Decision Support System - Phase II Report

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I. Introduction

This report summarizes Phase II activities associated with Management Information/ Decision Support System (SOW 4.0) work as defined in "Statement of Work for Technical Studies Prepared for WRIA 1 Watershed Management Project by the Utah Water Research Laboratory, Utah State University" dated July 21, 2000.

II. Software Development for Data Explorer/Modeler/Alternative Builder

This section discusses the SOW DSS Task 1 and 2 deliverables entitled "Data Explorer and Modeler" and "Alternative Builder".

A. Data Explorer/Modeler

Development of the "Explorer" portion of the decision support system (DSS) software skeleton is ahead of schedule. Software coding which was mostly scheduled for Phase III is already substantially underway. The system is being designed to enable the exploration of various scenarios associated with water quantity, water quality, instream flow and fish habitat. The initial work has focused primarily on water quality issues as described below. The other issues will be added as a part of the next phase. The "Modeler" portion of the DSS software is still in the early stages of development because many of the decisions as to which models are most appropriate for WRIA 1 issues will not be implemented until Phase III.

The Watershed Characterization Module described in the Geodatabase Management System Phase II Report provides a broad-scale summary overview of WRIA 1 watershed characteristics based on previous work undertaken by Whatcom Water Resources and the Public Utility District #1. It enables data aggregation of the 170 delineated basins and is intended as a "top" layer of summary data access. On the other hand, the Data Explorer (also referred to as the Data Visualization Module) provides the ability to visualize more detailed spatially explicit data. This is necessary for the simulation and comparison of management alternatives in the DSS.

A prototype data viewer (SWQDV), has been designed for the purpose of providing a GIS map-based capability for analysis of decision-relevant data. The initial focus of this work has been on water quality issues. The design philosophy is based on the observation that many stakeholders identify well with spatial presentation of information, that many stakeholders want to view more than the simple data summaries often provided in reports, and that many stakeholders desire to have these data 'at their fingertips' within a single repository. To this end, USU is constructing a database that will ultimately provide a repository for all decision-relevant data collected historically in the WRIA 1 WMA and, in addition, will provide a vehicle for the organization of future data collection efforts. In addition, USU is in the process of developing a GIS map-based data viewing tool, of which this manual describes a fully functional prototype, for the extraction, presentation, manipulation, and summarizing of these data. Following is a summary of the current version of the SWQDV.

A shaded relief map serves as a backdrop for all GIS-related functions as shown in Figure 1. In this example, a shaded relief map developed from U.S. Geological Survey's (USGS) 30 m digital elevation data was merged (providing an essentially seamless map), and then shaded by elevation contour. The purpose of this map is to orient the user spatially and topographically. This map provides the visual cues for locating data layers loaded later. The map is fully georeferenced and thereby places the map in the correct location so that subsequent data layers are properly positioned.

A number of GIS data layers in ArcView shapefile format have been assembled and modified, as needed, for use in the data viewer interface. As delivered, these layers include watershed delineations, urban areas, roads and highways, watercourses, including streams, lakes, and coastal areas, USGS flow gauging stations, surface water quality sampling stations, and registered dairies, among other layers of potential interest. Additional layers may be added by users for viewing purposes by editing a text file. As will be described, one of the layers currently provided will respond to user-selection - that is, clicking the mouse on a water quality sampling station will, after a moment, display a time-series and descriptive statistics for temperature at that station. Other layers can be selected, but the link to, for example, the stream flow database is pending.

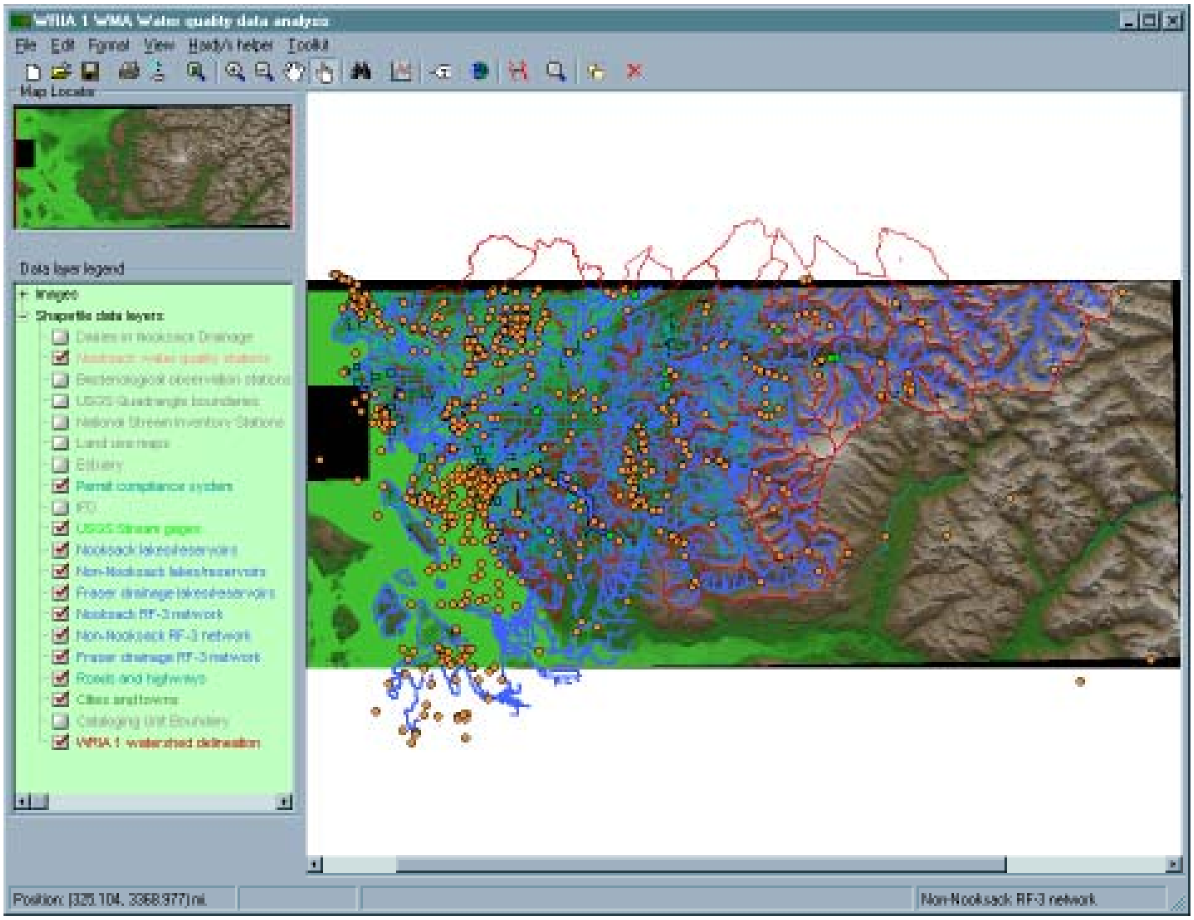


Figure 1. Example screen-shot showing the GIS-based viewer with a shaded DEM map underlaying the data.

Data are made available to the user by selection of particular objects in the data layer. At present, only water quality data are available via this interface. These data are displayed by selecting a water quality sampling station with the left mouse button - after a short delay, a plot of data for that location appears with descriptive statistics. More complete plotting and analysis of the data are available via the Water Quality Data Analyst accessible via the button bar.

Many other actions are possible from the map view including zooming a panning. The **Select** button, enables the user to select a shape on the map by clicking the left mouse button. When selected, the object generally changes color to yellow and, depending on the GIS layer selected, some action is taken, such as superimposing a time series plot of a water quality constituent or flow, or the characteristics of the object on top of the map. Figure 2 shows the result of selecting the water quality sampling station for the Nooksack Mainstem at North Cedarville. This plot is a time series of the dissolved oxygen and a table of descriptive statistics for this data.

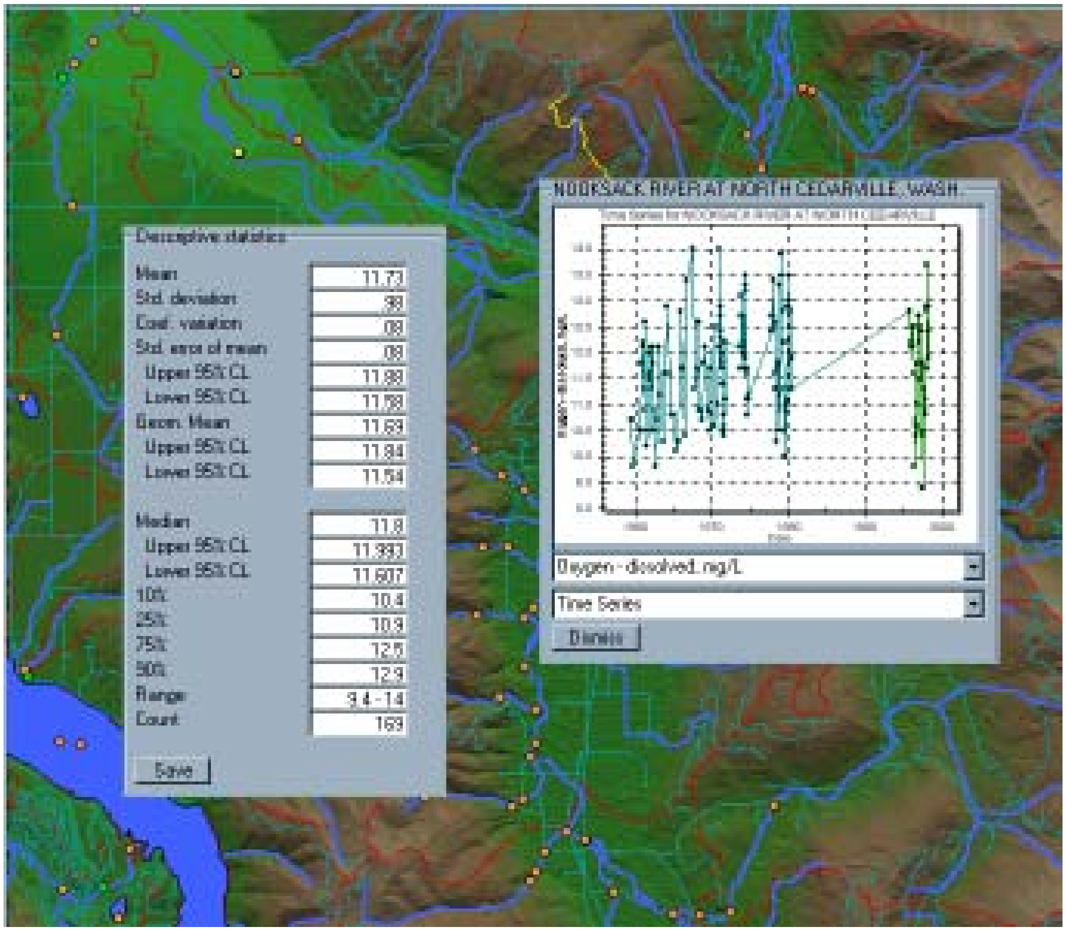


Figure 2. Map snippet result of selection of water quality sampling station for the Nooksack Mainstem at North Cedarville.

