to evaluate whether an alternative scheme for regulating and monitoring surface water bodies like Sinclair Inlet as a watershed should be developed, and if so, to develop and demonstrate alternative strategies. Initiatives to reduce and prevent marine pollution, ecosystem restoration schemes, long-term ambient monitoring plans, and possible regulatory flexibility, such as pollutant trading, are processes that may be included in the recommendations.

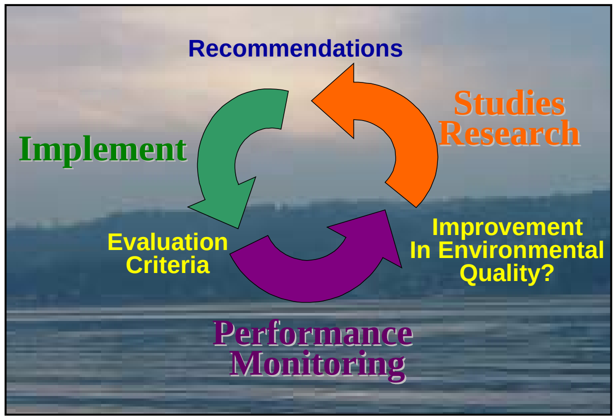

Figure 5. The scheme for obtaining flexibility (adapted from the Hamilton Harbor and Cootes Paradise Restoration Project, Ontario, Canada).

Conclusion

The risk to ecological resources is being assessed at the watershed scale to develop and demonstrate alternative strategies for protecting and improving the ecological integrity of Sinclair and Dyes Inlets. The watershed-based ecological risk assessment is evaluating environmental problems at the proper scale, providing an integrating framework for cooperative studies with stakeholders and partners, and developing linkages between problems and management options. The studies are providing data to address key issues identified by the working groups, improving the understanding of how the ecosystem functions, and increasing the ability to solve environmental problems. The Technical Working Groups are fostering partnering among stakeholders and establishing the technical and scientific basis to better protect and improve the health of the watershed.

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