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Keywords:

Graphical User Interface, User's Guide,
Installation, Input, Output, Help, Roadmap for
Consensus, Roadmap for TMDL Calculation

EPRI
FINAL REPORT
October 2000
Revised July 2001

User's Guide to WARMF

Documentation of Graphical User Interface

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EP-P2346/C1054

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REPORT SUMMARY

EPRI's Watershed Analysis Risk Management Framework (WARMF) provides a decision support system for analyzing watershed management strategies as well as calculating, allocating, and implementing total maximum daily loads (TMDLs). This report documents the Windows-based graphical user interface and presents a user's guide for WARMF. It explains how to create a scenario, run the simulation model, compare simulation results to observed data, view the spatial distribution of point and nonpoint loads, and depict the resulting water quality in color-coded maps. It also describes procedures for updating data and recalibrating the model. Such system information will be valuable to industry, agriculture, environmental groups, and government agencies involved in management and protection of watershed resources and compliance with water quality criteria.

Background

The U.S. EPA is promoting adoption of a new water resource management approach that uses watershed analysis and stakeholder consensus building in lieu of command and control. This approach considers all point and nonpoint sources within a watershed and the determination of TMDLs of various pollutants for water quality limited sections. EPRI sponsored WARMF development and testing to support the watershed approach and TMDL calculation and allocation. In cooperation with EPRI members, WARMF is being tested on the Catawba River (Duke Energy), Cheat River (AEP and Allegheny Power), Chartiers Creek (PA power companies), and Oostanaula Creek (TVA) basins. In addition, WARMF is being tested in cooperation with government agencies and other stakeholders in the Truckee River (CA/NV) and Blue River (CO) watersheds.

Objectives

- To develop a scientifically sound, user-friendly decision support system for watershed management and TMDL applications.
- To provide a detailed description of various menus for issuing commands to WARMF, discuss TMDL calculation procedures, and present example exercises.

Approach

WARMF developers adopted the popular graphical user interface (GUI) formatting and Geographic Information System (GIS) mapping to facilitate easy use by stakeholders who have little or no familiarity with modeling watersheds or water quality. The GUI – which simplifies data entry and represents results in understandable format – implements a unique stakeholder consensus building road map and TMDL calculator.

Results

The Windows based graphical user interface is very user-friendly. It uses a standard “point and click” system to issue commands. The dialog boxes display scientific data in well-explained format. A scenario manager allows the users to create a management scenario, specify management options, and save its results in the project file. The view menu allows the users to see the locations of pictures, meteorology stations, gauging stations, point source dischargers, water quality stations, etc on the basin map. Pointing and clicking at each specific location can lead to a display of pictures or numerical data in spreadsheet. New data can be added to extend the database.

The roadmap for TMDL provides a step-by-step procedure to specify the water quality limited section, its designate use, water quality criterion for the designated use, TMDL pollutant, and control strategy for point and nonpoint source loads. WARMF will automatically step down the pollution loading until the water quality criterion is met.

The roadmap for consensus process provides a step-by-step procedure to collect stakeholders’ name, addresses and concerns; to assign stakeholders to various committees; to develop a mission statement; to develop a work plan; to formulate alternatives; to run simulation; to see spatial distribution of waste loads; to see water quality improvement; to engage stakeholders to rank alternatives; to evaluate cost benefit of alternatives; to evaluate pollution trading schemes; to display nominal scores of alternatives; to find agreement and disagreements for consensus; and to try again with revised alternatives.

This report documents the Windows based graphical user interface of WARMF. Exercise examples are used to demonstrate the procedures.

EPRI Perspective

The WARMF decision support system helps watershed and government agencies prepare for two significant changes in water resource management policy –the use of watershed TMDLs and stakeholder consensus decision making. For the next 20 years, TMDLs will be a major factor in determining water resource management policy. TMDLs will also affect air quality management since atmospheric deposition is a significant nonpoint source in many watersheds. Stakeholder consensus decision making creates opportunities for effluent trading and ecological resource management, both of which are active areas of EPRI research and may result in new revenue development. In the future, these two activities will likely be an integral part of many business plans. EPRI Reports TR-110709, Watershed Analysis Risk Management Framework and 1000252, Peer Review of the Watershed Analysis Risk Management Framework provide further information about WARMF.

Keywords

Watershed Analysis Risk Management Framework

Total maximum daily loads

Water management

Air quality

Stakeholders

Decision analysis

ABSTRACT

WARMF is a decision support system designed for watershed approach and TMDL calculation. The scientific basis of WARMF has been described in the documentation report. This report documents the Windows Graphical User Interface (GUI), which is more a product of art than science. The GUI performs several functions: 1) interacting with the user for data entry, command menu, context sensitive help and road maps for TMDL calculation and consensus building process, 2) functioning internally to furnish data to simulation models, to automatically interface catchment, stream and reservoir models, and to process simulation results for map displays. The GUI displays a map of the river basin, which is divided into the objects of catchments, river segments, and stratified lakes. By pointing and clicking at an object, one can review and change its parameter values. The GUI can show the map locations of meteorology, stream gage, and water quality stations, or point source discharge. By pointing and clicking at a station, one can review its data. The GUI provides a menu to assign intended uses to various points in the watershed, set water quality criteria for the intended uses, and then calculate multiple possible TMDL solutions to protect the intended uses. The GUI also provides a menu to engage stakeholders to select a consensus TMDL plan that takes into account cost-effectiveness and cost-sharing between point and nonpoint dischargers. This report is a user's guide for WARMF. It explains how to create a scenario, run the simulation model, compare simulation results to observed data, view the spatial distribution of point and nonpoint source loads, and view the resulting water quality in color-coded maps. It also describes the procedure for updating data and recalibrating the model. The report includes a series of exercises for the general use of WARMF.

ACKNOWLEDGEMENTS

EPRI provided major funding for the development of WARMF. Dr. Robert A. Goldstein of EPRI was the project manager who provided the overall guidance.

SUMMARY

Watershed Analysis Risk Management Framework (WARMF) is a decision support system (DSS) designed to support the watershed approach and TMDL calculation. This report documents the Windows based graphical user interface, which makes WARMF user friendly. The report provides a detail description of various menus to issue commands to WARMF. It also describes the procedure to calculate TMDL. Example exercises are provided.

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1

INTRODUCTION

WARMF

WARMF stands for Watershed Analysis Risk Management Framework, which is a decision support system (DSS) designed for a watershed approach and TMDL calculation. WARMF contains engineering, data, knowledge, consensus, and TMDL modules. The consensus and TMDL modules provide road maps to engage stakeholders in building consensus on a watershed management or TMDL plan. The engineering and data modules furnish scientific information to each step of the road map in a format understandable to stakeholders.

Graphical User Interface

The Windows graphical user interface (GUI) of WARMF serves several functions. The first function is to provide interface among modules so that they can work together as a unit. The **data** module supplies data to **engineering** module for model simulations. In the **engineering** module, the output from catchment model is fed to the stream model and the output from stream model is fed to the lake model. The stakeholders can specify the intended uses of water bodies and water quality criteria for the intended uses in **consensus** module. The **TMDL** module uses the information to adjust point and nonpoint source loadings until the water quality criteria are met. The GUI automatically handles the exchanges of information between modules and models.

The second function is the interface to interact with the user. The GUI provides menus and dialog boxes for data entry, viewing data and coefficients, updating data, and displaying GIS maps or time series plots. The GUI also provides a scenario manager to set up management scenarios for alternative comparisons.

This report documents the graphical user interface of WARMF. It is intended to be a supplement to the documentation report of WARMF (1), which described the theory, formulations, and general application procedures.

User's Guide

This report can serve as a user's guide for WARMF. The report will provide information about how to use the menus and dialog boxes in each module. Some structured exercises are included to demonstrate how to formulate and evaluate alternatives and how to update data when new data are collected during or after the TMDL process.

Context Sensitive Help System

WARMF contains a context help system. In any dialog, the user can click on the help button to access valuable information related to the subject. For the engineering module, the focus of the help system is on parameter descriptions and reasonable value ranges. For the consensus and TMDL modules, the focus is on explaining the procedures for consensus building and TMDL development.

Conventions

Windows

The GUI of WARMF follows the standard Windows convention. It uses a menu bar to display main menu items and a pull down menu for sub-items. A sub-item is also referred to as a function. WARMF GUI uses the point and click system to select a menu item. When the mouse is pointed at a tool bar item, a screen tip is displayed in a pop-up box and its function is described in the status bar. For some frequently used menu items, short cut icons are provided in the tool bar.

For on-screen data entry, numerical values can be entered into dialog boxes. To change an existing value, one can highlight the old and type in the new. The dialog box for date contains month, day, and year fields separated by slashes. To change a date, one can highlight month, date, or year and type over it. One can also click at a specific field and change its value with the up or down arrows.

Some data entry has pre-defined selections. In that case, WARMF provides an empty box with a pull down arrow to the right. Clicking on the pull down arrow will lead to a pull down list of selections. Clicking on an item on the list will make the selection. The selected item will appear in the box. In some cases, the user can add a new item to the pre-defined selections by typing it into the blank line at the bottom of the list.

All new data entered during a session will be used in model simulation. However, it is not saved until the user invokes **Save** or **Save As** commands under the **File** or **Scenario** menus.

Keyboard entry notation

WARMF provides short cut for keyboard entry. Following are abbreviations used for keystrokes:

Alt = Alternate

Ctrl = Control

BkSp = Backspace (←)

Del = Delete

Ins = Insert

Esc = Escape

arrow keys = ←, ↑, →, ↓

When the key strokes are separated by commas (e.g. Alt, F, O), the strokes are pressed in sequence with each key released after being typed. When the key strokes are linked by a plus sign (e.g. Ctrl+O), all strokes are pressed down together.

Mouse notation

References to clicking or double-clicking with the mouse imply the left mouse button unless otherwise specified.

Contact Information

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2

INSTALLATION

Computer Requirements

WARMF requires an IBM compatible PC, with a Pentium or better processor and 32 MB RAM, running on a Windows 95/NT or higher platform. A faster processor and more RAM will provide better performance.

The WARMF program and model coefficients files occupy 20 MB. Model results typically require 1 MB to 100 MB depending on size of watershed and length of simulation.

WARMF CD

A WARMF CD contains the simulation models, the database for a specific river basin, and all necessary software for graphs, spreadsheets, and GIS maps. WARMF is a self-contained system. It does not require other licensed software (e.g. ArcView).

The database includes topography of the river basin, its soil and land use, meteorology, and point source loading. It also includes model coefficients that have been calibrated to the river basin. The level of calibration is always a function of time, budget, and available data for the model set up. In addition, the database contains observed stream flow and water quality data for comparison to the model results. The WARMF CD contains a base case that represents the current condition. The user can make changes to the base case and create new scenarios that represent specific management alternatives.

With a WARMF CD, the user can do the following: 1) review the parameter values used in the model simulation; 2) change coefficients to improve calibration; 3) collect and store information about stakeholders and their concerns; 4) educate stakeholders about the watershed; 5) calculate TMDLs for various water quality limited sections; 6) evaluate various cost sharing schemes for pollution trading between point and nonpoint dischargers; 6) try different management alternatives to meet the water quality criteria or habitat requirements; 7) modify alternatives to achieve consensus among stakeholders; and 8) enter new data, re-calibrate the model, and re-evaluate alternatives as a continuous planning process.

Installation

1. Insert the CD into CD ROM drive.
2. From Windows Explorer, go to the CD ROM drive and click on **Setup.exe**.
3. The setup program will guide you through the installation process. By default, the program will install WARMF in the C:\Program Files\Systemtech\WARMF directory.

Running WARMF

There are two ways to run WARMF from Windows 95/NT:

1. Click on *Start / Programs* and select *WARMF*, or
2. Click on *Start / Run* and browse to the directory where the program is installed and choose WARMF.EXE.

Opening a Project File

After starting WARMF, the user must open a project file that contains a watershed map and data to run the model. Using the menu, go to **File / Open**. Select a file with a WSM extension and choose OK. Wait a few moments for WARMF to load. After opening a project, the following dialog will appear showing the five modules (Figure 2.1).

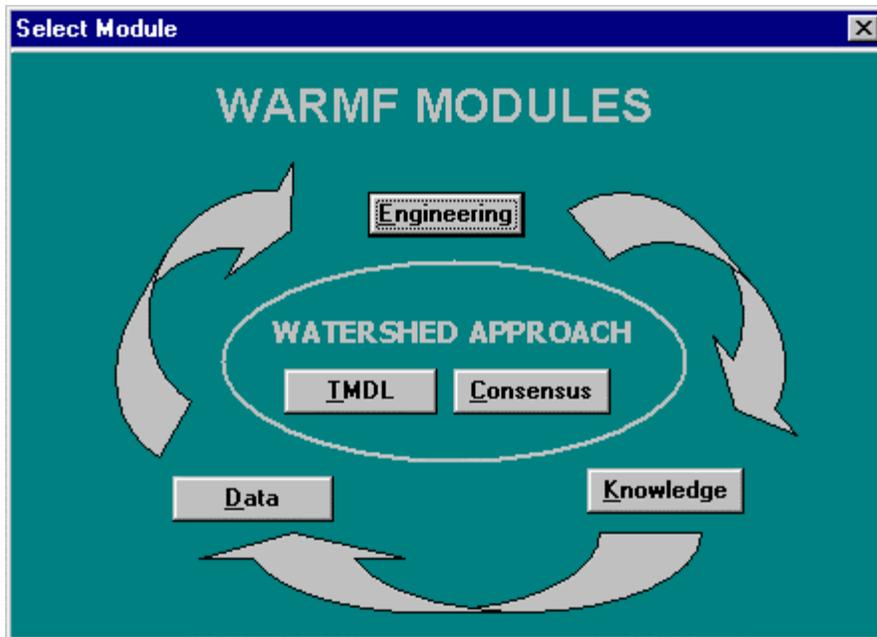


Figure 2.1
The Five Modules of WARMF.

WARMF Modules

WARMF contains models, a database, and graphic software. It is organized into 5 modules, integrated by a Windows-based graphical user interface (GUI). With the help of the GUI, a user can enter, review and revise input, formulate alternatives, run simulations, and display map-based output. All commands are done through the menu or by pointing and clicking with the mouse.

Engineering Module

The engineering module contains catchment, river, and reservoir models. The catchment model accepts daily meteorological data and monthly air quality data, and simulates canopy processes, snow pack on the land, infiltration into the ground, ex-filtration of ground water, acid mine drainage, surface runoff, and associated nonpoint source load. The river model accepts outflow from catchments and point source discharges, and routes the hydrology and water quality from one stream segment to the next until the water flows into a reservoir. The reservoir model accepts inflow from adjacent rivers and catchments, direct point source discharges, and direct deposition, and simulates thermal stratification and water quality in the lake and its outlet. The outflow from a reservoir can enter a river which may flow into the next reservoir. The interface between models is automatic and seamless. It allows WARMF to represent an entire watershed

as a single, interconnected system. WARMF outputs hydrology and water quality throughout the river basin.

Consensus Module

The consensus module provides a road map that contains seven steps of the consensus building process. The engineering module works in the background to provide scientific data for stakeholders to make informed decisions. The consensus module engages stakeholders in place-based water quality management and follows the guidelines of EPA's watershed approach.

TMDL Module

The TMDL module provides a step-by-step process of calculating the total maximum daily load of various pollutants entering upstream of a water quality limited section (WQLS). Calculation moves from the most upstream WQLS to the most downstream WQLS. The engineering module works in the background to supply scientific information to the TMDL module. The TMDL module allows the public allocation of assimilative capacity and follows the guidelines of EPA's watershed approach.

Data Module

The data module plots time series data of meteorology, air quality, managed flow, observed hydrology and water quality, and point source data. It also displays the data in a tabular format, which can be edited by the user. Pictures of the watershed can also be added, removed, and viewed within the data module.

Knowledge Module

The knowledge module stores reference information about legal constraints on stream flow and water quality in any part of the river basin. It may also contain suggestions based on the experience of other WARMF applications.