It is possible to superpose information from the shapefile database on the screen at the objects' locations. This type of information is layer dependent but may include a station name, river mile of a station, lake surface area and volume, and identification numbers. This feature is illustrated in Figure 3. Note that the screen can get very crowded when there are many objects in the selected shapefile. This limits the usefulness of this feature to times when the map is **zoomed** to a small area or for shape files with few objects. In the WRIA-1 WMA, over 900 sampling stations have been found and are spread unevenly over the area. Finding and selecting the station you want can get tedious with so many, so a way to select stations by name or identifier is helpful: Figure 4 shows the **Review WQ Station Descriptors** dialog. Selecting either a station name or identifier from one of the two list boxes finds the desired station.

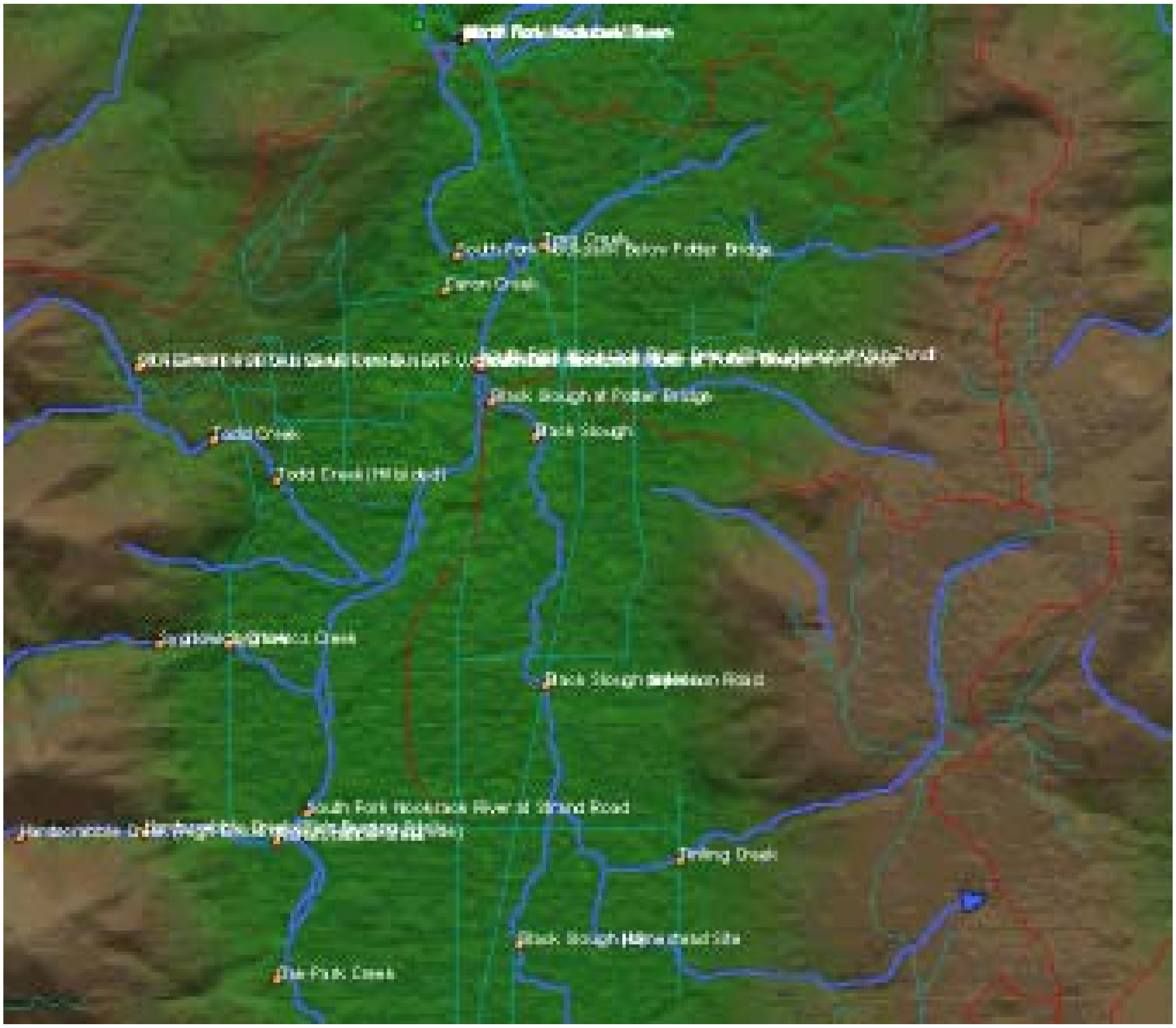


Figure 3. Example of Data Layer Labels tool for a portion of the South Fork Nooksack - Water quality sampling stations.

The project has currently identified nine specific subwatersheds for water quality analysis. The software enables one to automatically zoom to these subwatersheds via the **Zoom to Watershed** menu. This action also shows the location of the window on the Map Locator in the upper left corner. The boundaries of the preset subwatersheds may be altered and presets may be added or removed. The editing window is shown in Figure 5. The preset watersheds align approximately with those laid out in the Phase II Preliminary Draft. The boundaries are somewhat arbitrary defined reflecting a subjective view of the subwatershed. The top and left boundaries in the editor are in UTM NAD83 northing and easting (m) and the heights and widths are in m.

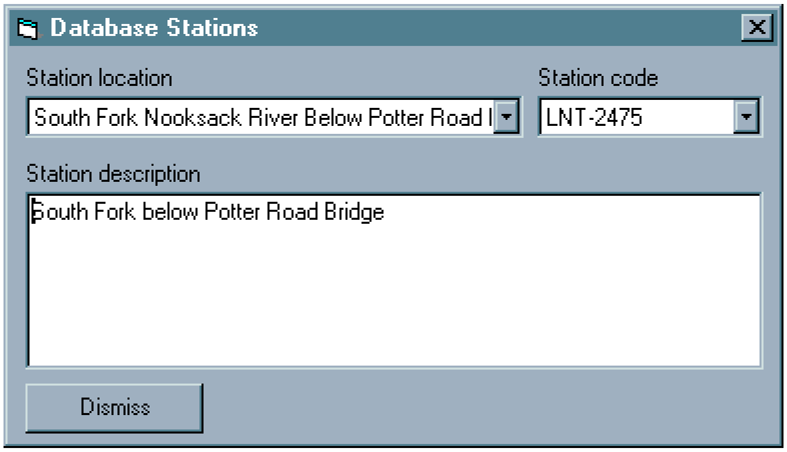


Figure 4. Review WQ Station Descriptors dialogue box.

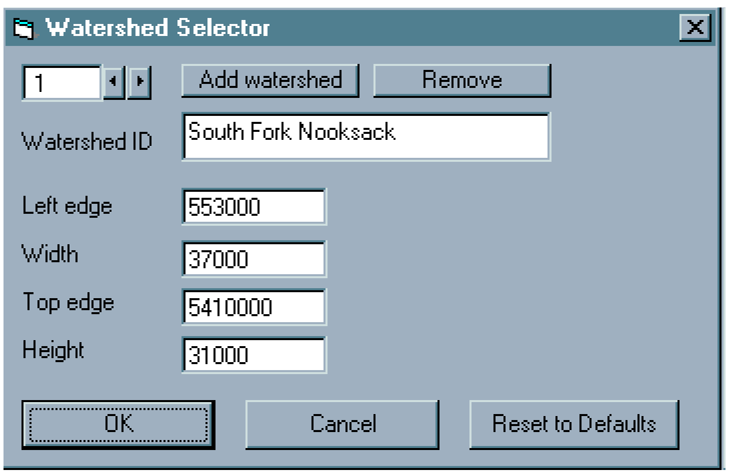


Figure 5. Watershed extent editor.

B. Data Analyst/Modeler

Selection of a specific toolbar button in the data viewer described above activates the water quality data analyst. The opening screen is shown in Figure 6. Although this system seems complex, an attempt has been made to organize it in a logical way. First, the center-right of the screen is the time-series plot of dissolved oxygen for the Nooksack Mainstem at North Cedarville. This is the plot that appears when the station is selected while the same plot is superimposed on the map. This plot covers the entire time range of data for dissolved oxygen at this location in the database. This plot may be exported, printed, enlarged to fill the screen, and customized in a variety of ways.

Additional customization is possible via the data analyst interface. For example, the time range plotted can be fixed via the **Data Selection** frame at the bottom of the screen. Modification of **Start date** and **End date** list boxes (both month and year) restricts the plot to a user-defined windows. Modification of the **Include months/seasons** selects only those months for ranges of months to display. In this fashion, data from the entire year, a particular season, a particular month, or a contiguous ranges of months may be viewed and analyzed.

List boxes in the **Data Selection** frame may also be used to change the sampling station by changing either the station ID or the station name. A water quality parameter list box allows the user to analyze any of 34 water quality parameters. Note that data for all 34 parameters may not be present in the database for each station.

To the left of the screen in Figure 6, a tab bar gives the user access to a variety of plotting and data analysis options and results.

The default tab is the plot type. This provides the user with 11 different plot types to choose from:

Time Series

The time series plot simply shows the raw data from the database plotted against time. This plot type can be used for trend analysis, looking for patterns in the data, and periods of excursion beyond water quality standards. Four options are available for the time series. These options are accessed through another tab on the tab bar, **Averaging Method**. Choosing this tab shows the menu below. The choices are the (default) **Period of record**, that plots the raw data, **Monthly overplot**, in which data for each month are grouped and the averaging is taken (note that the all data for a month are grouped regardless of year), **Seasonal overplot**, similar to monthly overplot but grouped by season, and **Annual average**, for which data from each year are averaged and plotted against the year. An additional choice is to **Show Error Bars** that overplots error bars (+- one standard deviation from the mean), with the means for the three grouped plots. Note that error bars are not available for **Period of record** since only the raw data are plotted.

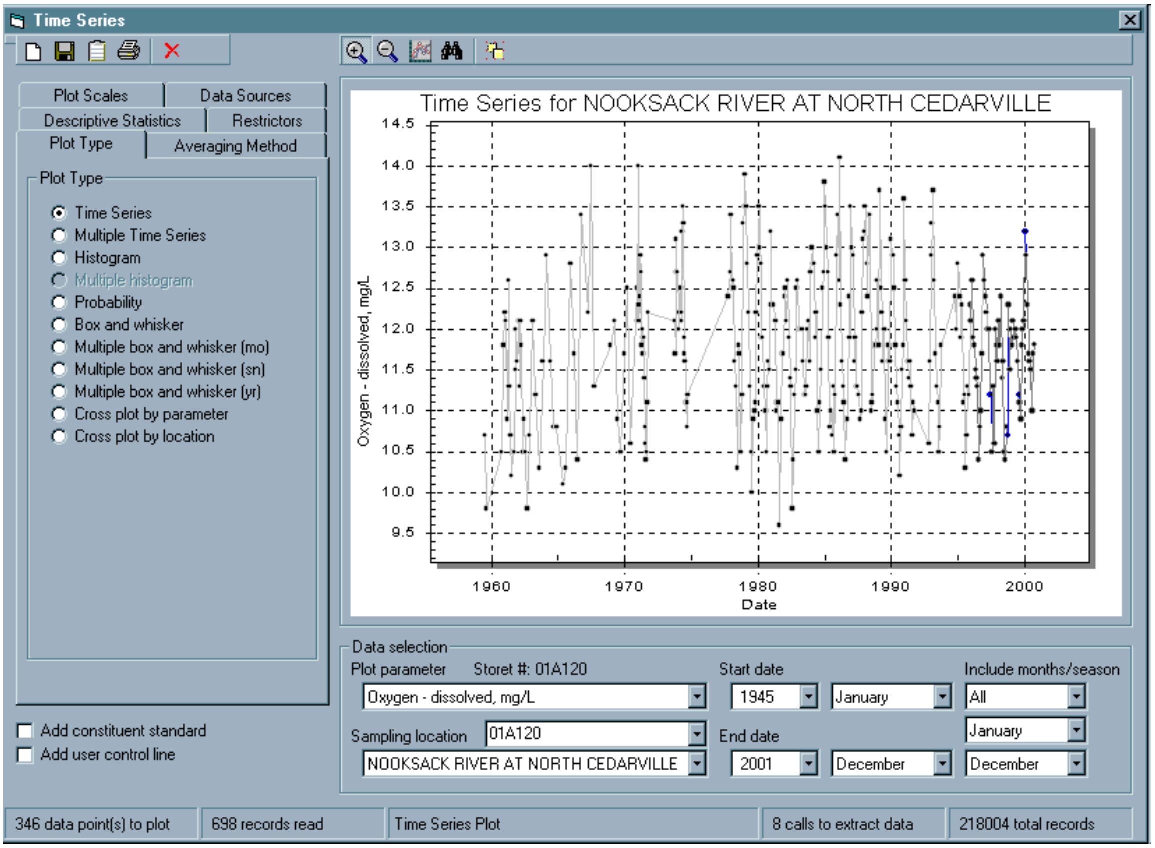
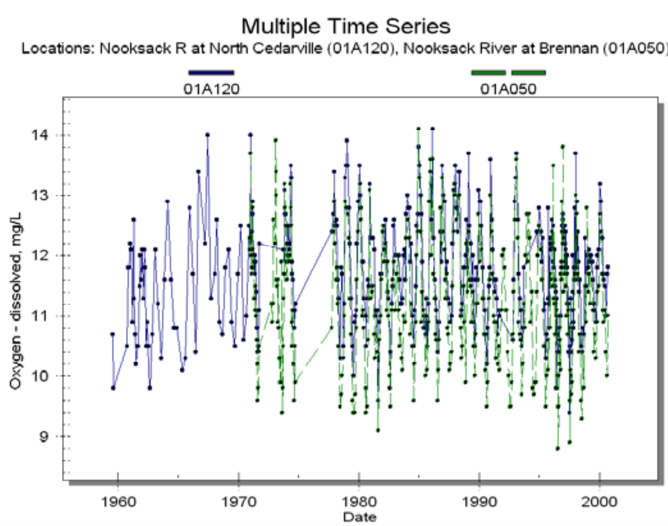


Figure 6. Opening screen of the data analyst.

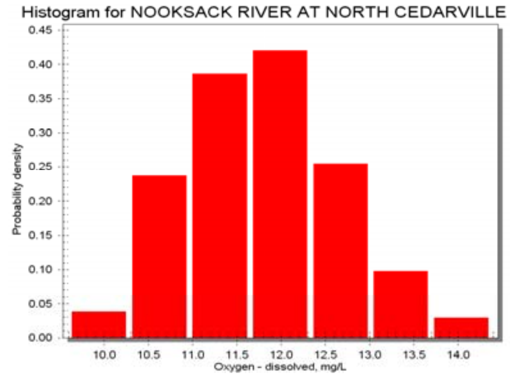
Multiple Time Series

The multiple time series plot provides the capability of putting time series for a chosen constituent from two locations on the same set of axes. This provides a means by which data from two stations can be compared. Similar averaging to the simple time series described above is available for multiple time series.



Histogram

This plot is a standard frequency histogram in which the data are binned by value into groups and the frequency of the observations that fall within a group is plotted versus the group midpoint.

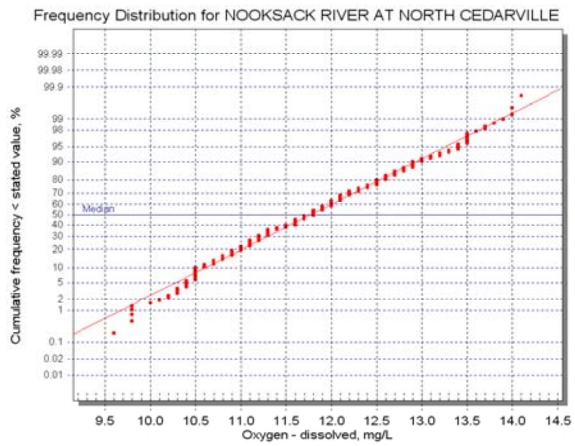


Multiple histogram (not implemented yet)

The multiple histogram will provide the user the ability to compare frequency distributions for two locations.

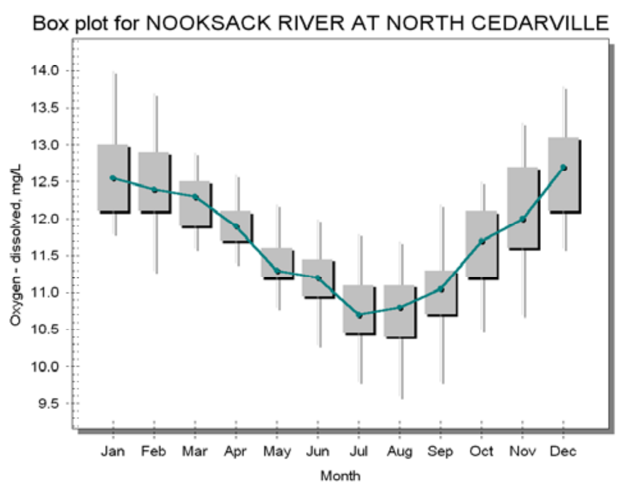
Probability plot

The probability plot can be viewed as a cumulative histogram, in which the frequency plot is the fraction (or percentage) of values falling above or below a given value, rather than the fraction falling within a bin. From plots such as these, it is a simple exercise to estimate the frequency of a water quality standard violation or to determine summary statistics.

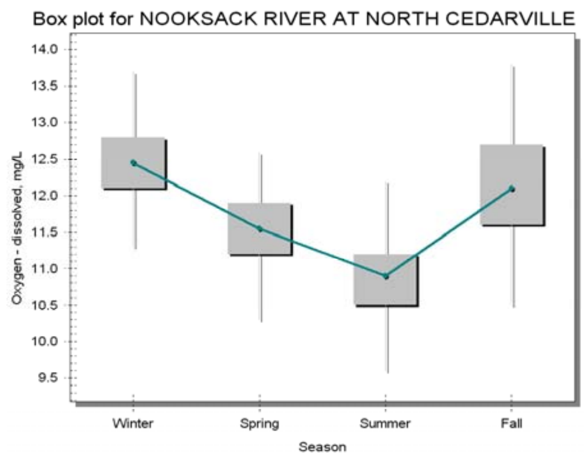


Multiple box and whisker (mo)

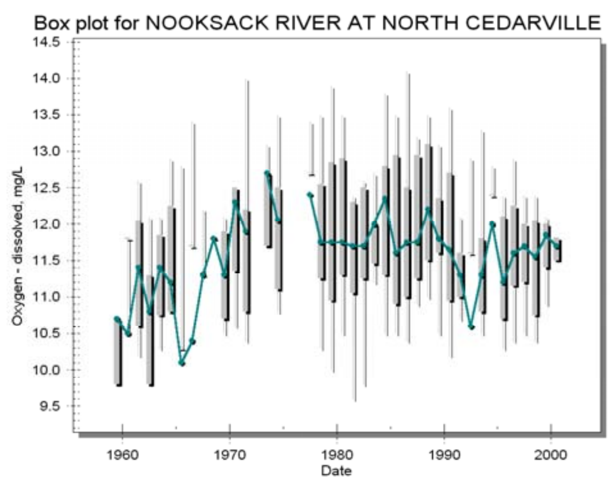
This is an extension of a standard box and whisker plot in which the data are separated by the month of observation. This type of plot is useful for analyzing the effect of the time of year on the median and variability. An example is shown to the right. Note the seasonal pattern for dissolved oxygen at North Cedarville - summer months have lower oxygen levels than winter. The variability is consistent throughout most of the year with, perhaps slightly less variability in the spring.