3

TMDL AND CONSENSUS MODULES

Introduction

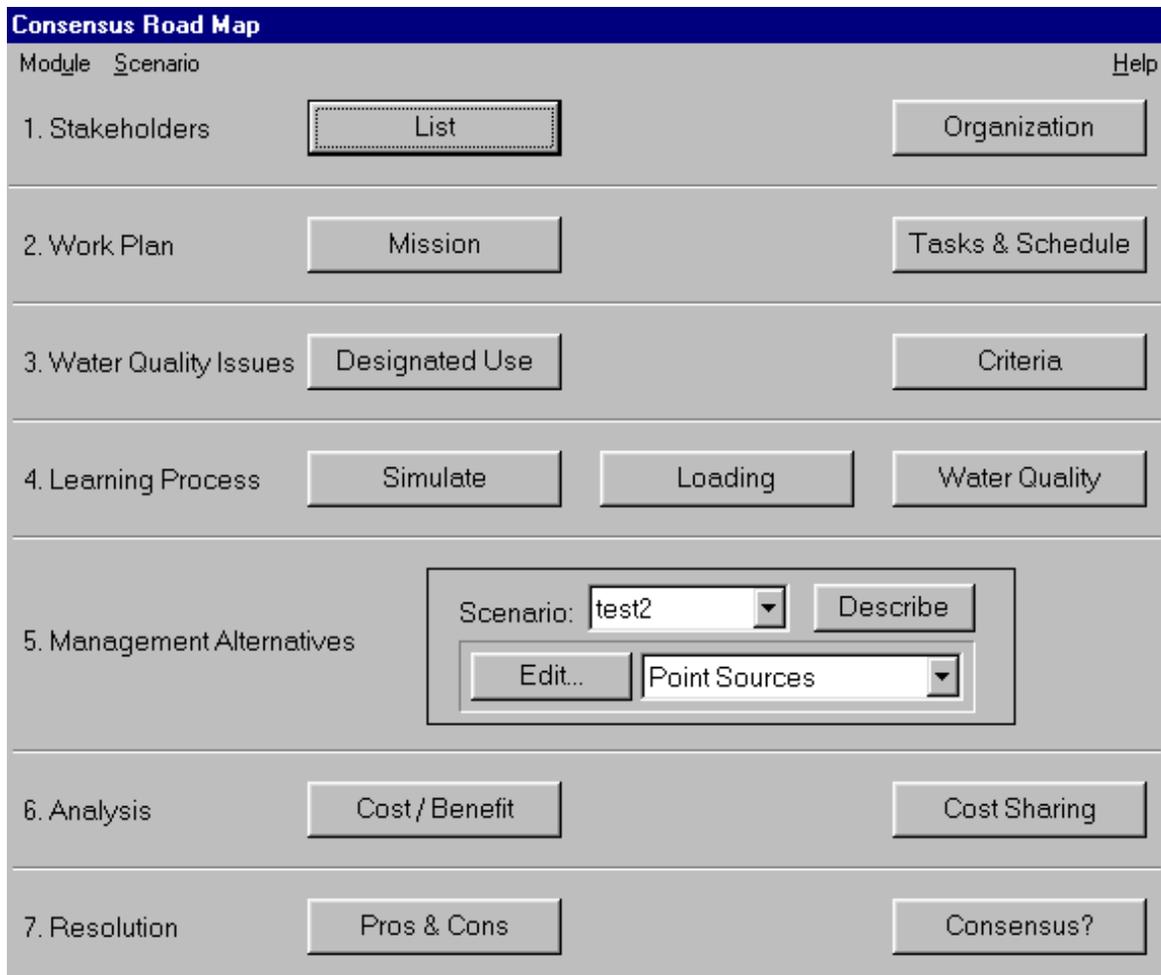
TMDL and Consensus are two application modules that will be used most often by the stakeholders. It is important to provide a quick overview of their menu functions and dialogs. The WARMF documentation report (1) has devoted a chapter to the TMDL module and a chapter to the consensus module. The report has provided a sufficient description of the menus and dialogs used in these modules. This chapter provides an overview of the current menu functions and dialogs.

Consensus Module

The EPA Guidelines require stakeholder involvement in the development of a TMDL plan. The consensus module provides a road map to organize stakeholders, to develop a mission statement, to identify water quality issues, to learn about the watershed, to evaluate alternatives, and to weight technical, social, and economic factors in the selection of a TMDL plan.

To invoke the consensus module, click on **Consensus** in the select module dialog (Figure 2.1) or select **Consensus** under the **Module** menu. Figure 3.1 shows the first dialog of the consensus module. It provides a 7-step road map for the consensus process.

Step 1 is to enlist and organize stakeholders. This step has two buttons: one for **List** and the other for **Organization**. By pushing **List** button, WARMF will display a dialog to enter stakeholder information (i.e. name, address, phone number, e-mail address, organization). In this dialog, there is **Concern** button, which can be pressed to enter the concerns important to each stakeholder. After pushing the **Organization** button, a dialog will appear for the entry of committee organization and assignments.



**Figure 3.1
Road Map of Consensus Process.**

Step 2 is to develop a work plan. There are buttons for **Mission** and **Tasks & Schedule**. By pushing the **Mission** button, a dialog will appear to show a proposed mission statement for the stakeholders. The stakeholders can revise the mission statement to their liking. By pushing **Tasks & Schedule**, WARMF will show a spreadsheet to enter tasks, their beginning and ending dates, and the committee responsible for each task.

Step 3 is to identify water quality issues. The water quality issues arise when the water quality cannot meet the criteria for the designated use, either for now or for the future. For that reason, there are **Designated Use** and **Criteria** buttons for step 3.

WARMF provides a list of sample designated uses, i.e. warm water fish, cold water fish, swimmable, public water supply, and aesthetic enjoyment. To add a new designated use to the list, push the **Designated Use** button and then the pull down arrow on the right of the designated use box. Click on the blank line at the bottom of the list and type in the new designated use.

By pushing the **Designated Use** button, a dialog will appear for the user to add or delete designated uses for various sections of the watershed. Select a designated use from the list. The areas of the watershed for this use will be highlighted on the map. To add a new location to this use, hold down the shift key and use the mouse to point and click at the new location on the basin map. To delete a location from this use, hold down the shift key and point and click at the location in the highlighted area. By this procedure, a given designated use can be applied to multiple locations on the river basin. A given location can serve multiple uses.

By selecting the **Criteria** button in step 3, the criteria editor will appear as shown in Figure 3.2. This is the dialog to specify one or more water quality criteria to protect a designated use. A criterion includes a specification of the parameter, its metric of evaluation, numerical criteria, and percent compliance. To select a designated use, push the down arrow and click on a specific use in the pull down list. Again, use the pull down list to select the first, second or third criterion. A criterion can be added or removed. The parameter can be selected from a pull down list of flow, depth, temperature, suspended sediment, dissolved oxygen, and concentrations of various chemical constituents.

For the example shown in Figure 3-2, the first criterion for the protection of warm water fishery is dissolved oxygen, whose minimum 4 day mean has to be above 5 mg/l 99.91% of time (once every three years). The metric of evaluation is totally flexible. It can be adapted to any specific criterion.

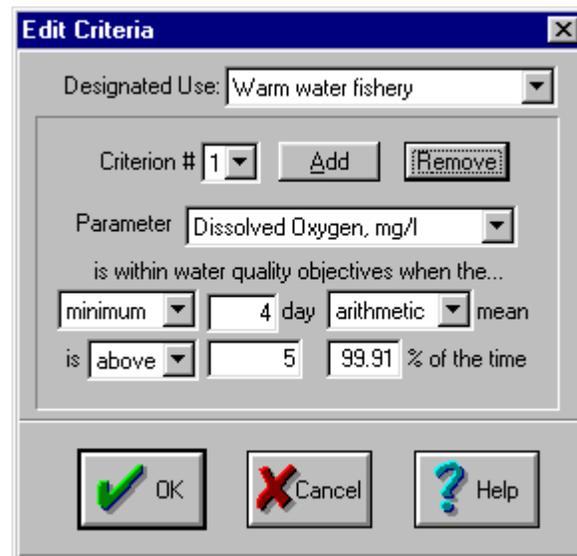


Figure 3.2
Editor of Water Quality Criteria.

Step 4 is learning how the watershed works. This is done through the use of the simulator. The **Simulate** button is used to initiate the model run. The **Loading** button is used to display the spatial distribution of point and nonpoint loading in GIS maps. The **Water Quality** button is used to display the water quality conditions in GIS color-coded maps. There is one GIS map for each designated use. In the map, the river and lake segments that violate the criteria for the

designated use are colored red and the segments that meet the criteria are colored green. This step helps stakeholders understand where the pollution loads are coming from and what is the resulting water quality.

Step 5 provides a mechanism to evaluate management alternatives. The first thing is to assign a scenario name for the proposed management alternative. To create a scenario name, select **Scenario** in the menu bar and then **Manager**. Click **Copy** and type in a name. At this point, the new scenario will contain the same model coefficients, point, and nonpoint loading data as the currently active scenario. With the new scenario selected, click on **Open**. Push the down arrow next to the **Scenario** box and select the new scenario name from the list.

To define the condition for the new scenario, push the down arrow next to the **Edit** button. WARMF will show a list of point source, nonpoint source, atmospheric deposition and diversion where control measures can be proposed. WARMF allows a management alternative to include a combination of controls. The user can specify the proposed reduction factors (or multipliers) for the pollution load or flow diversion.

This is quick way to evaluate the impact of a global change in pollution load or flow diversion. Alternatives involving changes in land use, buffer zone and/or fertilizer application can be evaluated through the **Engineering** module.

Steps 4 and 5 are iterative. The user can go from one button to the other in any sequence.

Step 6 is for analysis. A button allows the user to evaluate the **cost** and **benefit** of alternatives. The cost is quantified in dollars, but the benefit is quantified by the percent of river miles or reservoir segments that meet the criteria for their designated uses. Another button allows user to evaluate a **Cost Sharing** scheme in which point source dischargers may evaluate the options of providing partial payment to the cost of nonpoint source controls in exchange for a less stringent effluent requirement.

Step 7 is for resolution. The **Pros & Cons** button allows stakeholders to rank alternatives with respect to their areas of concern. A nominal score is calculated by giving each stakeholder an equal weight. WARMF provides information about the ranking of each alternative based on the category of stakeholders. It also provides ranking information with respect to each area of concern. This information provides incentives for stakeholders to modify the alternatives that can support the designated use and can win the widest support of stakeholders.

TMDL Module

According to EPA, the total maximum daily load (TMDL) is the sum of point and nonpoint loads that can be discharged upstream of a water quality limited section (WQLS) without violating the water quality criteria of its designated use. Many WQLS can exist in a watershed. The TMDL

module provides a road map to calculate TMDL for each WQLS one at a time, working from upstream to downstream.

To invoke the **TMDL** module, click on **TMDL** in the select module dialog (Figure 2-1) or select **TMDL** in the **Module** menu. Figure 3.3 shows the first dialog of the **TMDL** module. It provides a 6-step road map to calculate TMDL.

The first step is to provide a scenario name for future reference (e.g. TMDL1). The scenario name cannot be typed into the box. It must be chosen from a list by pushing the down arrow. If the desired scenario is not on the list, click on the **Scenario** menu and select **Manager**. Click **Copy** and type in the desired scenario name (e.g. TMDL1). At this point, the TMDL1 scenario will contain the same model coefficients, point, and nonpoint loading data as the currently active scenario. With the new scenario selected, click on **Open**. Now, the user can push the pull down arrow of **Scenario** and select TMDL1 to activate the scenario. WARMF will adjust the loading until the water quality meets the criterion for the designated use at the WQLS. The result will be stored in the scenario name TMDL1.

The second step is to specify the WQLS for the TMDL calculation. WQLS can be an impaired stream section or reservoir segment, which is on the 303(d) list. When there are many WQLS in a river basin, the TMDL calculation must follow a bottom up approach. The calculation starts with the most upstream WQLS and moves the downstream WQLS, one by one. To specify the WQLS, push the **Select** button. The basin map will appear. Use the mouse to click at the location of the WQLS on the map. WARMF will display the name of the WQLS chosen (e.g. Lower Sugar Creek).

The designated use for the selected WQLS can then be selected from a pull down list. For the example, it is warm water fishery. If the TMDL is to be calculated to protect another designated use, push the **Edit** button to make a change. The numerical criterion for the designated use can be selected from a second pull down list. In this example, it is shown to be a minimum 7-day mean dissolved oxygen concentration above 5 mg/l. Push the **Edit** button to make a change, if the TMDL is to be calculated for an unlisted criterion. Step 3 is to specify TMDL pollutant to be controlled in order to meet the water quality criteria for the designated use. To select a TMDL pollutant, push the pull down arrow for a list and select the appropriate pollutant to control. The TMDL pollutant may be different from the parameter for criterion. For example, BOD and ammonia are pollutants to control for a dissolved oxygen criterion. Ammonia, nitrate, and phosphorus are pollutants to control for an algae criterion. Sulfate is a pollutant to control for a pH criterion.

TMDL Calculation

Module Scenario Help

1. Specify scenario: TMDL1

2. Specify Water Quality Limited Section: Lower Sugar Creek

Designated Use: Warm water fish

Criterion: min. 7-day mean Diss. Oxygen above 5 mg/l

3. Specify TMDL Pollutant: BOD

Calculate Point Source Nonpoint Source loading, given specified loading multipliers:

	Point Sources	Nonpoint Sources
BOD		1
Ammonia	0.7	0.8
Aluminum	1	1
Calcium	1	1
Magnesium	1	1

4. Run simulation

5. View Results

6. Is the TMDL acceptable? Yes:

No: Try another combination of specified loading in step 3.

Figure 3.3
Road Map for TMDL Calculations.

With so many interrelated water quality parameters, it is possible for the user to specify an incorrect TMDL pollutant. If an irrelevant TMDL pollutant is selected, the program will not blow up. After two trials, the program will return a message “Control parameter does not affect water quality criterion”.

The TMDL pollutant can be derived from point source and nonpoint source loads. The TMDL can be calculated for point source allocation (WLA) or nonpoint source allocation (LA). Click the diamond button of Point Source to calculate WLA or the diamond button of Nonpoint Source to calculate LA. For WLA, the program will gradually step down (or up) the point source loads until the water quality criterion is barely met. For LA, the program will step down (or up) the nonpoint source loads until the water quality criterion is barely met.

Figure 3-3 presents a large number of possible variations for TMDL calculations. For example, the TMDL for point source load can be calculated under various levels of nonpoint source control. The TMDL of BOD (organic carbon or biochemical oxygen demand) can be calculated under various assumptions of ammonia removal at the treatment plant. With WARMF, the stakeholders can explore a large number of possible scenarios to meet the water quality criteria. After all the conditions for TMDL calculations are specified, push **Start** to initiate a simulation (step 4). WARMF will show a control dialog for simulation, as shown in Figure 3.4. For TMDL calculations, it is necessary to check the boxes for chemistry, sediment, fertilizers, and point sources. It is also necessary to make sure that the subwatersheds contributing point and nonpoint source loads to the WQLS are all high lighted. Also, make sure to check the box for **Generate Loading Data**.

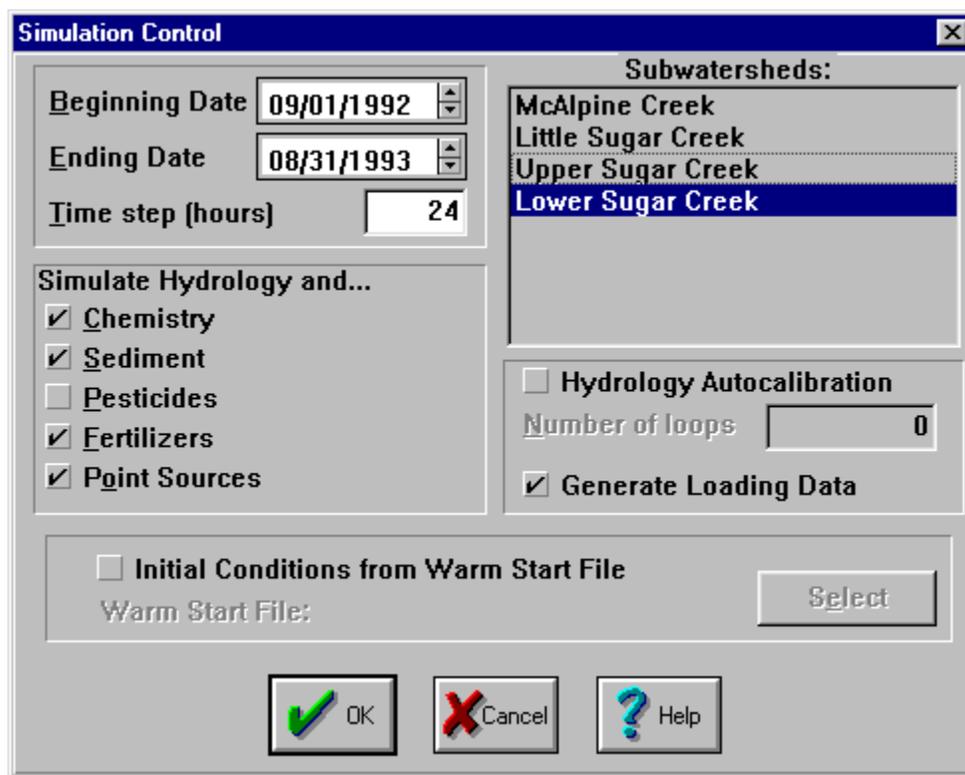


Figure 3.4
Simulation Control Dialog.

WARMF allows the user to break the entire river basin into subwatersheds. Each subwatershed has a breakpoint, which allows the water and pollutants to transfer from the upstream section to the downstream section. The breakpoint can be a lake or a river segment. The user can set a breakpoint by clicking on the **View** menu, selecting **Subwatershed** from the pull down list, and clicking on the desired breakpoint location on the basin map.

It is advisable to set all WQLS as a breakpoint. During the TMDL calculations, the user can save time by turning on (highlighting) only the subwatersheds that contribute point and nonpoint source loads to the WQLS. After the TMDL is calculated, the user can save the answer by turning off the subwatersheds in subsequent calculations of TMDL for the downstream WQLS. When the simulation is completed, one can view the results (step 5). The results are presented in terms of loading and water quality. Push the **Loading** button to compare loading under TMDL and base conditions. Push the **Water Quality** button and switch between BASE and TMDL scenarios to see whether the color of the water quality limited segment changes from red (not meeting the criterion) under the base condition to green (meeting the criterion) under the TMDL condition.

Step 6 will determine whether there is a feasible solution of TMDL. If a solution is obtained, the answer is yes to the question of “is the TMDL acceptable”. Push the **Save TMDL** button. The TMDL solution will be saved in a spreadsheet. If the answer is no, it means that WARMF cannot meet the water quality criterion by reducing the load of TMDL pollutant. This can happen in the calculation of WLA when the nonpoint source load alone would cause a violation of the water quality criterion. In such case, WARMF would advise the user to try again with a higher level of nonpoint source control.

The user can push the **View TMDLs** button to review the spreadsheet for all feasible solutions of TMDL. Any TMDL can be removed from the spreadsheet through this button.

4

ENGINEERING MODULE – MAIN WINDOW

Main Window

The GUI Main Window for the engineering module is divided into several components (Figure 4.1). They are CAPTION, MENU, TOOL BAR, DRAW TOOLS, MAP WINDOW and STATUS BAR.