Multiple box and whisker (sn)

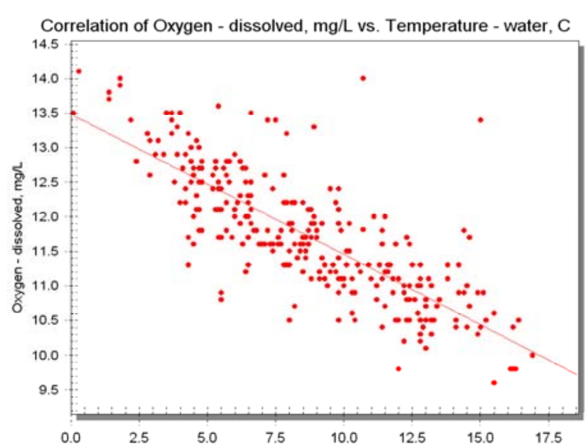


This plot type is another extension of the box and whisker plot in which the data are separated by the season of observation. This type of plot is useful for analyzing the effect of the time of year on the median and variability when too few data are available for the monthly plot or when the seasonal variation is of interest. Again, an example is shown to the right. Note that the seasonal pattern for dissolved oxygen at North Cedarville mimics that for the monthly plot above - summer months have lower oxygen levels than winter. The variability is more consistent due to the effects of lumping months together.



Multiple box and whisker (yr)

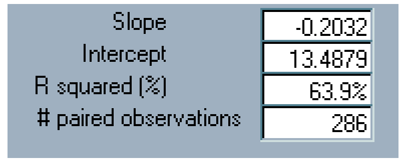
This plot type is slightly different extension of the box and whisker plot in which the data are now separated by the year of observation with all months or seasons lumped together. This type of plot is useful for analyzing trends in the median and variability - this is essentially a time series of data with, instead of individual points, annual statistics are calculated and presented concisely. Once again, an example is shown to the right. Here it is seen that the temperature dynamics at North Cedarville have been consistent for about 30 years, though there may have been a slight warming trend from 1960-1970.



Cross plot by parameter

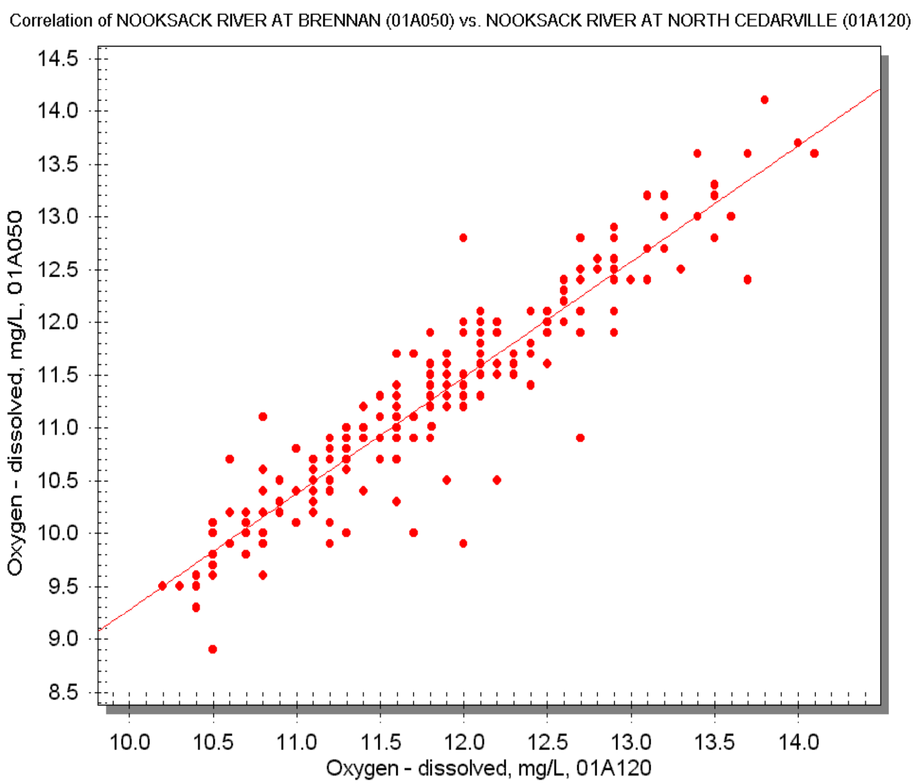
This plot type is used to look for correlations among water quality constituents at a given location on matched sampling dates. For example, to the right a plot of dissolved oxygen versus temperature at North Cedarville demonstrates a strong negative linear trend as would be expected. Any two constituents may be plotted in this manner, so long as paired data are available.

Correlation statistics are provided on the **Plot Type** tab, a snippet of which is shown to the right. These values are illustrative only - they are calculated within the plotting routines and no guarantee can be made concerning the accuracy, though the statistics appear reasonable. The slope has the correct sign and the coefficient of determination (R^2) value seems reasonable given the plot.

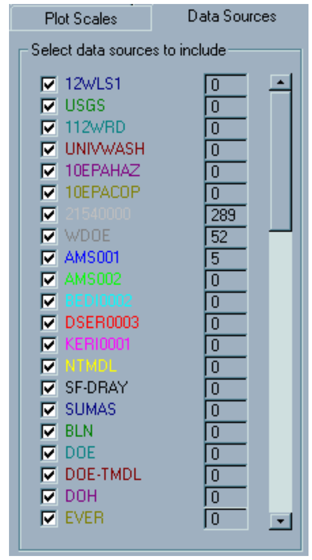


Cross plot by location

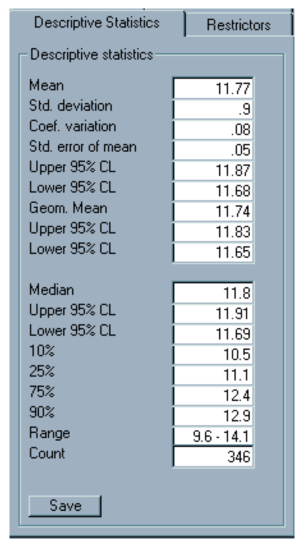
This plot type is used to look for correlations for a single water quality constituent at two locations on matched sampling dates. The following graph shows a plot of dissolved oxygen at the Nooksack River at Brennan (01A050) versus the dissolved oxygen at North Cedarville (01A120), demonstrating a strong positive linear trend. Again, correlation statistics are provided on the **Plot Type** tab. Any two locations may be plotted in this manner, so long as paired data are available.



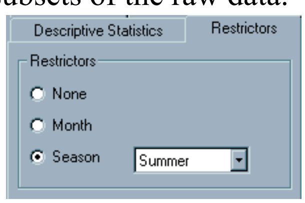
The next tab in the tab bar is labeled **Data Sources** and a portion of the list of data sources is shown on the next page. For the WRIA-1 WMA one data source is the equivalent of a water quality study or program. Thus far 43 data sources have been identified and these are listed by the source identifier used in the reports from which data were gathered or from the identifier included with STORET data. In this list, if the data source is checked, the database is searched for data from that source - if unchecked, the source's data are ignored. The number to the right of the source identifies the number of observations found in the database from that source (as long as other data selection criteria are met). Finally, the color of the text for that source is the color with which data from that source will be plotted in the time series (and possibly the probability plot), thus making it simple to identify the data source. If it is desired to remove data from a particular source, the user would simply uncheck the box next to the name. Recognizing that the source identifiers are somewhat cryptic, a more descriptive identifier will appear on-screen when the cursor hovers over the source identifier. Scroll down to view and manage more data sources.



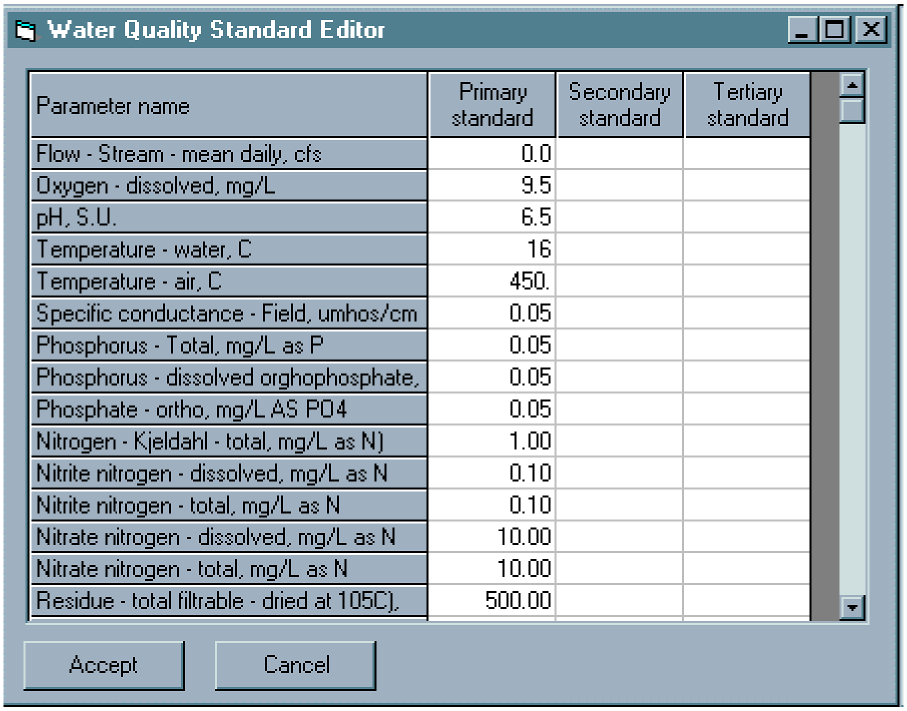
Descriptive statistics, identical to those shown on the GIS map view described above, can be generated. The statistics are shown by selecting the **Descriptive Statistics** tab on the tab bar, as shown to the right. These are simple summary statistics that represent central tendency and variability for the data shown in the plot when fully zoomed out, parametric (normal or log-normal) and non-parametric (order statistics).



The next tab, **Restrictors** shown to the right is used for calculating summary statistics on subsets of the raw data. Similar to selecting data for plotting, the selections here allow monthly or seasonal subsets for the descriptive statistics.