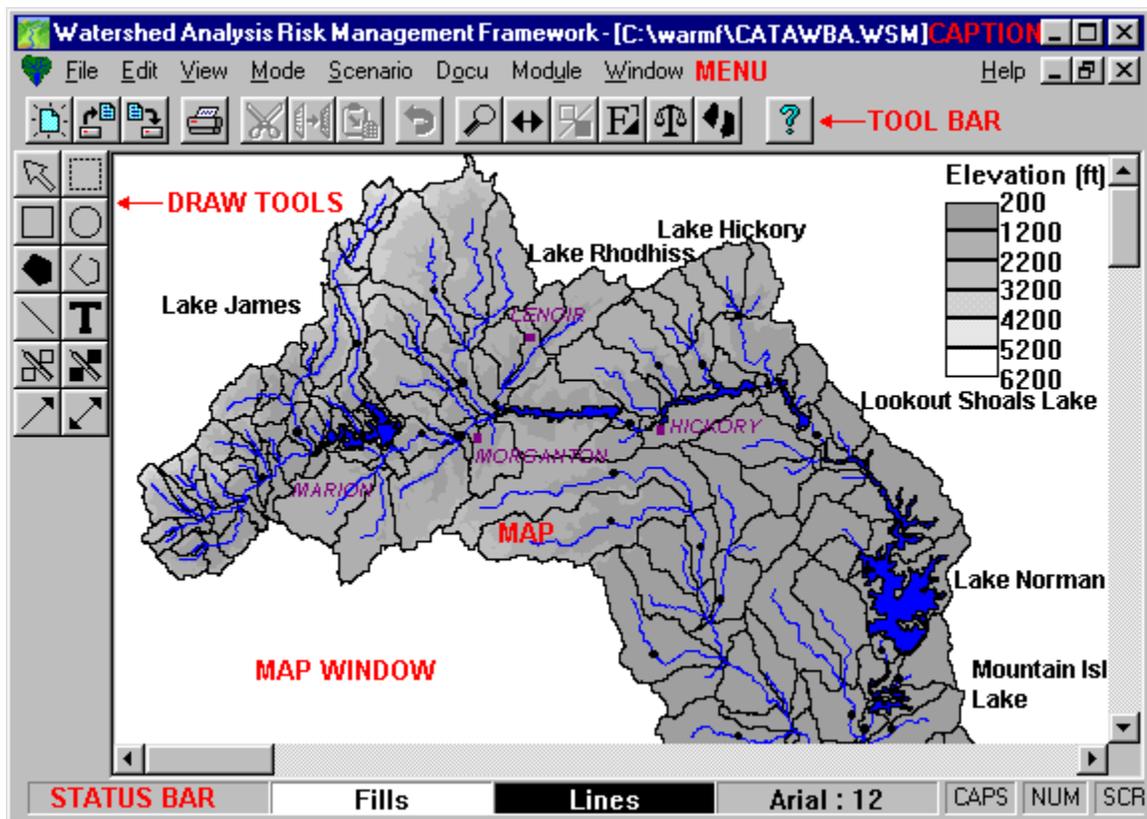


Figure 4.1
The Main Window of WARMF.

The **Caption** contains the name of the application (i.e. Watershed Analysis Risk Management Framework) and the name of the watershed file (i.e. C:\WARMF\CATAWBA.WSM). (Note: The  on the left side of the Caption is used to manipulate the Main Window of the GUI. The  buttons on the right side of the Caption are used to make the GUI an icon or reduce its size.) The **MENU** has many functions, which may be accessed either with the mouse or the keyboard. To access the menu with the mouse, click on the item directly with the left mouse button. To access the menu using the keyboard, press the **Alt** key and let go. Then type underlined letters or use the arrow keys to move through the menu.

(Note: The  button on the left side of the Menu is used to manipulate the Map Window within the GUI main window. The  buttons on the menu line are used to reduce the size of the Map Window within the GUI main window.)

The **TOOL BAR** has short cuts to some of the most frequently used menu functions. It also contains several tools which change the actions taken when using the mouse. When the mouse is held over one of the icons, a pop-up box appears and a brief description of the function appears in the Status Bar.

The **DRAW TOOLS** are used to create shapes, lines, and text in the Map Window. In general, DRAW TOOL items are used to set up the model for a specific river basin. They are not important to the general users who are not involved in the model setup.

(Note: Choose a draw tool by clicking on it with the mouse. Then use the mouse on the Map Window to add to the Map. To restore the mouse to its original functions, click on  in the upper left corner of the Draw Tools. When the mouse is held over one of the icons, a brief description of the function appears in the Status Bar.)

The **MAP WINDOW** is the area on which the basin map of the project is drawn. It consists of objects, which can be catchments, river segments, reservoir segments, descriptive text, and other shapes.

The **STATUS BAR** has two functions. The first function, displayed on the left side, shows text describing the function of an icon with the mouse placed over it. The second function, displayed in the right side, show shows the color of fills and lines, the font and size of text, and keyboard settings.

For example, when the mouse is over the  icon, the following message appears in the Status Bar (Figure 4.2). It indicates that shapes is filled in white with a black border line. Text is Arial 12 point. Caps lock, Num lock, and Scroll lock are all on.

Figure 4.2
Status Bar Showing WARMF Split Tool.

Menu Bar

The menu bar provides eight (8) functions: File, Edit, View, Mode, Scenario, Docu, Module, Window. In addition, there is Help menu at the far right of the menu bar. Each of these functions and sub-functions are described as follow.

File Menu

The pull down menu of **File** provides a list of sub-functions as shown in Figure 4.3. Following the Windows convention, they include menus for opening and closing files, saving files, and printing files.

The file menu also has functions to import digital elevation maps (DEM) and ArcView shape files for land use. It also has functions to delineate watershed boundaries. These functions are used primarily to set up the model. They are deactivated in the distributed WARMF CD.

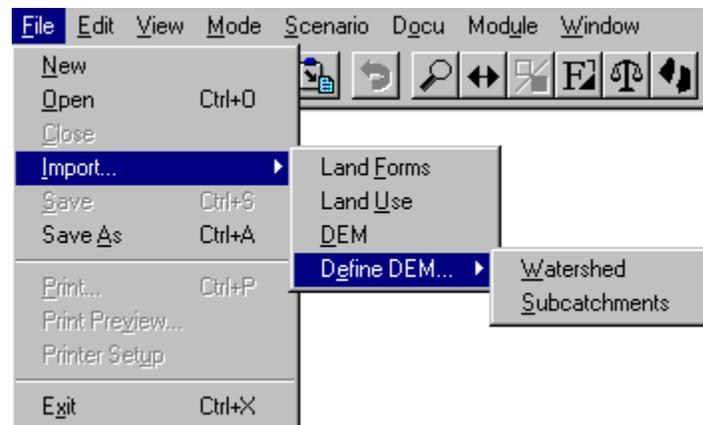


Figure 4.3
Pull Down Menu of File.

New

This function is used to create a new blank Map Window.

Mouse short-cut:  *in the Tool Bar*

Keyboard shortcut: Alt, F, N.

Open

This function is used to open an existing watershed file.

Mouse short-cut:  *in the Tool Bar*

Keyboard shortcuts: Alt, F, O; Ctrl+O.

Close

This function is used to close a watershed file without exiting the GUI.

Keyboard short-cuts: Alt, F, C; Ctrl+F4.

Import - Land Forms

This function is used to import an ArcView shape file with polylines or polygons and overlay it with the existing map. This feature is deactivated in the distributed WARMF CD.

Keyboard shortcut: Alt, F, I, F.

Import - Land Use

This function is used to import an ArcView shape file with land use/land cover coverage. The imported polygons with their respective land uses are overlaid with the catchment boundaries in WARMF to determine the overall percentage of each land use within each catchment.

Keyboard shortcut: Alt, F, I, U.

Import – DEM

This function is used to import Digital Elevation Map data (available from USGS Website) for a new watershed. This feature is deactivated in the distributed WARMF CD.

Keyboard shortcut: Alt, F, I, D.

Import – Define DEM – Subcatchments

This function is used to delineate subcatchment boundaries. This controls the spatial resolution of the model setup. This feature is deactivated in the distributed WARMF CD.

Keyboard shortcut: Alt, F, I, E, S.

Import – Define DEM – Watershed

This function is used to set areas, slopes, aspects, and elevations of an imported watershed and define the connectivity between catchments, rivers, and reservoirs. This feature is deactivated in the distributed WARMF CD.

Keyboard shortcut: Alt, F, I, E, W.

Save

This function is used to save changes made to the watershed project file.

Mouse shortcut: 

Keyboard shortcuts: Alt, F, S; Ctrl+S.

Save As

This function is used to save the changes made to the watershed project file under a new name.

Keyboard shortcuts: Alt, F, A; Ctrl+A.

Print

This function is used to print the Map Window.

Mouse shortcut: 

Keyboard shortcuts: Alt, F, P; Ctrl+P.

Print Preview

This function is used to provide a preview of the Map Window to be printed.

Keyboard shortcut: Alt, F, V.

Printer Setup

This function is used to specify the printer and its settings.

Keyboard shortcut: Alt, F, U.

Exit

This function is used to exit from WARMF, which will close the project file. Before closing, the program will prompt the user to save if changes have been made.

Keyboard shortcuts: Alt, F, X; Ctrl+X; Alt+F4.

Edit Menu

The pull down menu of **Edit** provides a list of sub-functions shown in Figure 4.4. Many of the sub-functions are derived from Windows, i.e. Undo, Cut, Copy, Paste, Delete, Bring to Front, Send to Back. Added features include Select Catchments, Select Reservoir Segments, Select Rivers, Select All, River Point, Graphics and Text, Convert, Connect, Scale, Open Polygons, Close Polygons, Weed Points, Match Polygons, Output List, Autocalibration Coefficients, Save Calibrated Coefficients.

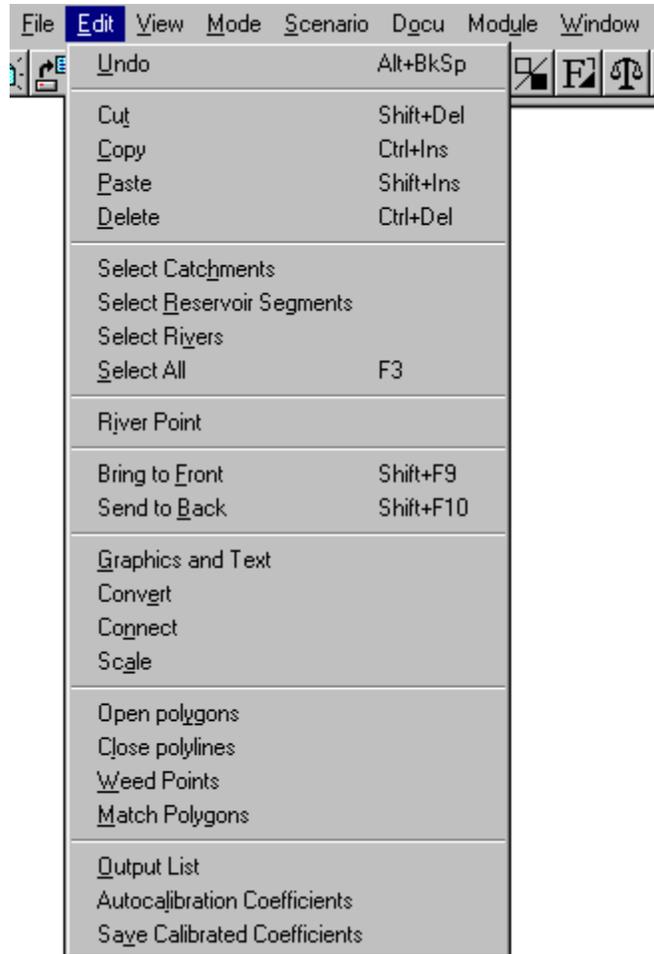


Figure 4.4
Pull Down Menu of Edit.

Undo

This function is used to restore the **Map Windows** to its previous appearance before the most recent change made by the **Move** or **Delete** function.

Mouse Shortcut: 

Keyboard shortcut: Alt, E, U; Alt+BkSp.

Cut

This function is used to cut the selected objects from the Map Window and places them in the Clipboard.

Mouse shortcut: 

Keyboard shortcut: Alt, E, T; Shift+Del.

Copy

This function is used to copy selected objects from the Map Window and places them in the Clipboard.

Mouse shortcut: 

Keyboard shortcuts: Alt, E, C; Ctrl+Ins.

Paste

This function is used to paste the objects stored in the Clipboard into the Map Window.

Mouse shortcut: 

Keyboard shortcuts: Alt, E, P; Shift+Ins.

Delete

This function is used to delete the selected objects on the Map Window. Deleted objects can be recovered by **Undo**.

Keyboard shortcuts: Alt, E, D; Ctrl+Del.

Select Catchments

This function is used to select and highlight all catchments in the Map Window.

Keyboard shortcut: Alt, E, H.

Select Reservoir Segments

This function is used to select and highlight all reservoir segments in the Map Window.

Keyboard shortcut: Alt, E, R.

Select Rivers

This function is used to select and highlight all river segments in the Map Window.

Keyboard shortcut: Alt, E, V.

Select All

This function is used to select and highlight all objects in the Map Window.

Keyboard shortcuts: Alt, E, S; F3.

River Point

This function is used to toggle a river point (black dot) on selected river segment. Clicking on a river point is the same as clicking on the stream segment.

Keyboard shortcut: Alt, E, I.

Bring to Front

This function is used to move selected objects to the front of the Map Window. This function can prevent objects from being hidden behind other objects.

Keyboard shortcut: Alt, E, F.

Send to Back

This function is used to move selected objects to the back of the Map Window. This function can prevent objects from being hidden behind other objects.

Keyboard shortcut: Alt, E, B.

Graphics and Text

This function is used to change the color of lines, polygons, and text in Map Window. The changes are applicable to any selected map objects and to any map objects to be created.

Mouse shortcut: 

Keyboard shortcut: Alt, E, G.

Convert

This function is used only during the model set-up for defining watershed objects. It converts a selected object into catchment, river, or reservoir segment. The object can be a polygon or line created by the drawing tool.

Mouse shortcut: 

Keyboard shortcut: Alt, E, E.

Connect

This function is used to specify or change the flow connectivity between two objects. To do that, select **Connect** from the menu to change the function of the mouse. Move the pointer of the mouse to the upstream object (catchment, river segment, or reservoir segment). Click with the left mouse button. Hold down the button, drag the mouse to the downstream object and release the button. The program will display all tributary connections by arrows. To turn off the arrows, go to **Tributary Connections** in the View menu.

Mouse shortcut: 

Keyboard shortcut: Alt, E, N.

Scale

This function is used to set the scale of the map. To do that, select **Scale** from the menu to change the function of the mouse. Click the button down at a point in the **Map Window**. Hold down the button and drag the mouse to another point in the **Map Window**. Upon release of the mouse, a prompt will ask for the distance between the two points. This feature is used during the model set-up. It should not be used by general users.

Mouse shortcut: 

Keyboard shortcut: Alt, E, A.

Open Polygons

This function is used to convert polygons to polylines. Select one or more polygons and select this function. To convert, press Convert. This feature is used during the model set-up. It should not be used by general users.

Keyboard shortcut: Alt, E, Y.

Close Polylines

This function is used to convert a polyline into a closed polygon. To do that, select one or more polylines and select this function. This feature is used during the model set-up. It should not be used by general users.

Keyboard shortcut: Alt, E, L.

Weed Points

This function is used to discard duplicate points in a selected polygon. To do that, select one or more polygons and then select this function. This feature is used during the model set-up. It should not be used by general users.

Keyboard shortcut: Alt, E, W.

Match Polygons

This function is used to eliminate minor gaps or overlaps between adjacent catchments reservoir segments. The program will adjust the points representing two adjacent polygons so that the points will coincide. To do that, select two neighboring polygons and then select this function. This feature is used during the model set-up. It should not be used by general users.

Keyboard shortcut: Alt, E, M.

Autocalibration Coefficients

This function is used to specify the coefficients and watershed areas to adjust during the hydrology autocalibration.

Keyboard shortcut: Alt, E, L.

Save Calibrated Coefficients

This function is used to store the calibrated coefficients into default values. It is necessary to select **File/Save** or **Scenario/Save** to save them in the project file.

Keyboard shortcut: Alt, E, V.

View Menu

The pull down menu of View provides a list of sub-functions, as shown in Figure 4.5. They include Zoom, Zoom In, Zoom Out, Restore Map, Tributary Connections, Entity IDs, Tributary

Connections, Selected Entities' Points, Subwatersheds, Meteorology Stations, Gaging Stations, Water Quality Stations, Managed Flow, Point Sources, Air Quality Stations, Scale, Pictures, and Labels.

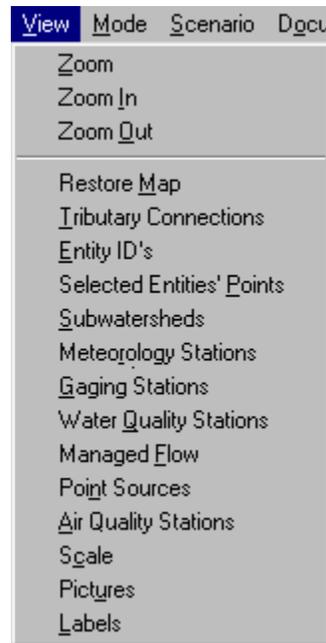


Figure 4.5
Pull Down Menu of View.

Zoom

This function is used to expand a specified area of the map. Select the function and wait for the change of mouse pointer. Press the left mouse button down at a point in the map. Drag the mouse to encompass the area to be viewed, and let go of the mouse. The specified area will be expanded to the full Map Window.

Mouse shortcut: 

Keyboard shortcut: Alt, V, Z.

Zoom In

This function is used to zoom in so that the objects in the **Map Window** appear twice as large as before.

Keyboard shortcut: Alt, V, I.

Zoom Out

This function zooms out so that the objects in the **Map Window** appears half as large as before.

Keyboard shortcut: Alt, V, O.

Restore Map

This function is used to restore the **Map Window** to its original appearance.

Keyboard shortcut: Alt, V, R.

Tributary Connections

This function provides a toggle between showing and hiding **Tributary Connections**. The tributary connections display arrows showing the flow path throughout the watershed.

Keyboard shortcut: Alt, V, T.

Entity ID's

This function provides a toggle between showing and hiding Entity ID's. It is used to display the ID numbers of catchments, river segments, and reservoir segments. To change the font size, click on .