Two additional controls have been provided for the purpose of water quality assessment. They are located on the bottom left of the main screen. The first of the two, **Add constituent standard**, draws a line on the current plot (vertical if the plot is a probability plot, horizontal otherwise) at the location of the water quality standard set using the feature of the plot management button bar. The dialogue in Figure 7 is used within which the user may edit the values of the water quality standards. The new standard is typed in the primary standard box corresponding to the constituent. The columns for secondary and tertiary standards are reserved for future use.



Parameter name	Primary standard	Secondary standard	Tertiary standard
Flow - Stream - mean daily, cfs	0.0		
Oxygen - dissolved, mg/L	9.5		
pH, S.U.	6.5		
Temperature - water, C	16		
Temperature - air, C	450.		
Specific conductance - Field, umhos/cm	0.05		
Phosphorus - Total, mg/L as P	0.05		
Phosphorus - dissolved orghophosphate,	0.05		
Phosphate - ortho, mg/L AS PO4	0.05		
Nitrogen - Kjeldahl - total, mg/L as N)	1.00		
Nitrite nitrogen - dissolved, mg/L as N	0.10		
Nitrite nitrogen - total, mg/L as N	0.10		
Nitrate nitrogen - dissolved, mg/L as N	10.00		
Nitrate nitrogen - total, mg/L as N	10.00		
Residue - total filtrable - dried at 105C),	500.00		

Figure 7. Editor for setting water quality standards.

The second control is **Add user control line**, for the user to add lines in addition to the water quality standards. A **User Control Line Editor** is used for this purpose as shown in Figure 8. All lines added will be displayed in the location set by the **Control Line Value** with the **Control Line Label** when the **Add user control line** box is checked. An example of a user control line labeled "Class AA Standard" at a value of 9.5 mg/L is shown to the right.

C. Alternative Builder

Skeletal software demonstrating potential interface designs for an alternative builder are in the early stages of development. This software will facilitate the invention, development, and analysis of a set of possible plan elements that when grouped represent alternative courses of action. Alternatives may involve plan elements such as increasing water availability through strategies that include, but not

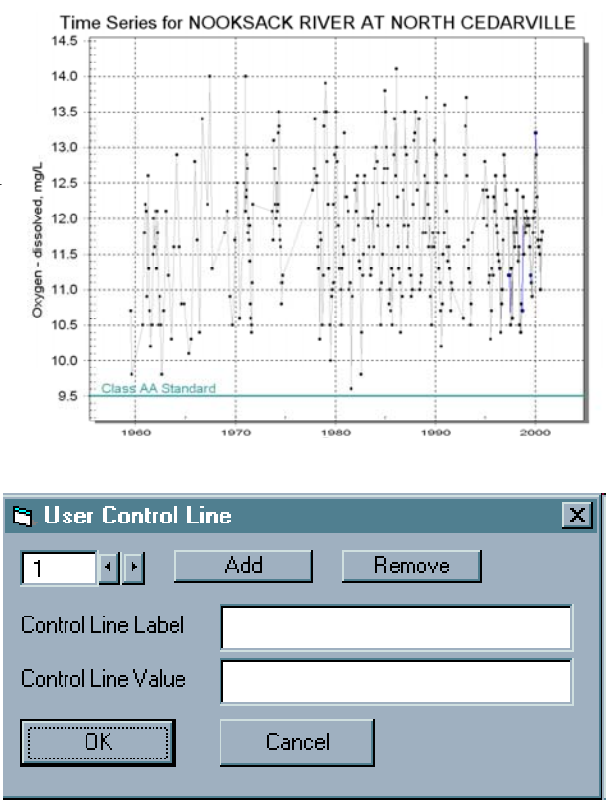


Figure 8. Editor for user control lines.

limited to: conservation, water reclamation and reuse, voluntary water transfers, additional water allocations, additional water storage, implementing TMDLs, enhancing fish habitat, etc. Figure 9 shows a possible interface where several plan elements are grouped into alternatives. Associated with these plan elements are assumed boundary condition that when combined enable simulations using chosen models. This interface is very preliminary and will evolve in Phase III into the data analysis and visualization interfaces described in the previous sections.

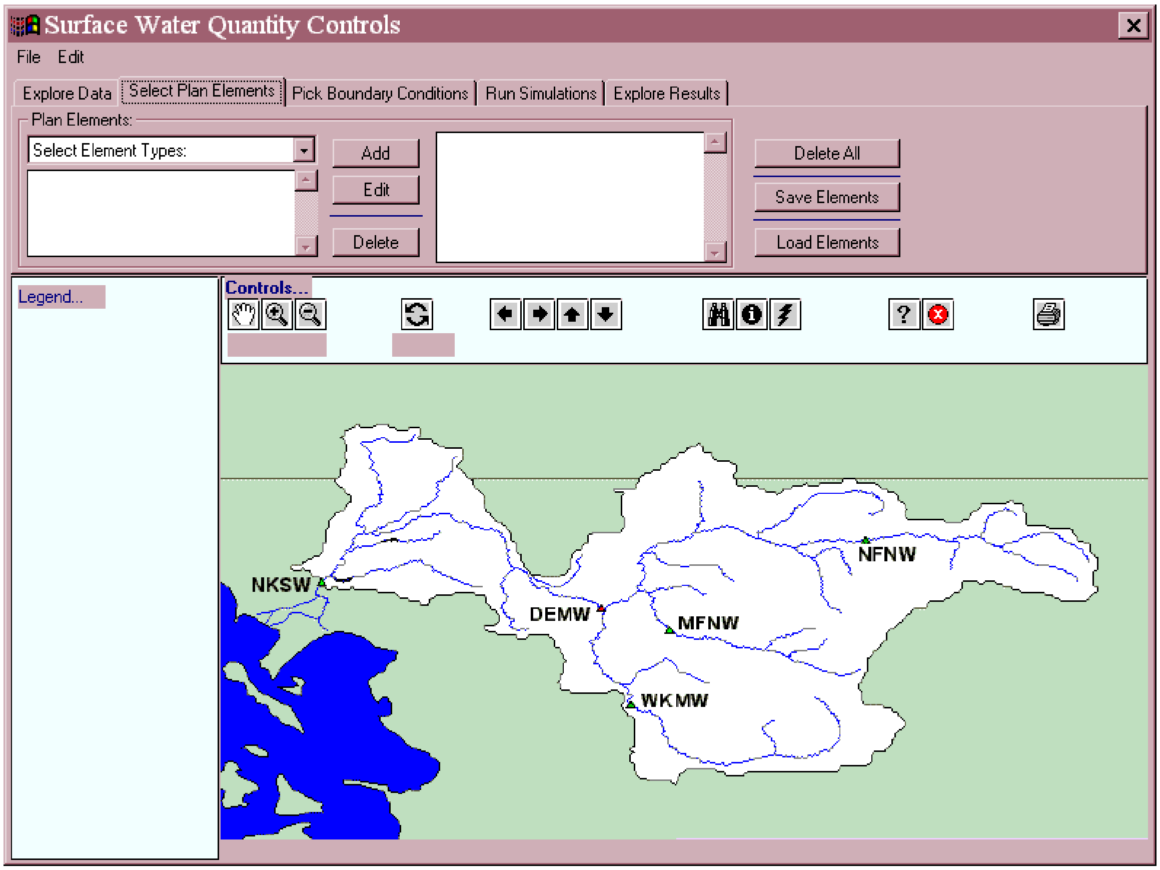


Figure 9. Screen shot of the possible orgainization of the alternative builder where plan elements are assembled for a given alternative.

II. Decision Analyst

This section discusses the SOW DSS Task 3 deliverable entitled "Decision Analyst". The goal of this software tool is to allow the insertion of specific criteria (e.g. effectiveness criteria or feasibility criteria) for selection of the "best" alternative or no alternative. This process involves judgement of "importance", "value", and/or "preference" to alternative outcomes, can help resolve "interest" conflicts, and facilitate the making of the final decision. The ability to develop this DSS is highly dependent on the degree of formality by which the issues can be formulated and judgements can be expressed. To date, the answer to this question "is this possible?" is still uncertain. In complex cases formal tools can be of limited value.

In order to help answer this and other questions, a formal process has been introduced that is facilitating the exchange of information between WRIA 1 participants and is providing insight into the relevant WRIA 1 issues. This process has involved formal expression of issues through what is termed a "DSS worksheet". A worksheet format has been developed that serves as a structured framework by which information critically needed for model development and the assessment of alternatives can be communicated by all participants in the watershed planning process. These worksheets are now being used in an iterative process with the USU team.

The process of developing the DSS follows a methodology that depends on a relatively small core group of analysts and support staff, whose prime experience is the integration of information and the coordination with stakeholders and decision-makers. The integration consists of the joint development of issue/problem formulations, management alternatives, assessment needs, applicable models, and feasible alternatives. The coordination comes from the development of a series of meetings and information exchanges that allow for involvement of a wider spectrum of stakeholders and analysts than is normally possible.

Stakeholder and technical team meetings are currently being held to formulate and refine perceived problem definitions. This is proving useful in assisting USU in both the development of the DSS and helping stakeholders to articulate their issues and interests so that they are included in the product of the WRIA 1 Watershed Management Project – the Watershed Management Plan. For Planning Unit caucuses, this will involve the next level of refinement of the issues/interests submitted in the Caucus Applications and later adopted as an appendix to the Planning Unit’s Procedural Agreement.

The Planning Unit Caucuses and Initiating Governments are being asked to complete the initial worksheets. As they are completed, the worksheets are being submitted to the Database Development Tech Team, which is then distributing them to USU and all other Technical Teams. USU and Tech Teams are assisting in further refinement in the technical aspects of the worksheets. Their feedback, including model recommendations, are being fed back to the Planning Unit and IGs.

The WRIA 1 Watershed Management Project efforts so far (e.g. Final Scope of Work, March 27, 2000 and Scope of Work for Technical Studies, July 21, 2000) have resulted in considerable progress towards defining the DSS system and output requirements. To move to the next step in DSS development there are two areas of information that are being focused on:

- Identification and refinement of the issues and scenarios to be considered within WRIA 1

- Identification of decision-relevant information that will have to be produced by the DSS models

At this state, little progress has been made in exploring specific decision criteria. Therefore little progress has been made on assessing the feasibility of formal decision analyst software. However, it is anticipated that significant progress will be made during Phase III. The DSS worksheet guidebook is provided in Appendix I a summary of which follows.