Keyboard shortcut: Alt, V, E.

Selected Objects' Points

This function provides a toggle between showing and hiding a **Selected Objects' Points**. The menu will display objects' points at the vertices of all selected polygons and polylines. An object's points can be moved by clicking on one with the left mouse button, dragging it to the new location, and then releasing it.

Keyboard shortcut: Alt, V, P.

Subwatersheds

The entire watershed is divided into sub-regions. This function can be selected to display the subwatersheds in different colors on the map. To see the subwatershed names, select the **View/Labels** function. This can sometimes make the basin map look too busy. To change the

font size, click on . Toggle **View/Labels** function to eliminate the display of subwatershed names. Toggle the **Subwatershed** function to eliminate the display of subwatersheds in color.

(Note: The user can divide the entire watershed into subwatershed regions. The breakpoint for subwatersheds can be a reservoir or a river segment. To create a new subwatershed, simply click on the desired breakpoint location on the basin map. WARMF performs the simulation one subwatershed at a time. The GUI provides the interface between subwatersheds. The user must run the simulation for the entire watershed once. After that, the user can run for only one or a few subwatersheds to save time.)

Keyboard shortcut: Alt, V, S.

Meteorology Stations

This function can be selected to display the meteorology stations with white dots on the map. To see the names of meteorological stations, select the **View/Labels** function. To display the meteorological data, double-click on the white dot of a specific station. Toggle this selection to eliminate its display.

Keyboard shortcut: Alt, V, R.

Gaging Stations

This function can be selected to display the gaging stations with white dots on the map. To see the names of gaging stations, select the **View/Labels** function. To view the stream flow data, double-click on the white dot a specific station. Toggle this selection to eliminate its display.

Keyboard shortcut: Alt, V, G.

Water Quality Stations

This function is used to display the water quality stations with white dots on the map. To see the names of water quality stations, select the **View/Labels** function. To view water quality data, double-click on the white dot of a specific station. Toggle this selection to eliminate its display.

Keyboard shortcut: Alt, V, Q.

Managed Flow

This function is used to display the locations of controlled flow diversions and flow releases with white dots on the map. To see the names of managed flow points, select the **View/Labels** function. To view the managed flow data, double-click on the white dot of a specific point. Toggle this selection to eliminate its display.

Keyboard shortcut: Alt, V, F.

Point Sources

This function is used to display the locations of point source discharges with white dots on the map. To see the names of point source discharges, select the **View/Labels** function. To review the point source discharge information, double-click on the white dot of a specific point source. Toggle this selection to eliminate its display.

Keyboard shortcut: Alt, V, N.

Air Quality Stations

This function can be selected to display the locations of air/rain chemistry stations with white dots on the basin map. To see the station names, select the **View/Labels** function. To view the air quality data, double-click on the specific dot of a station. Toggle this selection to eliminate its display. This type of data is not always available within the watershed, in which case the stations will not appear on the map.

Keyboard shortcut: Alt, V, A.

Scale

This function is used to display the scale of the watershed map. Toggle this selection to eliminate its display.

Keyboard shortcut: Alt, V, C.

Pictures

This function can be selected to display the locations, which have watershed pictures, with white dots on the basin map. To see the picture captions, select the **View/Labels** function. To see the pictures, double click on the dot of a specific location. To eliminate the display, toggle the selection.

Keyboard shortcut: Alt, V, U.

Labels

As discussed above, this function can be selected to display the names of subwatersheds, meteorology stations, gaging stations, water quality stations, air quality stations, managed flow (diversion or reservoir release points), point source discharges, and locations with watershed pictures. Change the font size with **F**. To eliminate the labels, toggle this selection.

Keyboard shortcut: Alt, V, L.

Mode Menu

The engineering module can be operated in **Input** or **Output**, as shown in Figure 4.6. Under the input mode, one can double-click at an object (catchment, river segment, lake segment) to view the parameter values and their units. Changes can be made on the computer screen. The changes can be saved or not saved at the user's discretion. Under the output mode, one can double-click at any stream or reservoir segment to view time series comparison of simulated and observed data on a graph.

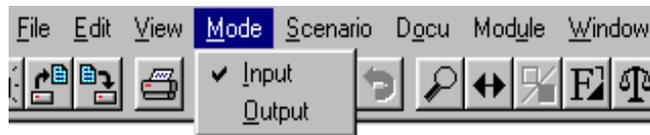


Figure 4.6
Pull Down Menu of Mode.

The **Run** function, which originally resided here in this pull down menu, was moved to the **Scenario** menu. The dialogs for Input are discussed in Chapter 5 and the dialogs for Output are discussed in Chapter 6 of this manual.

Keyboard shortcuts: Alt, M, I; Alt, M, O.

Scenario Menu

A scenario can be created to represent a simulation case. The input of a simulation case can represent a combination of land use conditions, a management alternative, and model coefficients. The input and output of the simulation case are stored under a scenario name, which can be retrieved for evaluation.

A watershed project file can contain an unlimited number of scenarios. At any given time, only one scenario is active (as shown by a check mark next to it at the bottom of this menu). However, up to 4 scenarios can be opened for alternative comparisons. Scenarios can have different applications. During the model calibration, a scenario can be used to represent one set

of model coefficients. The user can compare scenarios for a best set of model coefficients that produce a good match between observed and simulated values. During the alternative evaluation, the model coefficients may be fixed, whereas the parameter values for management alternatives are changed. The user can then compare scenarios for a best alternative to improve water quality.

Figure 4.7 shows the pull down menu of **Scenario**. The functions include Run, Manager, Save, Save As, Delete, View Coefficient File, Compare, and a list of scenarios. The scenario with a check mark next to it indicates that the scenario is activated.

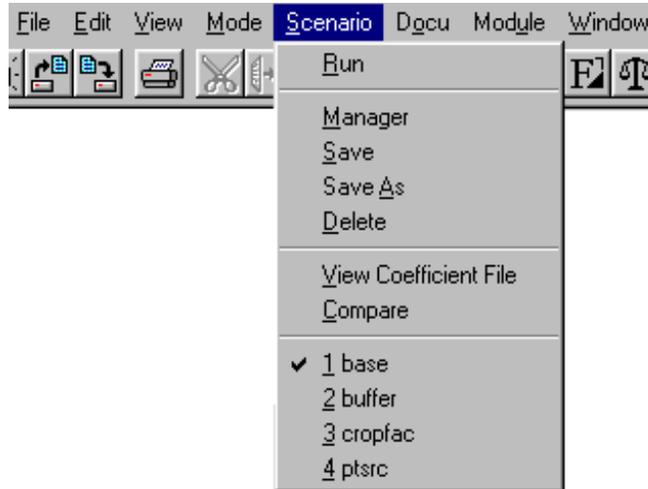


Figure 4.7
Pull Down Menu of Scenario.

The **Run** function is selected to initiate a simulation for the active scenario. The **Manager** function is used to create, delete, open, close, add, and remove scenarios. The **Save**, **Save As**, **View Coefficient File**, and **Compare** functions will operate on the active scenario. Details of these functions will be discussed later.

During the course of TMDL study, a large number of scenarios may be evaluated. To prevent confusion, it is important to document the scenario as it is created. The documentation should include the full scenario name, abbreviation, creator's name, creation date, purpose, and input conditions. The documentation of scenario is through the **DOCU** menu, to be discussed later. In addition to the written documentation of scenario, WARMF automatically saves all the input and output of each scenario. There are two ways to examine the record. One is through the modern GUI and the other is through the old fashioned ASCII file. Through the GUI, the user can activate a scenario and examine its input and output data in dialog boxes on the computer screen. WARMF also writes all input data into a coefficient file. Through the **View Coefficient File** function, the user can examine the data line-by-line and field-by-field. The user can also select the **Compare** function for the computer to compare the input files of two scenarios and to print out the differences.

In the example shown in Figure 4.7, there are four scenarios listed at the bottom of the scenario menu for which input and output can be examined. These are considered “open”. The check mark on **Base Case** indicates that it is active. To change the active scenario to **Buffer**, simply select it in the menu. When editing input data, only the active scenario’s coefficients can be modified. When viewing output for a specific catchment, river, or reservoir, results from all open scenarios can be compared. However, when viewing spatial output, only one scenario’s results can be displayed.

Run

This function is selected to start a simulation for the active scenario. Chapter 6 will have a more detailed discussion of this function.

Keyboard shortcut: Alt, S, R..

Manager

Figure 4.8 shows the dialog of the scenario manager. On the left hand side, there are buttons for modifying the scenario configuration. In the middle, a list shows all scenarios in the project. The open scenarios are listed on the right.

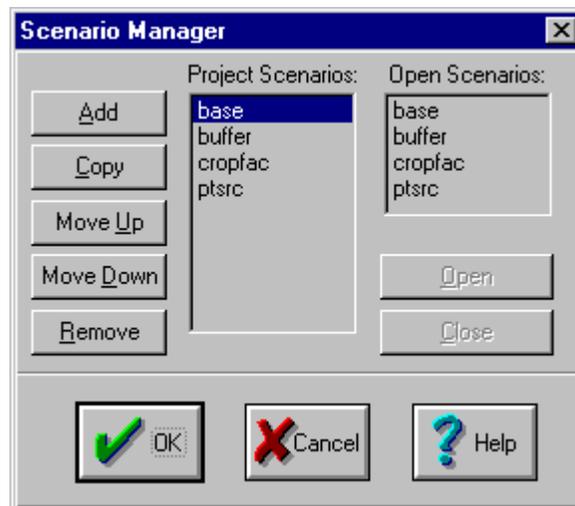


Figure 4.8
Scenario Manager.

As stated earlier, a project can have many scenarios. Some of the scenarios may be saved on disk, but not in the scenario manager. To add a scenario to the project, push the **Add** button and select the desired scenario. To remove a scenario from the project, select the scenario on the list on the left and then push the **Remove** button.

The procedure to create a new scenario is accomplished through **Copy**. WARMF comes with a base case scenario, which represents the current condition, used in the model calibration. The idea is to create a new scenario by making modifications to the base case. Before using the scenario manager, ensure that the base case is active (has a check mark next to it in the scenario menu). In the scenario manager, click on the **Copy** button. It creates a duplicate of the active scenario. Enter the new scenario name when prompted and then click **Open** in the scenario manager with the new scenario selected. After leaving the scenario manager, activate the new scenario in the scenario menu. Make changes to coefficients or parameters for the new management scenario. Perform the model simulation with the new parameter values. Input and output are saved under the new scenario name. Through this process, one can create as many scenarios as necessary for the project.

In the example shown in Figure 4.8, the project scenarios include BASE, BUFFER, CROPFAC, and PTSRC. To reorder the scenarios, click on a scenario and choose **Move Up** or **Move Down**. Up to four scenarios can be opened for alternative comparison. To open a scenario, select the scenario in the list on the left. The scenario will be highlighted. When there are less than four open scenarios listed on the right dialog box, the **Open** button can be activated. Press the **Open** button and the scenario will appear in the open scenario list. If the open scenario list is full, the open button cannot be activated. In this case, click on an open scenario from the list on the right and press **Close** to make room for another scenario.

Keyboard shortcut: Alt, S, M.

Save

This function is selected to save the conditions of the active scenario. It does not save changes made to the map, the project file configuration, the consensus module or the TMDL module.

Keyboard shortcut: Alt, S, S.

Save As

This function is selected to save the conditions of the active scenario under a new name. It does not save changes made to the map, the project file configuration, the consensus module or the TMDL module.

Keyboard shortcut: Alt, S, A.

Delete

This function is selected to permanently delete a scenario from the hard disk. After selecting the function, a directory will appear to show all scenarios. Click on the scenario to delete it.

Keyboard shortcut: Alt, S, D.

View Coefficient File

WARMF saves all input data of a given scenario in ASCII file. This function is selected to load the coefficient file of the active scenario into a text editor for examination. Use “Coefficient File Key.pdf” as an index to identify individual coefficients in the file. NEVER make changes to the coefficient file directly. ALWAYS use the graphical user interface to view the coefficients.

Keyboard shortcut: Alt, S, V.

Compare

This function is selected to compare the coefficient file of the active scenario to the coefficient file of another scenario. Use “Coefficient File Key.pdf” to interpret which coefficients are different.

Keyboard shortcut: Alt, S, C.

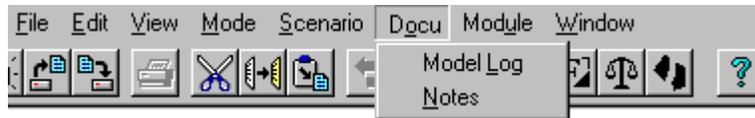
Scenarios 1, 2, 3, 4

This function is used to activate any scenario on the list. The active scenario will have a check mark to the left. In switching from one active scenario to the other, WARMF will prompt to save the data from the previously active scenario if changes have been made. If it is not saved, changes made to that scenario will be lost.

Keyboard shortcuts: Alt, S, 1; Alt, S, 2; Alt, S, 3; Alt, S, 4.

Document Menu

Figure 4.9 shows the pull down menu for Docu (documentation). This menu is used to provide an electronic note pad to document the watershed process as it progresses. While the memory is still fresh, one can keep a record of model runs (model log) as well as consensus deliberations (notes).



**Figure 4.9
Document Menu.**

Model Log

This function is used to document a model run. The date, scenario name, author, assumptions, interpretations, and conclusions of each model run can be briefly described for future reference. The notepad file will have a LOG extension.

Keyboard shortcut: Alt, O, L.

Notes

This function can be used to document the consensus processes of stakeholders. The date, participants, issues discussed, conclusions reached, and actions planned can all be recorded. The notepad file will have a NOT extension.

Keyboard shortcut: Alt, O, N.

Module Menu

This menu provides an avenue to switch from one module to another in WARMF. Figure 4.10 shows the pull down list of functions for the **Module** menu.



**Figure 4.10
Module Menu.**

The list only provides the modules to switch to. While in engineering module, the name of engineering module is not on the list. Point and click at the destination module, the program will bring you there. Once there, the engineering module will be on the module list.

Data

This function is used to switch WARMF to the Data Module.

Keyboard shortcut: Alt, U, D.

Knowledge

This function is used to switch WARMF to the Knowledge Module.

Keyboard shortcut: Alt, U, K.

TMDL

This function is used to switch WARMF to the TMDL Module.

Keyboard shortcut: Alt, U, T.

Consensus

This function is used to switch WARMF to the Consensus Module.

Keyboard shortcut: Alt, U, C.

Window Menu

This menu provides tools to change the appearance of multiple Windows on the computer screen. Figure 4.11 shows the pull down menu of Window.



Figure 4.11
Pull Down Menu of Window.

Cascade

This function is used to arrange the Map Windows of all opened project files in cascade form. In this form, Windows overlap each other with all captions visible. To activate a Window, one can simply click on its caption on the top.

Keyboard shortcut: Alt, W, C.

Tile

This function is used to display multiple Map Windows of all open files in tile format. In this format, Windows do not overlap each other. To activate a Window, one can simply click on its caption on the top.

Keyboard shortcut: Alt, W, T.

Arrange Icons

This function is used to put the icons of all minimized Map Windows in the lower left of the available space. A Window is minimized by clicking on  in the right upper corner.

Keyboard shortcut: Alt, W, I.

Close All

This function is used to close all open watershed files without exiting from the GUI.

Keyboard shortcut: Alt, W, A.

Help

Figure 4.12 presents the pull down menu of **Help**, which is activated by pushing **Help** at the far right of the menu bar (Figure 3-1).



Figure 4.12
Pull Down Menu of Help.

Help - Contents

This function is used to open the help system and provides a complete list of help items by topic. Help on a particular topic can be accessed by selecting that topic and clicking on Go To in the dialog.

Mouse shortcut: 

Keyboard shortcut: Alt, H, C.

Help - How to Use Help

This function is used to provide instructions on how to use the help system.

Keyboard shortcut: Alt, H, H.

Help - About

This function is used to display the author and version of WARMF.

Keyboard shortcut: Alt, H, A.

Draw Tools

The draw tools are used to create shapes, lines, and text in the Map Window. They are used primarily during the model set up, and not by general users of WARMF.

The draw tools are part of the engineering module. They are displayed by symbols in two vertical columns on the left hand side of the Map Window as shown in Figure 4.1.

To use a draw tool, first click on it with the mouse. This changes the mouse function to drawing tool. After that, move the cursor to a specific location on the Map Window where a new shape is to be added, and click with the mouse. For a shape, hold down the mouse button, drag the mouse for the desired shape, and then release the mouse. To reposition the drawn shape, first select the object and move it to the desired location by dragging it with the mouse. The size of the shape can also be changed by first selecting the object and then by positioning the cursor at the lower left hand corner and dragging it in diagonal directions, while holding down the Ctrl key.

To restore the mouse to its original functions, click on  in the upper left corner of the Draw Tools.

Rectangle Error! Objects cannot be created from editing field codes.

This button allows the mouse to draw a rectangle.

Ellipse Error! Objects cannot be created from editing field codes.

This button allows the mouse to create an ellipse.

Polygon

This button allows the mouse to draw a polygon. Use the mouse to create vertices of the polygon. When it has the desired shape, hit Enter. A connecting line is automatically drawn between the first and last vertices to close the polygon.

Polyline

This button allows the mouse to draw a polyline. Use the mouse to draw the vertices of the polyline. When it has the desired shape, hit Enter.

Line

This button allows the mouse to draw a straight line. After pushing the button, move the cursor to the starting point on the Map Window, hold the mouse button down while drawing the line, let the mouse button back up to finish.

Free Polygon

This button allows the mouse to draw a freehand polygon. After pushing the button, move the cursor to the starting point on the Map Window, hold the mouse button down while drawing the line, let the mouse button back up to finish. A line between the beginning and ending points is automatically drawn to close the polygon.

Free Polyline

This button allows the mouse to draw a freehand polyline. After pushing the button, move the cursor to the starting point on the Map Window, hold the mouse button down while drawing the line, let the mouse button back up to finish.