Description of the Issue

The first portion of the worksheet provides a synopsis of the given watershed issue. Watershed management involves addressing issues and solving or mitigating problems, preferably before they occur. Given the various issues and associated questions that arise, it is important that stakeholders have an opportunity to frame the issue or problem, and confirm that the technical analysis maintains the original intent. For example, a question such as the following was posed by one of the technical teams: "If the Blaine sewage treatment plant were relocated to Birch Point, what would the water quality benefits be? Would they result in significant enough improvements to Drayton Harbor water quality to justify the cost?" In this section, the question was reformatted into the "problem synopsis": "The Blaine sewage treatment plant appears to be currently impairing the shell fishery in Drayton Harbor. Alternatives are sought on how to improve the fishery while at the same time meeting Blaine sewage treatment needs." This re-formatted question specifically states what the problem is and what needs to be resolved. It also raises decision-related questions, such as:

- Is there in-fact shell-fishery impairment?
- If there is a problem, is it getting worse?
- What management alternatives are there if there is a concern?
- What are the tradeoffs between management alternatives?

While statements addressing these types of questions can be inserted elsewhere in the worksheet, the initial problem synopsis needs to be detailed enough to raise decision-related questions like these. The example given above is intentionally brief but might be expanded to several paragraphs or pages.

Each worksheet focuses on a specific issue or problem. If, while filling out the worksheet it becomes apparent that two issues or problems have accidentally been bundled together, the participants can separate them out into two separate worksheets. This facilitates clear statements later in the worksheet. If one issue relates or depends on another issue or issues, this is stated in the synopsis.

Some problem statements might focus on a very limited area within WRIA 1. Others might encompass the entire watershed. How general or specific the problem synopsis is should reflect, where possible, the level at which the problem might be addressed. For example, if there is some chance that the Blaine sewage treatment plant might affect shell fisheries beyond Drayton Harbor, the problem statement might be expanded to encompass the larger area.

The scope or the problem statement should fit the needs of decision makers. The worksheet therefore asks not only who the decision makers are but also the levels of decision making that might be associated with managing the problem. For example, if the construction of a new sewage treatment facility requires approval by an agency with jurisdiction beyond Drayton Harbor, the problem formulation might be expanded to include potential effects up and down the coast from Drayton Harbor (remember this is a hypothetical example!).

Once this section is filled out, the scope of the preceding problem statement is reviewed to ensure that there is a match with the decision makers listed.

Management Alternatives

The second part of the DSS worksheet addresses management alternatives. In this section, the participant explores potential management alternatives associated with the issue. Alternatives consist of one or more actions and/or policies. Alternatives are placed in the context of the natural and man-made conditions that may affect them. Multiple management alternatives are built from combinations of actions, policies and assumed conditions. Each of the potential building blocks for alternatives are detailed in this section. It is particularly important that the participants provide insights into the *key* actions or policies that might be considered. It may not be possible to fully describe management alternatives until after a few iterations of the worksheet.

The first subsection describes *potential initial conditions* defined as current environmental, economic, or sociologic conditions over which humans have some influence. This set of conditions forms the starting point from which management alternatives are investigated. Initial conditions might include actual or assumed pollution levels, fish populations, or levels of water availability. These conditions might be real or synthesized as a part of the evaluation of alternatives both present and future.

The second subsection addresses background conditions, such as physical characteristics of the planning area, considered relevant to start with. These can be defined as natural conditions over which humans have little or no control. Examples might include a 100 year flood, seven day minimum average stream flows, or potential drought conditions. The conditions assumed for the formulation of a management alternative might be based on historical records, or be a synthesized worst-case scenario.

The third subsection addresses specific actions and/or policies available for managing a problem. Examples of actions might include the construction of a waste water treatment plant, building a fish hatchery, or building a water diversion. Polices are the rules by which actions are initiated and facilities are managed. They state at what time or under what conditions actions are taken. Examples might include restriction of water diversions during periods of minimum flow, or fishing restrictions during certain times of year. Each action and/or policy will likely have one or more beneficiaries associated with it. Environmental, economic, and sociologic beneficiaries are listed and described in this section. Examples of beneficiaries might include culinary water users within a certain district, blueberry farmers, water use fee collectors, tribal fishermen, forests, or certain fish species.

The next DSS worksheet subsection addresses management alternatives or scenarios that consist of combinations of specific actions, policies, and assumed conditions. The combinations are listed and described in this subsection. Several combinations of actions, policies and assumed conditions can be explored in developing the watershed management plan. Both the feasibility and constraints associated with each alternative considering ecological, economic and sociologic points of view are examined. For example, one alternative might consist of building a fish hatchery of a certain size, accompanied by a fishing policy, as well as a minimum instream flow requirement controlled by water diversion policy. This alternative might be further refined into several more detailed alternatives where various sizes of fish hatcheries for various species are considered. The potential effects of drought on fish hatchery operation could be included. An example constraint might include upper limits on the amounts of water diversion allowed in order to meet consumptive needs. Feasibility might be dependent on the cost a proposed facility relative to the financial means of the agency that pays the bills.

The third major part of the DSS worksheet focuses on assessment needs. The first subsection addresses performance measures. The participant is encouraged to list the measurable data that could be used to evaluate the performance of actions, policies and alternatives. These hit at the heart of an eventual decision analyst tool. These data are performance measures (or attributes) that the DSS might be designed to estimate so that a comparison of alternatives can be made. They may also become the focus of future monitoring programs. Example measures include concentrations of critical pollutants, fish population counts, or the cost of facility construction.

It is important to answer why the measure (or attribute) is thought to be directly or indirectly associated with the problem. The degree of reliability of the attribute in making this association is also stated if possible.

In the next subsection the participant is encouraged to list and describe the location or locations that would (1) likely be impacted by the actions, policies and alternatives; (2) likely influence the problem (e.g. areas upstream); and (3) be candidates for the prediction and monitoring of performance measures. For example, the impacts and influences associated with some problems might be confined to stream reaches and 100 meter wide buffers on either side. The assessment might therefore be confined to this area. On the other hand, performance measures and monitoring sites might be far downstream or in a harbor. The spatial extent of an assessment is defined by all of these considerations.

In the next subsection, the timeline(s) associated with alternative actions, policies, and alternatives should be described. Also, the period over which the performance measures should be estimated by DSS models should be suggested. This will also facilitate the estimation of future monitoring needs.

The next subsection emphasizes comparison criteria. At some point in the process, the criteria used to subjectively judge the merits of one assessment result over another needs to be judged by the stakeholders. These criteria will serve as the basis for the evaluation of alternatives.

The last major part of the DSS worksheets helps identify which predictive models might best be employed in the analysis process. A listing of model options -- leading to ultimate model selection -- is derived from information from the worksheets provided to USU. The USU team, in conjunction with Technical Teams, is reviewing and refining the worksheets and are providing feedback to stakeholders. From this process, the technical scope of the modeling effort is being revealed. Following its completion at the beginning of Phase III, USU will then be in a position to provide a selection of model options that will include data needs, costs, and limitations. The ultimate aim of the foregoing process is the development of modeling tools that assist in solving important WRIA 1 watershed management problems. The particular techniques chosen to represent or model the dynamics of a system need not all be numerical simulation models. The characteristics of the problem in part suggest the technique chosen. The three key characteristics include 1) the number of model variables, management alternatives, and spatial elements; 2) the level and breadth of understanding of underlying physical, ecological, and economic processes; and 3) the number and quality of data. Regardless of what combination of characteristics a specific problem has, there is a modeling technique available. Essential in the model choice is the assessment of model credibility.

III. Outline of DSS Documentation

This section addresses the SOW DSS Task 4 deliverable entitled "Documentation and Training". At this stage of the study, it is premature to provide a DSS documentation outline that will likely stand at the time a draft technical manual is provided during Phase III. However, a User's Manual for the GIS Water Quality Data Viewer is in progress. To-date, this manual has the following outline:

Chapter 1 - Getting Started
- Introduction
- Installation
    - Minimum System Requirements
    - Recommended System Requirements
    - Backups
    - Installation
- Quickstart

- Starting the Program
- Navigating the GIS Map

Chapter 2 - Description of Water Quality Data Viewer

- Parts of the User Interface
  - Shaded Relief Base Map
  - GIS Data Layers
- Navigating the Main GIS Screen
  - Button Bar
  - Select
  - Toggle Station ID Tracking
  - Water Quality Data Analyst
  - Data Layer Labels
  - Reload Shape Files
  - Review WQ Station Descriptors
  - Toggle Selection From Group to Station
- Menus

Chapter 3 - Water Quality Data Analyst

- Analysis of Water Quality Data
- Plotting Data
- Plot Type
- Data Sources
- Descriptive Statistics
- Restrictors
- Plot Scales
- System Management
- Plot Management

Chapters to be added will include those for the modeling of sets of plan elements that constitute various alternatives. Because this software design is in its infancy, formal outlining of the documentation has not yet been completed.

APPENDIX A

DSS Worksheet Guidelines

WRIA 1 Decision Support System Worksheet

A Guide for WRIA 1 Stakeholders & Technical Teams

October 24, 2000

Introduction

This guide has been prepared to assist the WRIA 1 Project teams in participating in the development of the Decision Support System (DSS), *the "primary technical tool with which the WRIA 1 planners will examine the database to construct the management plan" (USU SOW 2.6, line 2269).* The goal of the DSS is to provide the best available information about relevant issues and trade-offs to all interested parties so that good management decisions can be made and implemented. A primary task in USU's work plan for the development of the DSS necessitates a more in-depth understanding of the watershed issues that will be addressed in the Watershed Management Plan. The ultimate success of this tool will be in-part determined by the accuracy and comprehensiveness of the issues and interests submitted via these worksheets. It is essential that the participants bring to the table perspectives of both the stakeholders and technical teams.

The worksheet format described herein serves as a structured framework by which information critically needed for model development can be communicated by all participants in the watershed planning process. These worksheets will be used in an iterative process with USU team.

The IGs and Planning Unit caucuses, in conjunction and coordination with the Technical Teams and USU, are being asked to expeditiously complete and submit worksheets.

This guide is organized into two parts. The first part introduces the DSS development process and where the worksheet fits into it. The second part fully describes how to complete the worksheet.

The DSS Development Process

The process of developing the DSS follows a methodology that depends on a relatively small core group of analysts and support staff, whose prime experience is the integration of information and the coordination with stakeholders and decision-makers. The integration consists of the joint development of issue/problem formulations, management alternatives, assessment needs, and, finally, recommendation of applicable models. The coordination comes from the development of a series of meetings and information exchanges that allow for involvement of a wider spectrum of stakeholders and analysts than is normally possible.