Text

This button allows text to be entered into the Map Window. Simply use the keyboard to type text. To finish, type Esc.

Arrow (1 Head)

This button allows the mouse to draw a one-headed arrow. After pushing the button, move the cursor to the starting point on the Map Window, hold the mouse button down while drawing the line, let the mouse button back up to finish.

Arrow (2 Head)

This button allows the mouse to draw two headed arrows. After pushing the button, move the cursor to the starting point on the Map Window, hold the mouse button down while drawing the line, let the mouse button back up to finish.

Rubber Band

This button allows the mouse to select all the objects within the rubber band. Click at the beginning point of the rubber band. Hold down the mouse and drag it across the Map Window for the area to be covered. When the button is released, all objects entirely within the rectangle will be selected.

Manipulating Objects

Using the drawing tools and a series of mouse operations, it is possible to manipulate objects in the Map Window. In WARMF, an object can be a catchment, river segment, or reservoir segment. It can also be any item in the Map Window.

Each object has its own properties, including location, points representing the boundary, fill color, and line color. Objects may be manipulated to set up a Map or to change the appearance of an existing Map. Following is a description of the method used to manipulate objects in WARMF.

Selecting an Object

To select an object (e.g. catchment, river segment, or lake segment), move the mouse so that the cursor is over the object. Click once with the mouse. A rectangle will appear around the object and the object itself will invert colors to indicate that it has been selected, as shown in Figure 4.13. Since this operation will select one object at a time, the previously selected object will become un-selected.

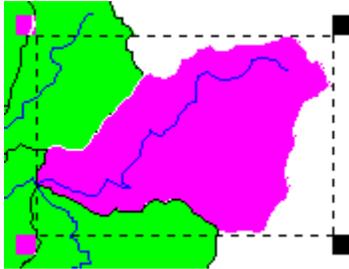


Figure 4.13
Selecting an Object.

Selecting Multiple Objects

To select more than one object at the same time, select the first object as described previously. Hold down the **Shift** key and select other objects. When the hold down key is released, the colors of all selected objects will be inverted inside a rectangle (Figure 4.14). This task can also be accomplished through **Rubber Band** tool, described earlier.

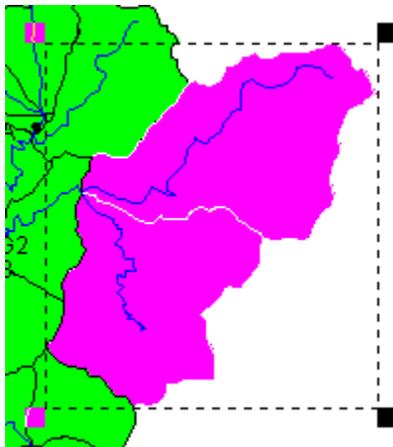


Figure 4.14
Selecting Multiple Objects.

Changing the Appearance of Objects

Select the objects to change, as shown in Figure 4.15.

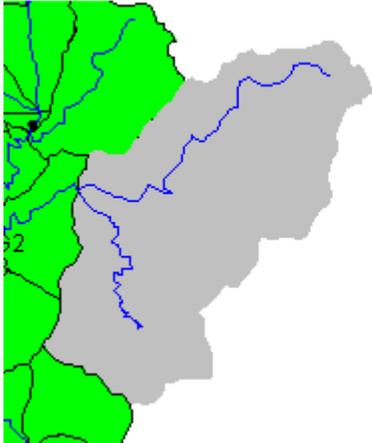


Figure 4.15
Selecting Objects to Change.

Then, select **Edit / Graphics and Text**. The dialog box as shown in Figure 4.16 will appear:

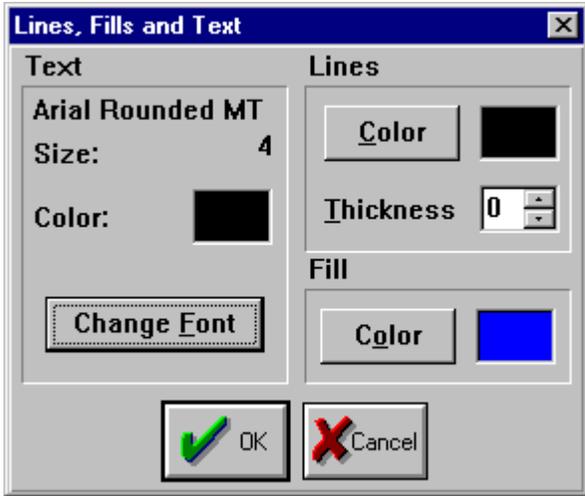


Figure 4.16
Dialog for Line, Fills and Text.

To change the font of text, click on **Change Font**. To change the color of lines, click on the **Color** button under **Lines**, choose a color, and click OK. To change the thickness of lines, click the box next to **Thickness** and change the thickness by the up and down arrows. To change the

color of polygons, click on the **Color** button under **Fill**, choose a color, and click OK. This also changes the default display of any objects created later.

Moving Objects

Select the objects to be moved. Then hold down the Ctrl key, click inside the selection rectangle, and drag the mouse. When the objects are in the desired location, release the mouse (see Figure 4.17).

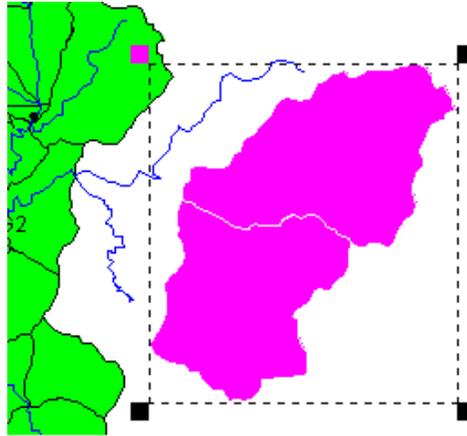


Figure 4.17
Moving Objects.

To return an object to its original location, use **Edit / Undo**. **Undo** can be performed several times in sequence.

Resizing Objects

Select the objects to be resized as shown in Figure 4.18.

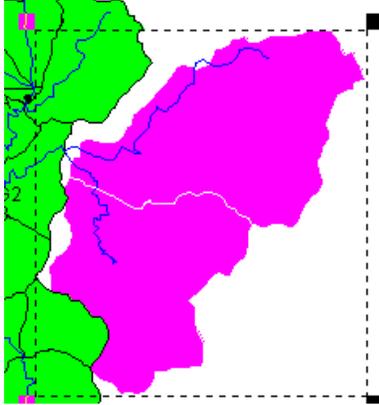


Figure 4.18
Selecting Objects for Resizing.

Then hold the Ctrl key down and move the mouse over a small square at the corners of the selecting rectangle. The cursor will change appearance to look like a two-headed arrow. Click and drag the mouse in the arrow directions. When the objects reach their desired size, release the mouse.

Copying Objects

Select the objects to copy, as shown in Figure 4.19.

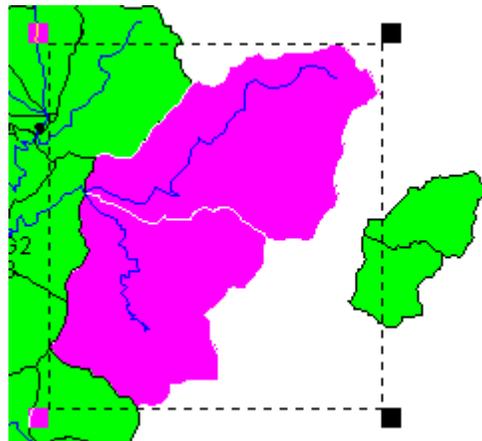


Figure 4.19
Copying Objects.

Then use **Edit / Copy** to put a copy on the Windows Clipboard. To paste it into the Map Window, use **Edit / Paste**. The copied object may not be the same size as the original, but it can be moved or resized as described previously.

Deleting Objects

Select the objects to be deleted. Then use **Edit / Delete** to remove the objects as shown in Figure 4.20.

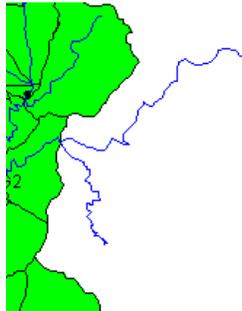


Figure 4.20
Deleted Objects.

To undelete the objects, use **Edit / Undo**. **Undo** can be performed several times in sequence.

5

ENGINEERING MODULE – INPUT

Introduction

WARMF requires two types of input: model coefficients and time series data. Model coefficients are for parameters that describe physical, chemical and biological characteristics of the watershed. Mostly, their values do not change with time. Time series data is time varying. They are for meteorology, air quality, point source discharges, and managed flows (diversions or releases) that are generally referred to as driving variables. Time series data also includes observed flow and water quality, which are not model inputs, but are required for model calibration.

Model coefficients can be entered directly into the dialog boxes on the computer screen. Time series data is stored in ASCII files. WARMF also provides spreadsheet functions for the user to import or update time series data through the data module.

During the model adaptation, the data for a given watershed is compiled and input to the model. Model coefficients are adjusted for a good match between the simulated results and observed data. Therefore, the WARMF CD will contain all input and observed data for the model. This chapter describes the menus and dialogs that can be used to review, change, or update the model coefficients and time series data. The model coefficients are classified into four groups. The first group is **Catchment Coefficients**. The second group is **River Coefficients**. The third group is **Reservoir Coefficients**. The fourth group is **System Coefficients**, applicable to the entire river basin.

To review the model coefficients, WARMF must be in the **Input** mode. To be in the **Input** mode, click on **Mode** in the main menu bar of the **Engineering** module and then select **Input** in the pull down list. The user can point and click at a specific object (e.g. catchment, river segment, or reservoir segment) on the basin map to access its coefficients. For the system coefficients, point and double click at any location outside of the basin map and inside the Map Window.

Catchment Coefficients

To edit coefficients for a catchment, double-click on that catchment on the basin map. To edit coefficients for several catchments at once, select the catchments and then double-click on one of them.

Figure 5.1 presents the dialog box for catchment coefficients. The name of this catchment is shown in the **Name** box and in the caption of the dialog box. This can be the common name for the piece of land. If a common name is not available, WARMF will display the catchment identification (id) number in the **Subcatchment ID** box..

The image in the upper right corner is a shrunken copy of the Map. The catchment being edited is highlighted. Below the shrunken map, there is a **coefficient selector**. Below it, there are nine categories of data: **Physical Data**, **Meteorology**, **Land Use**, **Fertilization**, **Irrigation**, **Erosion**, **BMP(s)**, **Septics/Reactions**, and **Soil Coefficients**. The user can point and click at the diamond button to activate a category of coefficients. Only one category can be activated at a time.

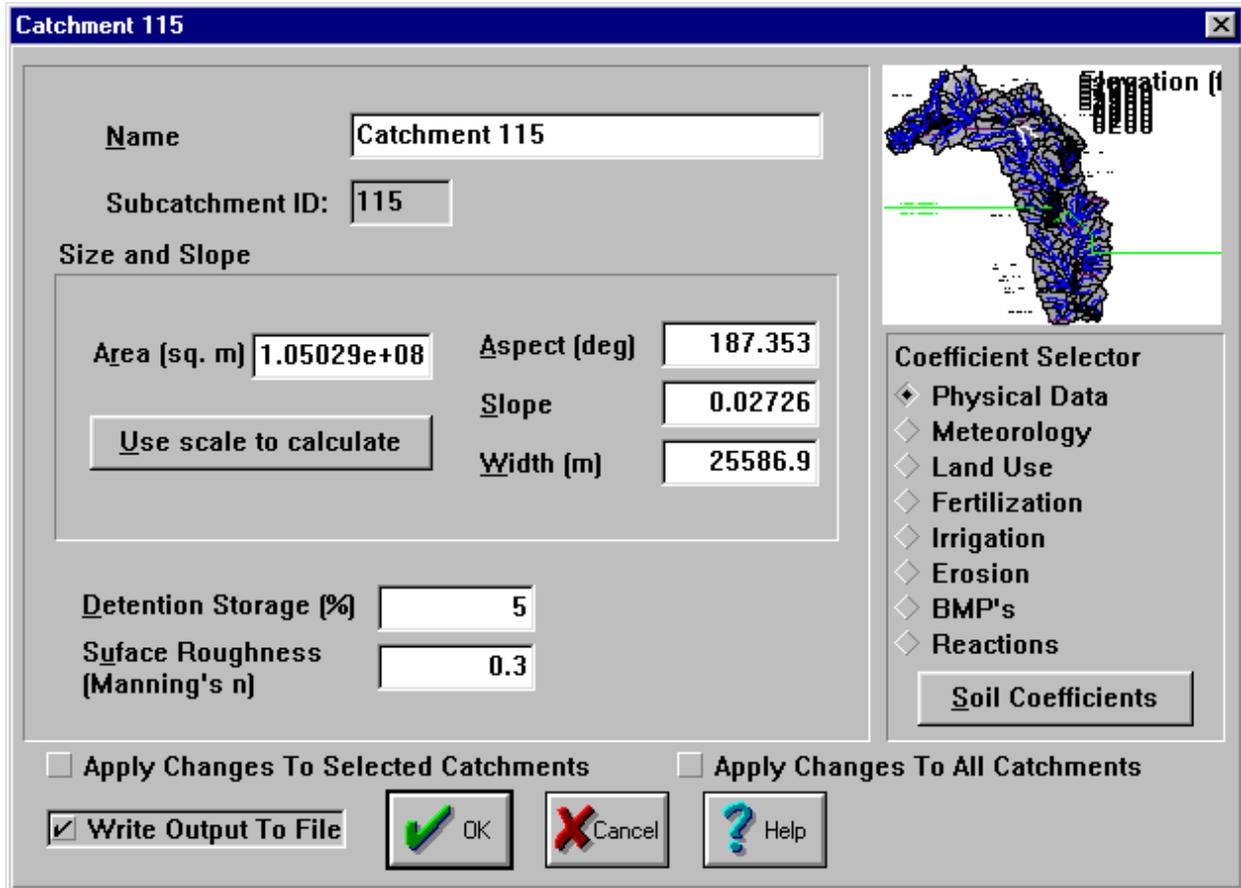


Figure 5.1
Catchment Input Dialog - Physical Data.

Physical data

Figure 5.1 presents the input dialog for physical data of a catchment. The physical data includes area, aspect, slope, width, detention storage, and surface roughness of the land catchment. Most of the values shown in the dialog boxes are calculated by WARMF using the DEM data. For that reason, their values have several decimal points.

The variable names of physical data, their units, ranges, and definitions are shown in Table 5.1.

Table 5.1
Physical Data for Catchments.

Variable	Units	Range	Description
Area	m ²	> 0	Catchment area
Use Scale to Calculate			Calculates the catchment area automatically
Aspect	degrees	0 - 360	Catchment facing, clockwise from north
Slope	m / m	> 0	Average slope of the catchment
Width	m	> 0	Average width of the catchment perpendicular to flow
Detention Storage	%	0 - 100	Surface depression storage
Surface Roughness		0.1 – 0.3	Manning's coefficient

All the numbers in dialog boxes can be modified directly on the computer screen. After the data corrections, the user can have several options on how the changes are to be stored. When the **Apply Changes to Selected Catchments** button is checked, the changes, other than catchment dimensions, will be made to all selected catchments. When the **Apply Changes to All Catchments** button is checked, the changes will be made to all catchments.

Click on **Write Output to File** for WARMF to write the simulation results in an output file for this particular catchment. When this is not checked, the output for the catchment will not be written to save disk space.

To save the changes made, click **OK**. To ignore changes, click **Cancel**.

Meteorology

Figure 5.2 presents the input dialog for **Meteorology**. This dialog provides a mechanism to assign the data file (e.g. MORGANTN.MET) of a nearby meteorological station to a land catchment. Data from a meteorological station can be assigned to multiple catchments, each with appropriate adjustment factors for precipitation and temperature. The applicable air quality data file (e.g. cranberry.air) can also be assigned in this dialog. The definition, unit, and range of meteorological input variables are presented in Table 5.2.

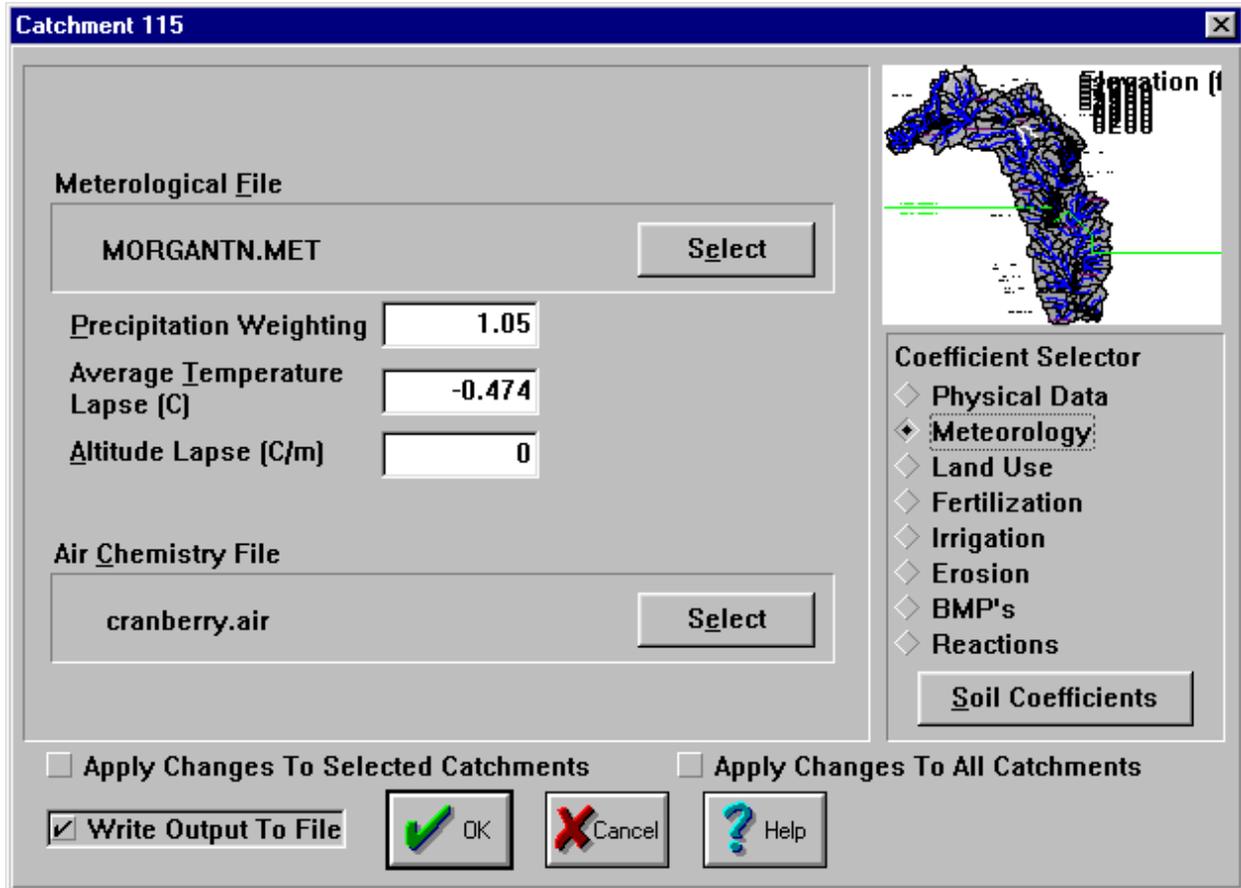


Figure 5.2
Catchment Input Dialog - Meteorology.