Stakeholder and technical team meetings are held to formulate and refine perceived problem definitions. This is useful in assisting USU in both the development of the DSS and helping stakeholders to articulate their issues and interests so that they are included in the product of the WRIA 1 Watershed Management Project – the Watershed Management Plan. For Planning Unit caucuses, this will involve the next level of refinement of the issues/interests submitted in the Caucus Applications in May 1999, and later adopted as an appendix to the Planning Unit's Procedural Agreement.

The Planning Unit Caucuses and Initiating Governments are being asked to complete the initial worksheets during November and December 2000. As they are completed, the worksheets will be submitted to the Database Development Tech Team, which will distribute them to USU and all other Technical Teams. USU and Tech Teams will assist in further refinement in the technical aspects of the worksheets. Their feedback, including model recommendations, will then be given back to the Planning Unit and IGs.

Completing the Worksheets

The WRIA 1 Watershed Management Project efforts so far (e.g. Final Scope of Work, March 27, 2000 and Scope of Work for Technical Studies, July 21, 2000) have resulted in considerable progress towards defining the DSS system and output requirements. To move to the next step in DSS development there are two areas of information needed.

- Identification and refinement of the issues and scenarios to be considered within WRIA 1

- Identification of decision-relevant information that will have to be produced by the DSS models

To facilitate this process, a worksheet has been developed that will help to uniformly characterize this information for the model's development. The bare-bones structure of the worksheet is given in Appendix A.

Following is a discussion designed to help participants in completing the worksheets in a consistent way. Keep in mind that the worksheets will go through an iterative process of refinement with Caucuses, USU, and Technical Teams. Therefore, nothing is ever final and the participant should not be discouraged from making educated guesses where necessary.

Some sections of the worksheet need to be completed immediately. If information is not currently available, the remaining sections can be completed at a later time. USU has therefore categorized the completion of the worksheets into "Immediate" and "Later". Items requiring immediate attention are marked with a "!" icon.

Many of the examples given in the guide are necessarily brief. Statements given on the actual sheets should be concise -- but not necessarily brief. If an issue is complex, several paragraphs, if not pages, of explanation might be appropriate. Also, participants should remember to keep the discussion focused on the subject of the subsection.

Worksheet Guide

PART I - DESCRIPTION OF PROBLEM OR ISSUE

Synopsis:

Watershed management involves addressing issues and solving or mitigating problems, preferably before they occur. It is therefore essential that a synopsis of existing or Given the various issues and associated questions that arise, it is important that stakeholders have an opportunity to frame the issue or problem, and confirm that the technical analysis maintains the original intent. For example, a question such as the following was posed by one of the technical teams:

> "If the Blaine sewage treatment plant were relocated to Birch Point, what would the water quality benefits be? Would they result in significant enough improvements to Drayton Harbor water quality to justify the cost?"

In this section, the question should be reformatted into a "problem synopsis", such as:

> "The Blaine sewage treatment plant appears to be currently impairing the shell fishery in Drayton Harbor. Alternatives are sought on how to improve the fishery while at the same time meeting Blaine sewage treatment needs."

This re-formatted question specifically states *what the problem is and what needs to be resolved.* It also raises decision-related questions, such as:

- *Is there in-fact shell-fishery impairment?*
- *If there is a problem, is it getting worse?*
- *What management alternatives are there if there is a concern?*
- *What are the trade offs between management alternatives?*

While statements addressing these types of questions will be inserted elsewhere in the worksheet, the initial problem synopsis needs to be detailed enough to raise decision-related questions like these. The example given above is intentionally brief but might be expanded to several paragraphs or pages.

Each worksheet should focus on a specific issue or problem. If, while filling out the worksheet it becomes apparent that two issues or problems have accidentally been bundled together, the participants should not hesitate to separate them out into two separate worksheets. This will facilitate clear statements later in the worksheet. If one issue relates or depends on another issue or issues this should be stated in the synopsis.

Some problem statements might focus on a very limited area within WRIA 1. Others might encompass the entire watershed. How general or specific the problem synopsis is should reflect, where possible, the level at which the problem might be addressed. For example, if there is some chance that the Blaine sewage treatment plant might affect shell fisheries beyond Drayton Harbor, the problem statement might be expanded to encompass the larger area.

Decision maker(s):

The scope or the problem statement should fit the needs of decision makers. It is therefore important to list and describe not only who the decision makers are but also the levels of decision making that might be associated with managing the problem. For example, if the construction of a new sewage treatment facility requires approval by an agency with jurisdiction beyond Drayton Harbor, the problem formulation might be expanded to include potential effects up and down the coast from Drayton Harbor (remember this is a hypothetical example!).

Once this section is filled out, the scope of the preceding problem statement should be reviewed to ensure that there is a match with the decision makers listed.

Part II - MANAGEMENT ALTERNATIVES

In this section, the participant explores potential management alternatives associated with the issue. Alternatives consist of one or more actions and/or policies. Alternatives must also be placed in the context of the natural and man-made conditions that may affect them. Multiple management alternatives are built from combinations of actions, policies and assumed conditions. Each of the potential building blocks for alternatives are detailed in this section. It is particularly important that the participants provide insights into the *key* actions or policies that might be considered. It may not be possible to fully describe management alternatives until after a few iterations of the worksheet.

Potential initial conditions:

This section describes *potential initial conditions* defined as current environmental, economic, or sociologic conditions over which humans have some influence. This set of conditions form the starting point from which management alternatives are investigated. Initial conditions might include actual or assumed pollution levels, fish populations, or levels of water availability. These conditions might be real or synthesized as a part of the evaluation of alternatives both present and future.

Background conditions:

Background conditions are the background information, such as physical characteristics of the planning area, considered relevant to start with. These can be defined as natural conditions over which humans have little or no control. Examples might include a 100 year flood, seven day minimum average stream flows, or potential drought conditions. The conditions assumed for the formulation of a management alternative might be based on historical records, or be a synthesized worst-case scenario.

Specific actions, policies, and beneficiaries:

Specific actions and/or policies available for managing a problem are listed and described here. Examples of actions might include the construction of a waste water treatment plant, building a fish hatchery, or building a water diversion. Polices are the rules by which actions are initiated and facilities are managed. They state at what time or under what conditions actions are taken. Examples might include restriction of water diversions during periods of minimum flow, or fishing restrictions during certain times of year.

Each action and/or policy will likely have one or more beneficiaries associated with it. Environmental, economic, and sociologic beneficiaries should be listed and described in this section. Examples of beneficiaries might include culinary water users within a certain district, blueberry farmers, water use fee collectors, tribal fishermen, forests, or certain fish species.

Management alternatives or scenarios (including feasibility):

Management alternatives or scenarios consist of combinations of specific actions, policies, and assumed conditions. The combinations are listed and described in this section. Several combinations of actions, policies and assumed conditions should be explored in developing the watershed management plan. It is also important to fully examine both the feasibility and constraints associated with each alternative considering ecological, economic and sociologic points of view. For example, one alternative might consist of building a fish hatchery of a certain size, accompanied by a fishing policy, as well as a minimum instream flow requirement controlled by water diversion policy. This alternative might be further refined into several more detailed alternatives where various sizes of fish hatcheries for various species are considered. The potential effects of drought on fish hatchery operation could be included. An example constraint might include upper limits on the amounts of water diversion allowed in order to meet consumptive needs. Feasibility might be dependent on the cost a proposed facility relative to the financial means of the agency that pays the bills.

PART III - ASSESSMENT NEEDS

Performance measures (why):

The participant is encouraged to list the measurable data that could be used to evaluate the performance of actions, policies and alternatives. These data are *performance measures* (or attributes) that the DSS might be designed to estimate so that a comparison of alternatives can be made. They may also become the focus of future monitoring programs. Example measures include concentrations of critical pollutants, fish population counts, or the cost of facility construction.

It is important to answer why the measure (or attribute) is thought to be directly or indirectly associated with the problem. The degree of reliability of the attribute in making this association should also be stated if possible.

Focus area:

The participant is encouraged to list and describe the location or locations that would (1) likely be impacted by the actions, policies and alternatives; (2) likely influence the problem (e.g. areas upstream); and (3) be candidates for the prediction and monitoring of performance measures. For example, the impacts and influences associated with some problems might be confined to stream reaches and 100 meter wide buffers on either side. The assessment might therefore be confined to this area. On the other hand, performance measures and monitoring sites might be far downstream or in a harbor. The spatial extent of an assessment is defined by all of these considerations.

Timeline:

The timeline(s) associated with alternative actions, policies, and alternatives should be described in this section. Also, the period over which the performance measures should be estimated by DSS models should be suggested. This will also facilitate the estimation of future monitoring needs.

Comparison criteria (why?)

At some point in the process, the criteria used to subjectively judge the merits of one assessment result over another needs to be judged by the stakeholders. These criteria will serve as the basis for the evaluation of alternatives.

PART IV - MODEL CHOICE - USU Will Provide Recommendations

A listing of model options -- leading to ultimate model selection -- will be derived from information from the worksheets provided to USU. The USU team, in conjunction with Technical Teams, will review and refine the worksheets and provide their feedback to stakeholders. From this process, the technical scope of the modeling effort will be revealed. USU will then be in a position to provide a selection of model options that will include data needs, costs, and limitations.

The ultimate aim of the foregoing process is the development of modeling tools that assist in solving important WRIA 1 watershed management problems. The particular techniques chosen to represent or model the dynamics of a system need not all be numerical simulation models. The characteristics of the problem in part suggest the technique chosen. The three key characteristics include 1) the number of model variables, management alternatives, and spatial elements; 2) the level and breadth of understanding of underlying physical, ecological, and economic processes; and 3) the number and quality of data. Regardless of what combination of characteristics a specific problem has, there is a modeling technique available. Essential in the model choice is the assessment of model credibility.

APPENDIX A
DSS WORKSHEET STRUCTURE

PART I - DESCRIPTION OF PROBLEM OR ISSUE

Synopsis*:

Decision maker(s)*:

Part II - MANAGEMENT ALTERNATIVES

Potential initial conditions*:

Background conditions*:

Specific actions, policies, and beneficiaries*:

Management alternatives or scenarios (including feasibility):

PART III - ASSESSMENT NEEDS

Performance measures (why?)*:

Focus area*:

Timeline*:

Comparison criteria (why?)

PART IV - MODEL CHOICE

USU will complete this part of the worksheet

*Note: These items should be filled out immediately. Items not marked can be filled out later in the iterative worksheet-development process.

WRIA 1 Decision Support System Worksheet

Addendum 1

January 3, 2001

Level of Detail Required

As stated in the original guidelines, "This guide has been prepared to assist the WRIA 1 Project teams in participating in the development of the Decision Support System (DSS), *the "primary technical tool with which the WRIA 1 planners will examine the database to construct the management plan" (USU SOW 2.6, line 2269).* The goal of the DSS is to provide the best available information about relevant issues and trade-offs to all interested parties so that good management decisions can be made and implemented. A primary task in USU's work plan for the development of the DSS necessitates a more in-depth understanding of the watershed issues that will be addressed in the Watershed Management Plan. The ultimate success of this tool will be in-part determined by the accuracy and comprehensiveness of the issues and interests submitted via these worksheets. It is essential that the participants bring to the table perspectives of both the stakeholders and technical teams."

The question can then be asked: "What level of detail is required when accurately and comprehensively presenting a watershed issue?" The answer to this question, of course, varies depending on the specific issue. A general rule of thumb would be to start with a general formulation of the issue, then get more specific as required in multiple worksheets. For example, if an issue such as water supply shortages relates to the entire WRIA1, then the first worksheet could identify the problems, management alternatives, and assessment needs in a general way. However, the issue may be treated somewhat differently within individual subwatersheds. If the person filling out the worksheets has subwatershed-specific insight to an issue, it is then helpful to fill out individual worksheets at the subwatershed level, as time and resources permit. At the finest detail, worksheets could then be filled out for individual creeks or water user groups (as an example). Therefore, how specific the information is within worksheets is largely a reflection of the level of knowledge and resources of the person(s) filling them out.

It is important to remember that any level of detail found in the worksheet will facilitate the watershed management process to some degree. However, the level of utility is directly proportional to the level of knowledge and insight reflected therein.

Example Worksheet

USU/WRIA 1 Joint DSS Development Worksheet

Blaine wastewater treatment plant upgrade

PROBLEM

Problem Synopsis: The Blaine wastewater treatment plant appears to be contributing to the impairment of the shell fishery in Drayton Harbor. Alternatives are sought on how to improve the fishery while at the same time meeting Blaine wastewater treatment needs.

Problem Priority: Immediate

Decision makers: Blaine City Council; Blaine City taxpayers; land owners at Birch Point

Model analyst/user: Water quality technical team trainee; USU modeler; WA DOE collaborator(s)

Beneficiaries of analysis: Primary Blaine city taxpayers, Blaine wastewater treatment plant users, Drayton Harbor fisheries

Secondary Beneficiaries of analysis: Harbor recreators, Blaine wastewater treatment plant operations personnel

MANAGEMENT ALTERNATIVES

QUESTION 4: If the Blaine wastewater treatment plant were relocated to Birch Point, what would the water quality benefits be? Would they result in significant enough improvements to Drayton Harbor water quality to justify the cost?

Potential initial conditions:

The assessment would begin with the recent intensive water quality surveys in Drayton Harbor by the WA DOH and NWIC. These conditions would be assessed under current population pressures with regard to land use, water quantity, water quality, and socio-economic prevailing in the late 20th century. For this analysis, it is critical to estimate FC loadings into Drayton Harbor from all sources and to estimate flushing rates and mixing characteristics in the harbor under critical flow conditions. From these loading estimates and information concerned with the potential loading reductions possible from the variety of wastewater treatment alternatives and non-point load controls, the analysis will provide the likelihood of water quality improvement in the harbor under several management options.

Background conditions: Three levels of background conditions are envisioned: 1) pre-Columbian conditions with 'natural' contributions of FC to the harbor via wildlife and low levels of human activity; 2) 'no Blaine' conditions in which the FC loadings are via agricultural, and, possibly, recreational, practices in the watershed; and 3) 'Blaine only' conditions, in which the Blaine WWTP is the only known contributor of FC to the harbor, aside from wildlife. These background conditions would be assessed under current population pressures and, then, projected to future times given 'reasonable' expectations of population growth.

Water quality impairment by coliform bacteria is dynamic and often event-driven. To focus solely on the wastewater treatment plant when other potential sources exist may not provide ‘the’ solution to the FC problem. As we’ve seen in the water quality data assessment, fecal coliform concentrations in streams are often seasonal and flow-related. The presence of 36 dairies in the watershed suggests non-point sources of FC may be present in addition to the Blaine WWTP, underscored by the fact that Dakota Cr. is 303(d) listed for FC.

Management assessment should focus on conditions under which FC contamination is most severe and work backward to those less severe. For example, low flow conditions, typically of importance in water quality assessment in rivers dominated by point loads, may not be the most severe for estuarine FC contamination. Although low flow conditions provide less flushing, they are also correlated to lower FC concentrations. Conversely, higher flow, while providing more flushing, often provide significantly high FC loading. Growth and feeding stages of the shell fish may also dictate modeling conditions.

For this analysis, it is critical to estimate FC loadings into Drayton Harbor from all sources and to estimate flushing rates and mixing characteristics in the harbor under critical flow conditions. From these loading estimates and information concerned with the potential loading reductions possible from the variety of wastewater treatment alternatives and non-point load controls, the analysis will provide the likelihood of water quality improvement in the harbor under several management options.

Plan elements: Non-point source controls for California Cr. and, especially, Dakota Cr., in conjunction with

i) closing existing Blaine treatment plant and building a new treatment plant at Birch Point;

ii) upgrading existing treatment plant at Blaine;

iii) building a second treatment plant at Birch Point

In addition, the analyst may want to consider the above three options with no non-point source controls

Plan alternatives (including feasibility and constraints):

1. i) and iii) - feasibility depends on ability to acquire land at Birch Point and on the current conditions at the existing plant. If the plant at Blaine is aging and would undergo major renovations within or soon after the planning period, Option iii) may be a poor choice over a longer planning horizon

2. ii) - feasibility depends on ability to reduce fecal coliform concentration significantly at the existing plant. If it is found in the assessment that significant reductions in non-point FC sources are not feasible, the sound course of action may be i) even if the technology exists to meet water quality requirements at the existing plant due to the possibility of plant upsets. Again, this choice would be driven, in part, by the condition of the existing facilities.

3. ii) and iii) best for handling expanding population but may be constrained by combined effects of the two treatment plants as well as combined cost. Operation of two plants in a community the size of Blaine may not be cost effective due to the need to duplicate a variety of the equipment needs for maintenance, and the potential, as the community grows, for two sets of operating staff. The choice, of course, is economic, but the ‘pain-in-

the-neck' factor combined with the real desire to reduce FC pollution of Drayton Harbor, argues against maintaining parallel operations.

ASSESSMENT NEEDS

Performance measures (why?): Fecal coliform concentrations at various points within Drayton Harbor will be used to assessment performance because this pollutant is an indicator of organisms that most severely affects the quality of harvested shell fish and is the subject of the WA DOE 303(d) listing for Drayton Harbor and Dakota Cr. Sampling could be concentrated near the primary shell fish beds, at the harbor entrance, and in the stream current carrying water from the WWTP and Dakota and California creeks toward those beds. This would allow for assessment of the attenuation of FC in the estuary and aid in assessment of transport of pollutants. Additional performance measures would include the costs and benefits of each project alternative. These include the costs of

a) closing exiting treatment plant;

b) upgrading existing treatment plant;

c) building new treatment plant; and

d) reducing non-point FC sources.

They also include the benefits of

a) improved reliability of shell fish harvest

b) potential for growth in tax base due to improved wastewater management

c) improved potential for recreation in Drayton Harbor

Time and space: The planning horizons for improvement in wastewater treatment can be quite long, particularly when new facilities are contemplated. Land acquisition, securing of funding, the political process, technical design, construction, and start-up of facilities take time, often 10-20 years, Additionally, due to the low rate of many of the processes that drive FC control in natural waters, a number of years may be required before improvements in the target quality measures are realized. Long-term planning must begin immediately for facilities improvement, baseline water quality conditions must established, and resources must be secured for long term monitoring to determine if program goals are being met. Additionally, a system by which institutional knowledge may be maintained through personnel changes must be established. Software training, database management, and answers to the questions 'why did we do this way?' must not be ignored.

Daily time-step simulations for the region between and including the wastewater treatment plant and Drayton Harbor may be carried out for critical flow and season to assess the dynamics of FC loading and its impact. However, longer term (monthly or seasonal) steady-state modeling would also be carried out to establish the probability structure for the system. Monitoring would be set up to verify the longer term modeling results.

Comparison criteria (why?) Primary criterion would be cost versus the likelihood that fecal coliform concentrations would exceed an acceptable threshold for the shell fishery and the sensitivity of those concentrations to uncertainty and variability in model inputs. The calculated likelihoods are not fixed numbers – they are ranges of values with uncertainty attached to their estimates. It is equally important to determine this uncertainty along with the mean likelihoods. Additionally, narrative factors difficult to quantify can be included.

A secondary criterion would be constraints on the growth potential of the City of Blaine, or, conversely, the expansion of its growth potential. Although calculating the impact of these constraints is not part of the DSS as currently envisioned, a large part of the information needs of the city and county planners for determining these impacts can be met.

MODEL CHOICE

Relevant data available: Fecal coliform concentrations, flows, and temperatures for the effluent from the existing treatment plant, California and, especially, Dakota, creeks, and fecal coliform concentrations, temperatures and current velocities at various points within Drayton Harbor.

Existing Models: Treatment plant models may be used to determine fecal coliforms in treated effluent, though mechanistic approaches are generally not very sensitive. It is likely that a statistical approach will be used to relate treated effluent FC concentrations to process factors, such as flow, loading, temperature, time of day, and disinfection efficiency. Stream models such as QUAL2E (relatively low data requirements), CE QUAL-RIV 1, HSPF (relatively large data requirements), and statistical Bayesian network approaches may be used for steady state and dynamic simulations for the creeks and to determine the distributions of loading into Drayton Harbor. Estuary models for Drayton Harbor may be considered.

Modeling Methods: To be determined after specifics of problem are better defined.