Table 5.2
Catchment Input Dialog - Meteorology.

Variable	Units	Range	Description
Meteorology File			Meteorological data file. Click on Select to choose a file for the applicable station
Precipitation Weighting		0.5 - 1.5	A multiplier to adjust precipitation at meteorology station to the catchment
Temperature Lapse	°C	-5 - 5	Temperature difference between the catchment and the meteorology station.
Altitude Lapse	°C / m	0.001 - 0.009	Temperature lapse rate per meter of elevation
Air Chemistry File			Air/rain chemistry data file. Click on Select to choose a file for the applicable station

Land Use

Figure 5.3 is the input dialog for **Land Use** coefficients. The land use coefficients are expressed in percent of catchment area. The values can range from 0 to 100%. The sum of all land uses must equal 100.

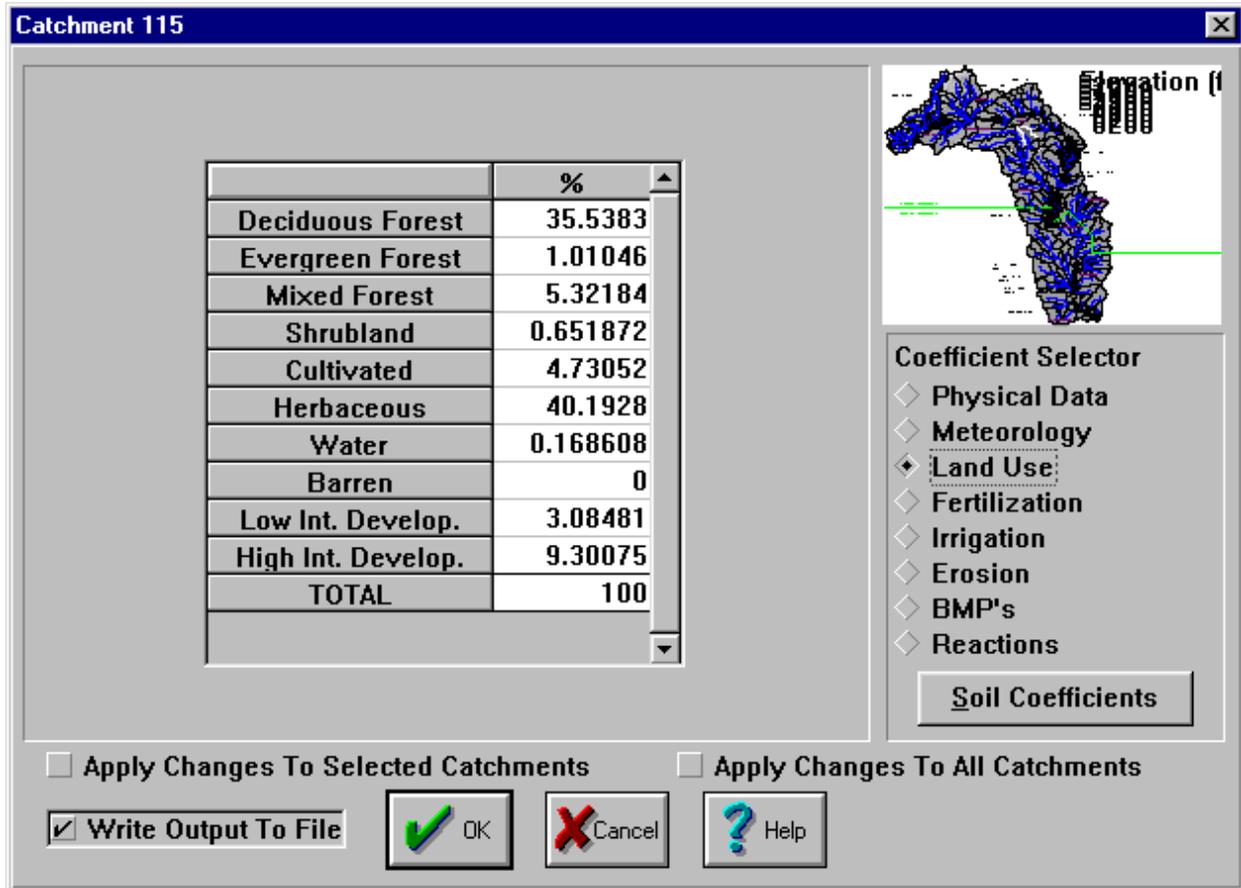


Figure 5.3
Catchment Input Dialog - Land Use.

Land use data can be imported as an **ArcView Shape File**. The data shown in Figure 5.3 represents the base case that has been imported during the model set up. The data can be modified in this dialog.

To import a projected land use, the first step is to check if there are new land use categories. Add the new land use categories into the land use category list (see a later section under System Coefficients). After the land use category list is updated, select **File / Import / Land Use** and then the appropriate **SHP** file. The program will display the dialog in Figure 5.4, asking for the field which contains land use:

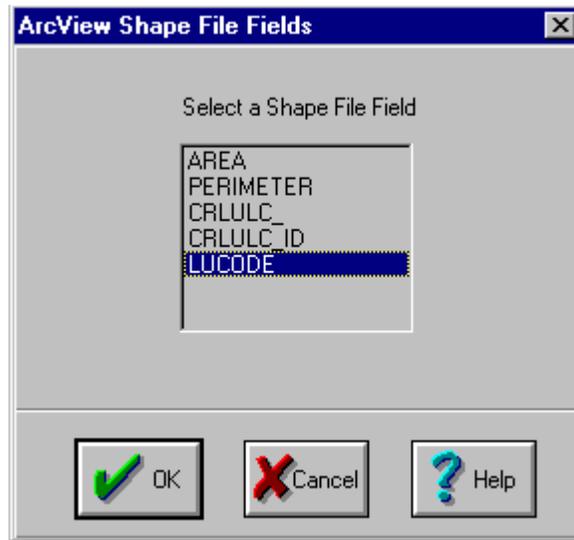


Figure 5.4
Fields in the Arc View Shape File.

After the field selection, the program will display Figure 5.5, asking you to match the land use codes:

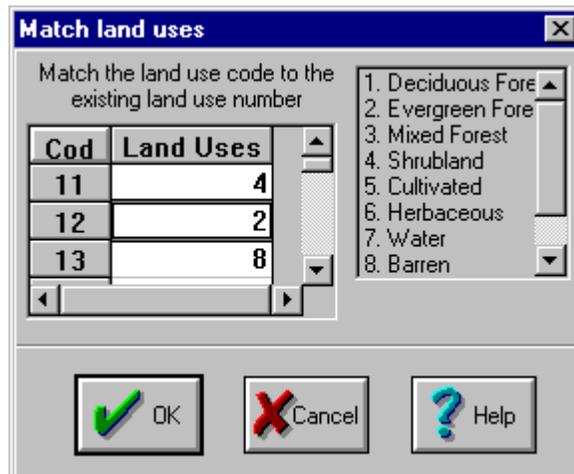


Figure 5.5
Matching Land Use Codes

The first column shows the code numbers used in the Arc View Shape file. The numbers below the **Land Uses** column are the corresponding land use categories used in WARMF. The complete list of the land use categories is provided in the dialog box on the right. You can find the corresponding land use from the list on the right and enter the number into the spreadsheet. After matching all of the codes, select **OK** and WARMF will import the new land use data.

Fertilization

Figure 5.6 is the input dialog for **Fertilization** coefficients. The fertilizer application is a function of land use, time (month), and chemical compositions. For cropland, these may be the actual fertilizer loadings. For others, they can be fertilizer equivalents, e.g. horse or cow manure on grazing land, and lawn chemicals, pet droppings, automobile exhaust, and garbage on urban land.

Subcatchment 364

Land Use: **Golf Course/Farm**

	April	May	June
Ammonia, kg/ha N	34.85	34.85	34.85
Aluminum, kg/ha	0	0	0
Calcium, kg/ha	0	0	0
Magnesium, kg/ha	0	0	0
Potassium, kg/ha	17.43	17.43	17.43
Sodium, kg/ha	0	0	0
Sulfate, kg/ha S	42.56	42.56	42.56
Nitrate, kg/ha N	0	0	0
Chloride, kg/ha	0	0	0
Phosphate, kg/ha P	8.714	8.714	8.714
Org. Carbon, kg/ha	0	0	0

Maximum Accumulation Time (days): **15**

Apply Changes To Selected Catchments Apply Changes To All Catchments

Write Output To File

Coefficient Selector

- Physical Data
- Meteorology
- Land Use
- Fertilization
- Irrigation
- Erosion
- BMP's
- Septic Sys./Reactions

Figure 5.6
Catchment Input Dialog - Fertilization.

Push the down arrow for a pull down list of land uses. Select the land use for fertilizer application. Monthly fertilizer loadings are for individual chemical constituents applied to the land.

The loading data can be entered one by one into the spreadsheet. If there is a spreadsheet for the fertilizer application rates, it can be copied into WARMF, using the **CTRL-C** (copy) and **CTRL-V** (paste) commands. **Maximum Accumulation Time** is the longest amount of time fertilization deposited on impervious land surface can build up without being washed off (>0, days).

Irrigation

Figure 5.7 is the input dialog for **Irrigation** coefficients. Irrigation is a function of land use. The coefficients show the amount of irrigation water applied to the specific land use area of the catchment. The coefficients also specify the source of irrigation water and percentage of its flow used.

Subcatchment 371

Land Use: Pasture

	%
Stmboat.flo	6
Lschance.flo	27
Lake.flo	10

Add

Click on a row and then Ctrl+Del to remove.

Coefficient Selector

- Physical Data
- Meteorology
- Land Use
- Fertilization
- Irrigation**
- Erosion
- BMP's
- Reactions

Soil Coefficients

Apply Changes To Selected Catchments Apply Changes To All Catchments

Write Output To File

Figure 5.7
Catchment Input Dialog - Irrigation.

Push the down arrow for a pull down list of land uses. Select the land use that is irrigated (e.g. Pasture, or Farmland). Then add the names of the diversions where the water is coming from with the **Add** button. For each diversion, set the percentage of its flow to apply to the catchment. The program allows for a land to be irrigated by water diverted from multiple locations. A single diversion may irrigate more than one catchment as long as the total percent from the diversion is less than or equal to 100. Diversions from rivers are set in the **River Input Dialog**.

Erosion

Figure 5.8 shows the input dialog for **Erosion** coefficients. The erosion coefficients specify the erosivity factor of the soil and its particle contents in terms of clay, silt, and sand. Table 5.3 provides a description of the **Erosion** coefficients.

Catchment 115

Soil Erosivity Factor: 0.1

Particle Content of Soil Surface (%)

Primary Clay	20
Primary Silt	40
Primary Sand	40

Coefficient Selector

- Physical Data
- Meteorology
- Land Use
- Fertilization
- Irrigation
- Erosion**
- BMP's
- Reactions

Soil Coefficients

Apply Changes To Selected Catchments Apply Changes To All Catchments

Write Output To File

Figure 5.8
Catchment Input Dialog - Erosion.

Table 5.3
Erosion Coefficients for a Catchment.

Variable	Units	Range	Description
Soil Erosivity	none	0.1 - 0.4	Erodibility of soil from Universal Soil Loss Equation
Primary Clay	%	0 - 100	Fraction of clay in erodible soil
Primary Silt	%	0 - 100	Fraction of silt in erodible soil
Primary Sand	%	0 - 100	Fraction of sand in erodible soil

BMP(s)

Figure 5.9 presents the input dialog of BMP(s). BMP(s) are best management practices, which can be used to reduce nonpoint source pollution. There are hundreds of BMP(s) including nonstructural and structural alternatives. The structural alternatives include animal fencing, detention ponds, and buffer zones. The nonstructural alternatives include street sweeping and the application rate of fertilizer or pesticide. The user can adjust fertilizer application rate to evaluate its effectiveness in improving water quality.

Subcatchment 371

Livestock Fencing

Livestock Land Use: Pasture

Direct Stream Access (%): 25

Detention Pond Volume (m³): 0

Street Sweeping

Frequency (days): 0 Efficiency (%): 0

Buffer Zone

Percent Buffered: 50 Slope: 0.01

Width (m): 10 Roughness: 0.3

Coefficient Selector

- ◇ Physical Data
- ◇ Meteorology
- ◇ Land Use
- ◇ Fertilization
- ◇ Irrigation
- ◇ Erosion
- ◆ **BMP's**
- ◇ Reactions

Soil Coefficients

Apply Changes To Selected Catchments Apply Changes To All Catchments

Write Output To File

OK Cancel Help

Figure 5.9
Catchment Input Dialog – BMP(s).

Livestock fencing is applicable to the pasture land only. The coefficient specifies the percentage of animals that have a direct access to the river bank. The model assumes that these animals will discharge their wastes directly into the river. The remaining animals will discharge their wastes to the land as fertilizer.

The model coefficient for detention pond includes the total volume of all ponds in the land catchment. The algorithm for the detention pond will be added in the near future.

Street sweeping is applied to the impervious area of urban land. Its coefficients include the sweeping frequency and removal efficiency. Buffer zones or buffer strips are areas of land adjacent to a riverbank that may have more vegetation and a flatter slope. The sediment laden surface runoff may flow over the buffer strips before entering the river. It is considered a best management practice for controlling sediments and their associated nutrients outflow from land to the river. Table 5.4 provides a description of the coefficients associated with **BMP(s)**.

Table 5.4
BMP Data for Catchments.

Variable	Units	Range	Description
Livestock Land Use			The land use for livestock grazing
Direct Stream Access	%	0 – 100	Percent of livestock whose waste is discharged directly to stream. The remaining livestock is assumed to drop directly on to land
Detention Pond Volume	m ³	≥ 0	Volume of all detention ponds in the catchment
Street Sweep Frequency	days	≥ 0	The number of days between street sweepings on impervious surfaces
Street Sweep Efficiency	%	< 100	Percent of solid build-up removed by each street sweeping pass
Percent Buffered	%	0 - 100	Percent of surface runoff that flows over a buffer strip, i.e. the percent of total river length that is buffered in the catchment.
Width	m	> 0	Average width of buffer strip
Slope	none	> 0	Average slope of buffer strip
Roughness	m ^{1/3} /s	0.035 - 0.1	Manning's n for buffer strip (Chow et. al 1988)

Septics / Reactions

Figure 5.10 is the input dialog for septic systems and soil reaction rates. For each catchment, the population served by septic systems is specified. Septics usually discharge into the top soil layer. Septics within each catchment are grouped into three categories: type 1, type 2, and type 3. These types may represent systems of varying performance and effluent quality such as standard systems, advanced treatment systems, or failing systems. In the system coefficients dialog, discharge concentrations of the different septic types is specified.

For oxidation of ferrous to ferric iron, the rate coefficient is the maximum oxidation rate under the atmospheric condition of 21% oxygen. Table 5.5 presents the variable names and their value ranges.

Subcatchment 372

Septic System Data

Discharge Layer:

Population Served by Septics:

Distribution of Septic Systems (total should = 100)

Treatment Type 1 (%):

Treatment Type 2 (%):

Treatment Type 3 (%):

Reactions

Organic Acid Decay, 1/yr:

Soil Nitrification, 1/day:

Soil Denitrification, 1/day:

Fecal Coliform Decay, 1/day:

Sulfate Reduction, 1/day:

Ferrous Oxidation Rate, 1/day:

Coefficient Selector

- Physical Data
- Meteorology
- Land Use
- Fertilization
- Irrigation
- Erosion
- BMP's
- Septic Sys./Reactions:**

Apply Changes To Selected Catchments Apply Changes To All Catchments

Write Output To File

Figure 5.10
Catchment Input Dialog – Septics Systems / Reactions.

Table 5.5
Soil Reaction Rates.

Variable	Units	Range	Description
Organic Acid Decay Rate	year ⁻¹	0.06	Organic acid to inorganic carbon reaction rate in soil
Nitrification	day ⁻¹	0.1 – 2.0	Ammonia to nitrate reaction rate in soil
Fecal Coli. Decay	day ⁻¹	0.1	Decomposition of fecal coliform
Denitrification	day ⁻¹	0.1	Nitrate to nitrogen gas reaction rate in soil under anoxic conditions
Sulfate Reduction	day ⁻¹	>= 0	Sulfate to hydrogen sulfide reaction rate in soil under anoxic conditions
Ferrous Oxidation	day ⁻¹	0.1 – 0.3	Max. oxidation rate under the atmospheric condition of 21% oxygen

Soil Coefficients

Soil coefficients are divided into 6 subcategories, i.e. hydrology, solution, adsorption, mineral weathering, TIC (total inorganic carbon), and mining. They are listed at the lower left corner of the soil coefficients dialog. Push the diamond button of a specific category to bring up its coefficients dialog.

Soil Hydrology

Figure 5.11 presents the input dialog for **Soil Hydrology Coefficients**, which is the default dialog when the soil solution button is pressed. This dialog is for editing parameters that control soil hydrology. The soil is divided into layers. The number of layers can range from 1 to 5. Layer 1 is on the top. Each layer has its own area, depth, field capacity, and hydraulic conductivity. With variable areas of soil layers, the model can account for a bowl shape basin or a catchment with constricting base rocks in each soil strata. Table 5.6 presents the variable names and their value ranges.

The screenshot shows a software dialog box titled "Soil Coefficients". At the top, there is a text input field labeled "Number of Soil Layers:" with the value "4" entered. Below this is a table with 8 columns: an unlabeled column for layer numbers, "Area m2", "Thickness cm", "Initial Moisture", "Field Capacity", "Sat. Moisture", "Horizontal Cond. cm/d", and "Vertical Cond. cm/d". The table contains 4 rows of data. At the bottom left, there are six diamond-shaped buttons for navigating to other coefficient categories: Hydrology, Solution, Adsorption, Mineral Composition, TIC, and Mining. At the bottom right, there are two buttons: "OK" with a green checkmark icon and "Help" with a blue question mark icon.

	Area m2	Thickness cm	Initial Moisture	Field Capacity	Sat. Moisture	Horizontal Cond. cm/d	Vertical Cond. cm/d
1	22270000	17.21	0.465	0.332	0.535	6060	453
2	22270000	39.89	0.284	0.185	0.284	2060	285
3	22270000	44.38	0.237	0.226	0.331	1075	296
4	354900	1520	0.012	0.011	0.015	3	3

Figure 5.11
Catchment Input Dialog - Hydrology Soil Coefficients.

Table 5.6
Soil Hydrology Coefficients.

Variable	Units	Range	Description
Area	m ²	> 0	Surface area of the soil layer
Thickness	cm	> 0	Thickness of the soil layer
Initial Moisture	m ³ /m ³	0 - 0.6	Initial soil moisture by volume
Field Capacity	m ³ /m ³	0 - 0.4	Field capacity of the soil
Saturation Moisture	m ³ /m ³	0.2 - 0.6	Saturated soil moisture of the soil
Horizontal Conductivity	cm / day	> 0	Horizontal hydraulic conductivity of the soil
Vertical Conductivity	cm / day	> 0	Vertical hydraulic conductivity of the soil
Root Distribution	none	0 - 1	Portion of roots in each soil layer. The total over all soil layers should equal 1.
Density	g / cm ³	2 – 3	Density of the soil
Soil Tortuosity	m / m	> 1	Ratio of flow path length to straight line distance

Soil Solution

Figure 5.12 presents the input dialog of soil solution coefficients. This is the dialog to specify the initial condition of soil solution chemistry. The parameters include temperature and the concentrations of ammonia, aluminum, calcium, magnesium, potassium, etc. The scroll bar can be dragged at the bottom of the spreadsheet to bring other parameters into view. All parameter values can be specified for each soil layer.

Soil Coefficients [X]

Number of Soil Layers:

Initial solution concentrations, mg/l. Temp. in Celsius.

	Temp.	NH4	Al	Ca	Mg	K	N
1	15	0.05	0.15	25	2	3	
2	15	0.05	0.15	25	2	3	
3	15	0.05	0.15	25	2	3	
4	10	0.05	5	25	2	3	

◊ Hydrology ◊ Mineral Composition
 ◆ Solution ◊ TIC
 ◊ Adsorption ◊ Mining

OK Help

Figure 5.12
Catchment Input Dialog - Soil Solution Coefficients.

Adsorption

Figure 5.13 presents the input dialog for adsorption coefficients. The cation exchange capacity (CEC) is expressed in meq/100g soil and major cations (H^+ , NH_4^+ , Ca^{2+} , Mg^{2+} , K^+ , Na^+) adsorbed on the exchange sites are expressed in percent of CEC as indicated in the dialog. The data can be determined by a standard laboratory procedure of extracting and measuring soil solution chemistry, followed by flushing out the cations on the exchange sites with concentrated barium chloride. The model assumes that the CEC not occupied by major cations will be assigned to hydrogen ions. For other cations and anions (e.g. SO_4 and PO_4), enter the adsorption isotherm in liters per kg of soil.

Soil Coefficients [X]

Number of Soil Layers:

Initial base saturation / adsorption isotherms
 Units are: % of base saturation for H, NH4, Ca, Mg, K, Na;
 meq/100 g soil for Cation Exchange Capacity (CEC); adsorption isotherm (L/kg) for all others.

	CEC	H	NH4	Al	Ca	Mg
1	36.68	23	1	0	50	20
2	12.22	23	1	0	50	20
3	9.31	23	1	0	50	20
4	2.16	23	1	0	50	20

Hydrology Mineral Composition
 Solution TIC
 Adsorption Mining

Figure 5.13
Catchment Input Dialog - Soil Adsorption Coefficients.

Mineral Composition

Figure 5.14 presents the input dialog to enter the mineral composition of each soil layer. The units are percent by weight. The weathering by-products of each mineral are set through the system coefficients dialog, which will be discussed later.

Soil Coefficients X

Number of Soil Layers:

Mineral composition, %

	Hornblend	Sphalerite	Calcite	Feldspar	Pyrite
1	1	0	0	1	0.001
2	5	0	0	5	0.01
3	15	0	0	10	0.1
4	40	1	7	40	1.5

Hydrology Mineral Composition
 Solution TIC
 Adsorption Mining

Figure 5.14
Catchment Input Dialog – Mineral Composition.

As described in the technical report, this part of the model was originally designed for watersheds in the Adirondacks region of upstate New York, where the soils are glacial tills, composed of primary minerals. For watersheds where the soils are made of well-weathered silt, clay, and sand, the content of primary minerals can become very small.

TIC

Figure 5.15 presents the input dialog for TIC, which stands for total inorganic carbon. This is provided so the model can account for the ground water being super saturated with carbon dioxide.

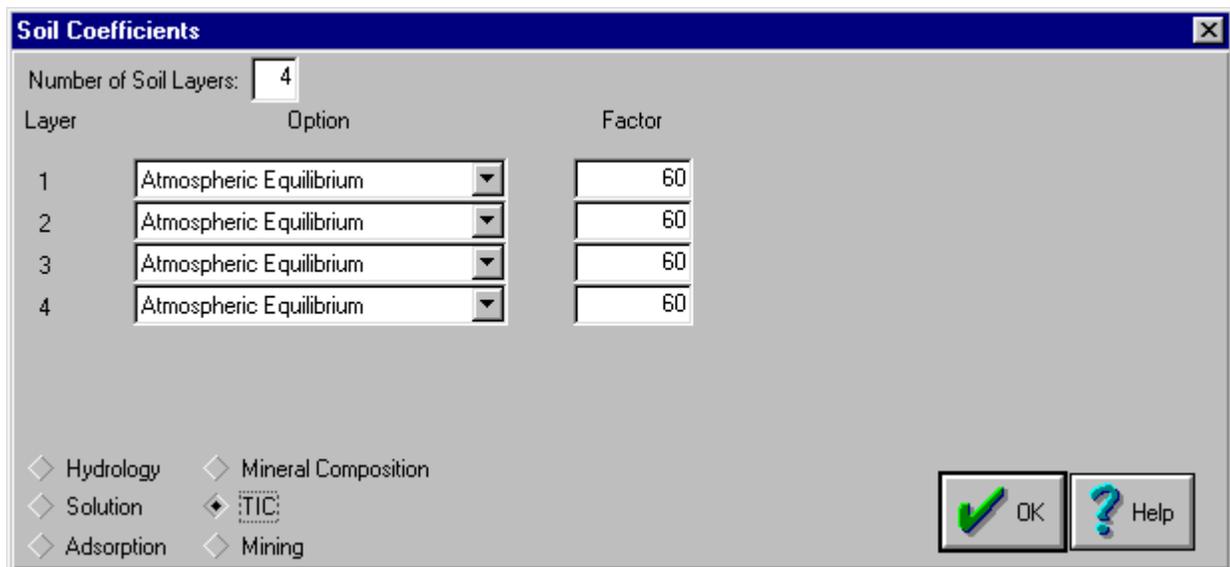


Figure 5.15
Catchment Input Dialog - TIC Coefficients.

Three options are provided to calculate TIC. Table 5.7 describes the options. In general, the **Atmospheric Equilibrium** option is recommended. **Factor** indicates the degree of super saturation over one atmosphere. Its value generally ranges from 20 to 100.

Table 5.7
TIC Calculation Options.

Option	Description
Calculate	Calculate TIC as the sum of TIC in water and CO ₂ in air space.
Atmospheric Equilibrium	Calculate TIC by Henry's Law. A super saturation Factor is applied. This option is recommended.
Constant Concentration	Set TIC as a constant in moles/l.

Mining

For the catchment with mining activities, there are three possibilities: deep mine only, surface mine only, and a mixture of surface and deep mines. Figure 5.16 shows the dialog to enter data for each possibility.

Soil Coefficients [X]

Number of Soil Layers:

Bottom layer is deep mine overburden Deep Mine Permits

Bottom layer is surface mine overburden in: Surface Mine Permits

Surface mine overburden characteristics:

	Area m ²	Thickness cm	Initial Moisture	Field Capacity	Sat. Moisture	Horizontal Cond. cm/d	Vertical Cond. cm/d
1	36774000	200	0.13	0.126	0.376	6000	296

Hydrology Mineral Composition
 Solution TIC
 Adsorption Mining

Figure 5.16
Catchment Input Dialog - Mining Coefficients.

If there are only deep mines, check the button for **bottom layer is deep mine overburden**. After that, push the down arrow of **bottom layer is surface mine overburden** and select no surface mine in the pull down list. In this case, the catchment surface will have the land use as specified in the input data. The water will percolate down to the deep mine tunnel for exit through a portal. If there are only surface mines in the catchment, do not check the button of **bottom layer is deep mine overburden**. Push the pull down arrow of **bottom layer is surface mine overburden**, select surface mine, and enter the parameter values for the characteristics of surface mine overburden. Since the land has been disturbed, the soil characteristics may have a higher porosity and hydraulic conductivity. In this case, WARMF will perform a separate simulation of acid mine drainage from the surface mine area of the catchment. The hydrology and nonpoint source load from other land uses in the catchment are simulated through normal procedure.

If there is a mixture of deep and surface mines, check the button for **bottom layer is deep mine overburden**. After that, push the pull down arrow of **bottom layer is surface mine overburden**, select surface mine, and enter the parameter values for the characteristics of surface mine overburden. In this case, WARMF will perform a separate simulation of acid mine drainage from surface mine area of catchment. The groundwater from other land use areas will percolate down to the deep mine tunnel for exit through a portal.

If specific mines are to be delineated as permitted point source discharges, press **Deep Mine Permits** or **Surface Mine Permits**. Figure 5.17 shows the dialog box which appears.

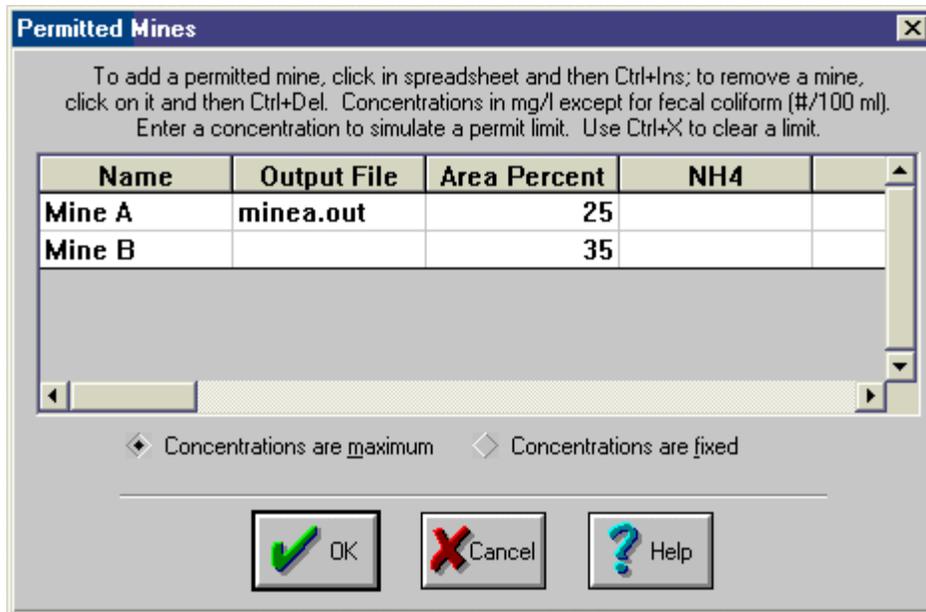


Figure 5.17
Permitted Mines.

To add a permitted mine, click inside the spreadsheet (even if it is blank) and press Ctrl+Ins. To remove a mine, click on it and then press Ctrl+Del. Enter the name of the mine in the first column. In the second column, enter a file name for text output from the mine (optional). In the third column, enter the percent of mined area (either deep or surface) in the catchment represented by the particular mine discharge. Loading from permitted mines is represented as point source loading. If a concentration limit on the mine discharge is to be represented, enter the concentration in the spreadsheet. There are two options for simulating specified concentrations. With **Concentrations are maximum** checked, the simulated concentration is set to the concentration limit when it otherwise would have been exceeded. With **Concentrations are fixed** checked, the concentration is always set to the specified value. To clear a concentration previously set, click on it and then press Ctrl+X.

River Coefficients

To edit coefficients for a river segment, double-click on the river segment on the Map. Figure 5.18 presents the dialog box of river coefficients. The name of this river segment is shown in the **Name** box. The default name of a river segment is the **Stream ID** number, which is used internally for connectivity among objects. The user can change the default name to its common name by simply typing it over the default. The stream ID number cannot be changed. The image in the lower left corner is a shrunken copy of the Map. Note that the river being edited is highlighted in this window.

There are tabs for nine different categories of river coefficients: **Physical Data**, **Stage-Width**, **Diversions**, **Point Sources**, **Reactions**, **Sediment**, **Initial Conc.**, **Observed Data**, and **CE-QUAL-W2**. To select a category, click on the tab. If changes have been made to any coefficients in the dialog boxes, there is a button to **Apply Changes to Selected Rivers**. There is also a button to **Apply Changes to All Rivers**.

The **Write Output to File** button is used to save the simulation results for later analyses. If this button is not checked, some disk space is saved but the simulation results for this particular stream segment cannot be reviewed.

To save changes when closing this dialog, click **OK**. To ignore changes, click **Cancel**.

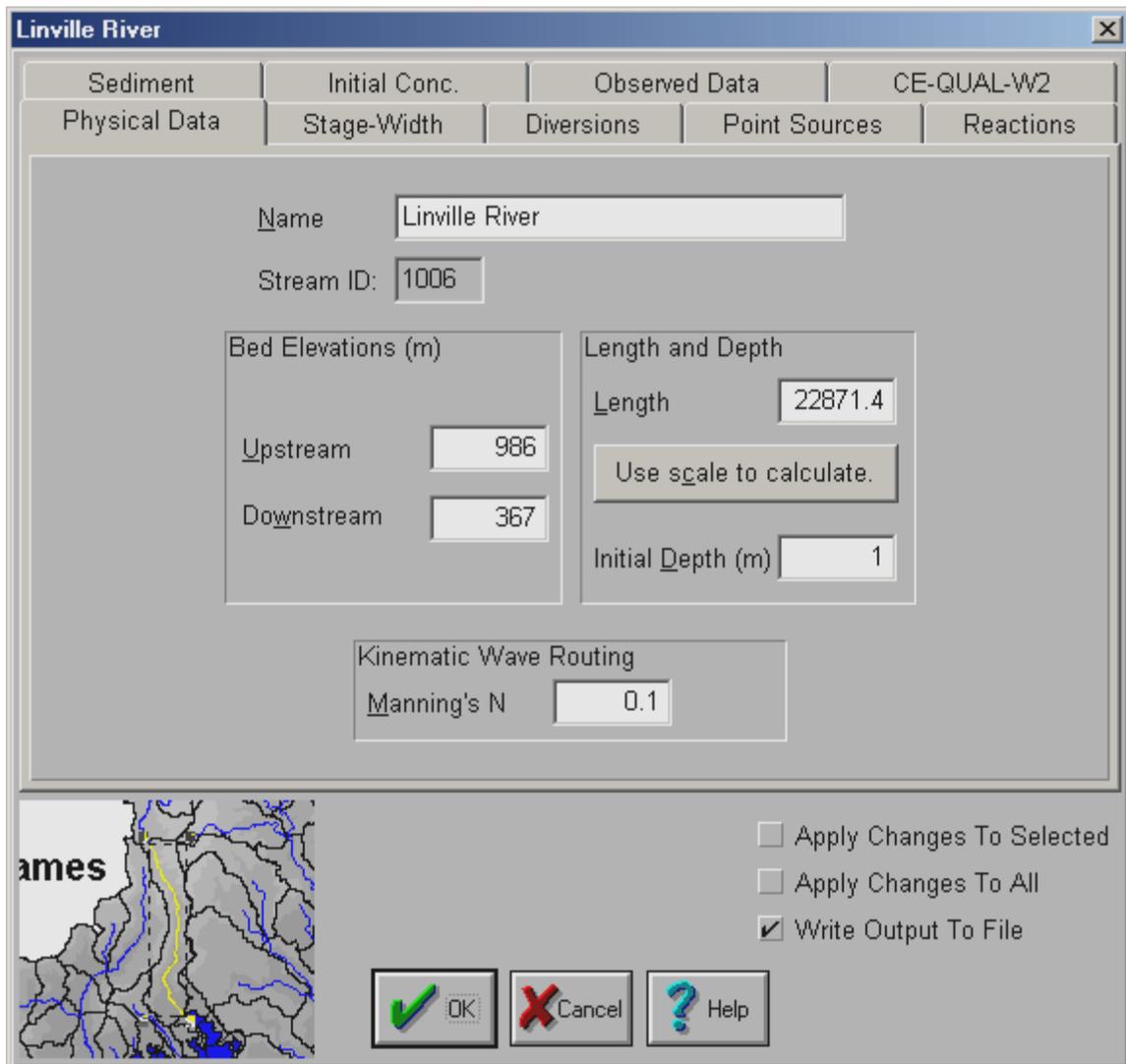


Figure 5.18
River Input Dialog - Physical Data.

Physical Data

Figure 5.18 is the input dialog for physical data of a river segment. The physical data of a stream segment includes bed elevations, length, initial water depth and Manning's N. WARMF automatically calculates the bed elevations with the DEM data. The user can push the **Use scale to calculate** button for WARMF to calculate the length of the river segment. If the river length has been estimated or measured, the user can type in the river length in meters. The initial water depth and Manning's N must be entered by hand.

Stage-Width Curve

Figure 5.19 is the tab for the stage-width curve. The spreadsheet provides two columns to enter up to 9 pairs of stage and width data. The curve for the relationship is automatically plotted. This curve represents the river cross section. It can be any shape. For the river with a flood plain on the side, a large increase of width can occur with a small increase in stage.

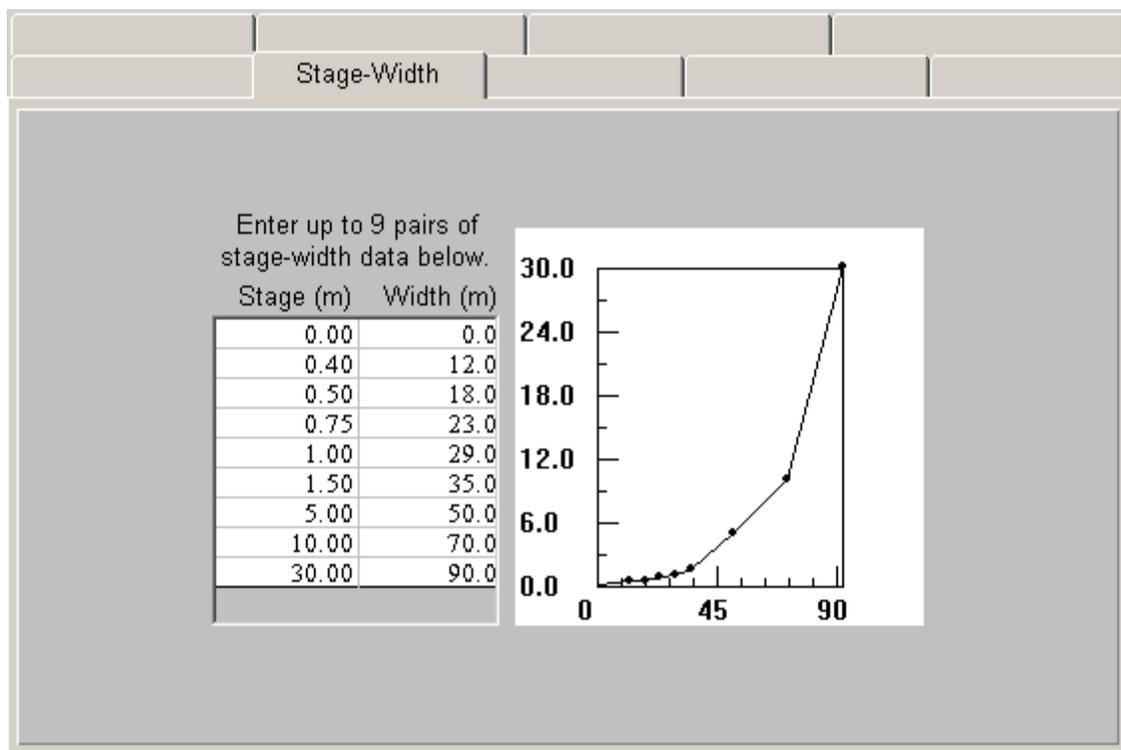


Figure 5.19
River Input Dialog - Stage-Width Curve.

Diversions

Figure 5.20 is the tab for diversions. The time series of a diversion is stored in an ASCII file. The user can use this dialog to assign the diversion file to a stream segment. Several diversions can be taken from a river segment. A stream segment can also receive flow from a diversion. In the example shown, there are three diversions from Truckee River at Farad. No diversion flow is discharged to this river segment. Diversion water used in land irrigation is entered through **Catchment Input Dialog** under **Irrigation**.

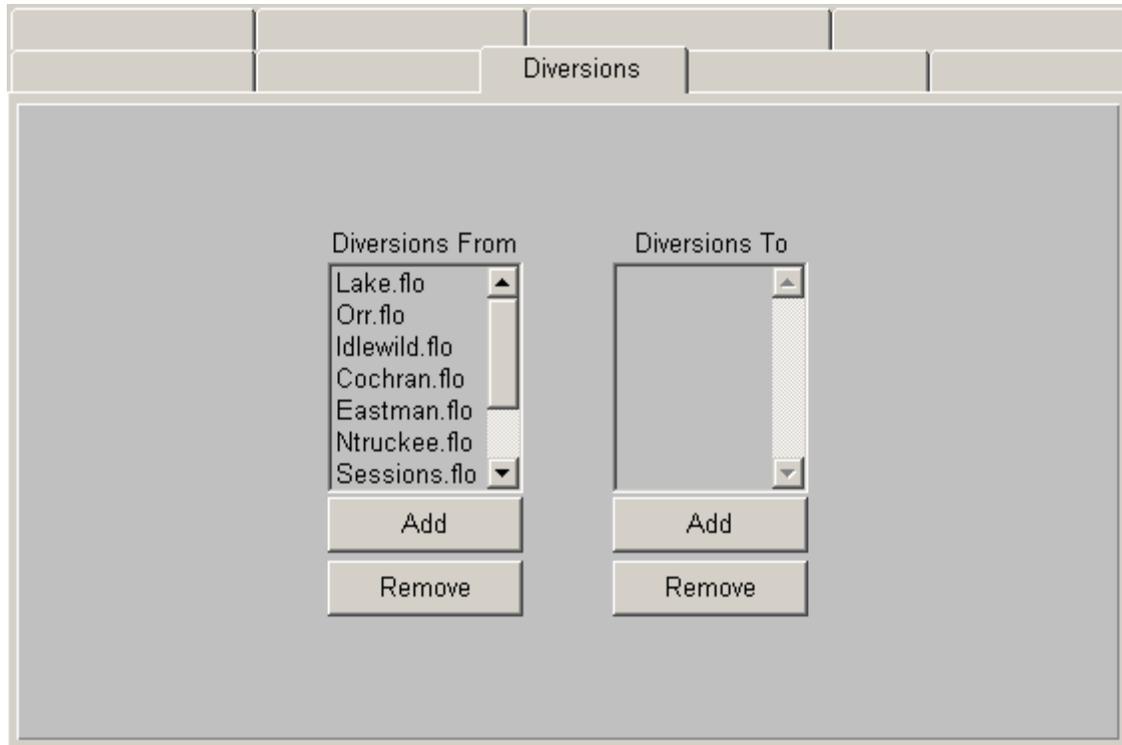


Figure 5.20
River Input Dialog - Diversions.

The **Add** and **Remove** buttons are used to add or remove diversion files (i.e. Lake.flo, Orr.flo, etc.), which contain day, month, year, and diverted flow in cubic meter per second. Their values can be viewed and modified through the **Data Module** under **Managed Flow**.

Point Sources

Figure 5.21 is the tab to assign the point source files to a river segment. WARMF stores all point source files in the same directory. To add a point source to the river segment, simply press the **Add** button. WARMF will show all point source files. Click on a specific discharge to add. To

remove a point source discharge from the river segment, select the point source file and press the **Remove** button.

Each discharger has a separate file that contains date, flow, and pollutant loadings. The data point can be as little as only one for the entire period or as frequent as daily. The model uses a step function to apply the pollutant loadings to the stream segment.

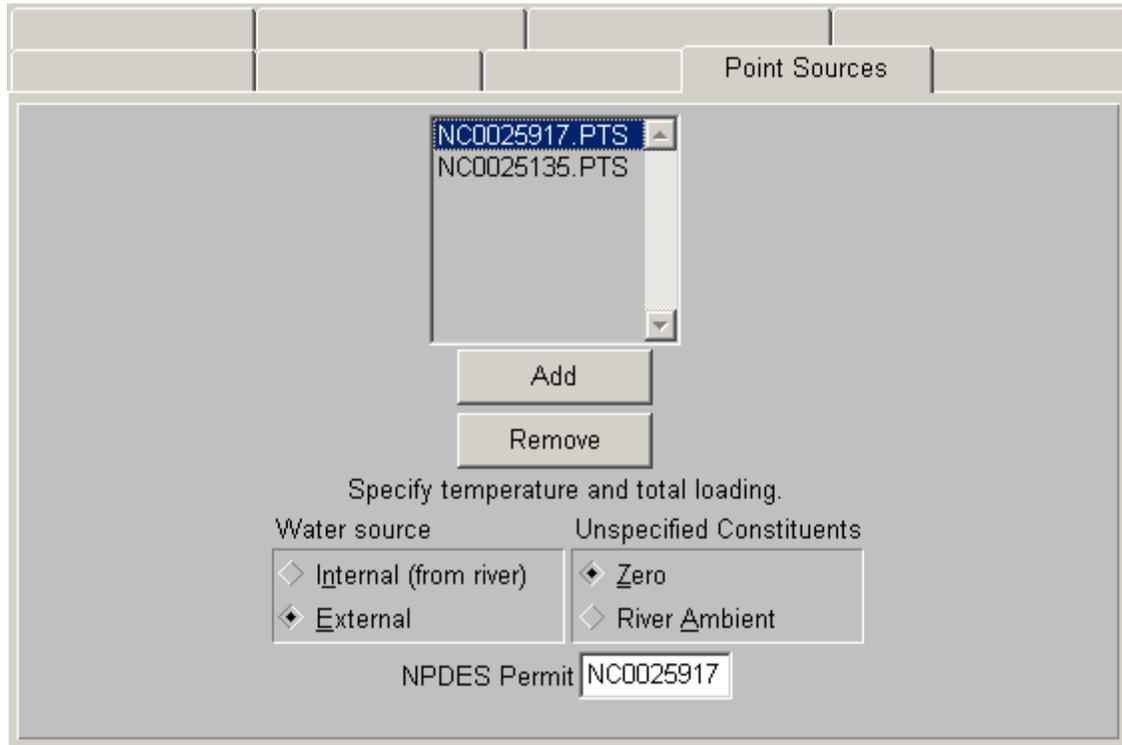


Figure 5.21
River Input Dialog – Point Sources.

A river segment can accept multiple point source discharges. WARMF accepts each discharge separately and puts them into the river segment. The location of point sources can be seen on the watershed map by selecting **View/Point Sources** from the main menu. To view point source data, double click on the white dot for a specific discharger. Point source file contains date, flow, and pollutant loading data. There is an issue of whether to enter the permitted loading or the actual loading. For the calibration and base case, we recommend to use actual loading. The permitted loading can be used in scenario evaluation.

Below the point source list, there is a line, “**water source information corresponds to selected point source**”. It invites user to point and click at a point source on the list to find out its water source. When NC0004243 is selected, for example, the two boxes below the line become activated. Since the water is from external source, the line changes to “**specify temperature and total loading**”. It means that the data in the point source file is the actual loading.

Point source load from a sewage treatment plant or an industrial facility is from an external source. A thermal discharge, on the other hand, is from an internal source, because the power plant withdraws water from the stream segment within the basin, adds heat or other chemical constituents, and discharges it again. For the internal source discharge, the line underneath the spreadsheet changes to “Specify changes in temperature and loading added”. In other words, the numbers in the point source file represent the increase of pollution loads for temperature and other water quality constituents. For the water quality constituents whose loading addition is not specified, one can select **River Ambient** to return the flow with the ambient concentrations of the water when it was diverted. One can also select **Zero** to return the flow with zero concentrations for all constituents not specified in the point source file.

Reactions

Figure 5.22 presents the input dialog of reaction coefficients for the river segment. The definition, units, and range of each reaction coefficient are presented in Table 5.8.

Reactions	
Agration Factor	1
SOD, g/m ² /day	0.5
Organic Carbon Decay, 1/day	0.1
Nitrification Rate, 1/day	1
Dentrification Rate, 1/day	0
Ferrous Oxidation Rate, (mol/l) ² /d	0
Sulfur Reduction, 1/day	0
Coliform Decay, 1/day	1
Convective Heat Factor	1e-08
Precipitate Settling, m/day	0
<input checked="" type="checkbox"/> Periphyton Growth	

Figure 5.22
River Input Dialog - Reactions.

Table 5.8
Coefficients for River Reactions.

Variable	Units	Range	Description
Aeration Factor	none	1.0	Scale factor to adjust the internally calculated re-aeration rate
SOD	g / m ² / day	0.1 - 2	Sediment oxygen demand
Organic Carbon Decay	day ⁻¹	0.1 - 1.0	Organic matter decay rate at 20 °C
Nitrification Rate	day ⁻¹	0.1 - 1.0	Nitrification rate at 20 °C
Ferrous Oxidation Rate	(mol/l) ² /d	1 x 10 ⁻¹²	The rate of ferrous (Fe ²⁺) oxidation to ferric ion (Fe ³⁺).
Sulfur Reduction	day ⁻¹	0 - 1.0	The rate of sulfate reduction to H ₂ S under anoxic conditions at 20 °C
Coliform Decay	day ⁻¹	0 - 1.0	The mortality of coliform bacteria at 20 °C
Convective Heat Factor	none	1.0e ⁻⁵	Empirical coefficient for convective heating
Precipitate Settling	m/d	0 – 1	The settling rate of chemical precipitates in the water column
Periphyton Growth		ON or OFF	Switch to indicate whether the substrate is suitable for periphyton growth

Sediment Transport

Figure 5.23 presents the tab for sediment transport coefficients. Table 5.9 provides a description of the coefficients for **Sediment**.

Sediment									
Detachment Velocity <u>M</u> ultiplier	1e-06								
Detachment Velocity <u>E</u> xponent	1								
Initial Sediment <u>D</u> epth (m)	1								
<u>V</u> egetation Factor	0.0003								
<u>B</u> ank Stability Factor	0.0003								
<table border="1"> <thead> <tr> <th colspan="2">Bed Particle Content (%)</th> </tr> </thead> <tbody> <tr> <td>Clay</td> <td>20</td> </tr> <tr> <td>Silt</td> <td>30</td> </tr> <tr> <td>Sand</td> <td>50</td> </tr> </tbody> </table>		Bed Particle Content (%)		Clay	20	Silt	30	Sand	50
Bed Particle Content (%)									
Clay	20								
Silt	30								
Sand	50								

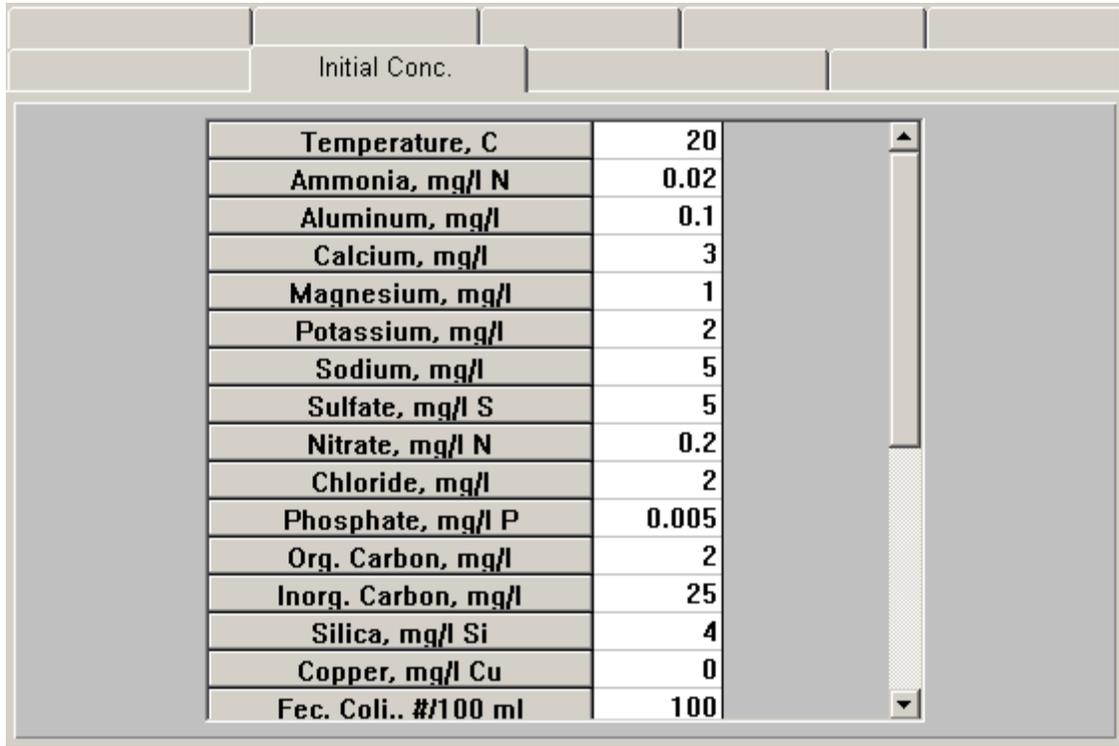
Figure 5.23
River Input Dialog - Sediment Coefficients.

Table 5.9
River Sediment Transport Coefficients.

Variable	Units	Range	Description
Detachment Velocity Multiplier	empirical	usually $1.0e^{-6}$	A proportional constant in the empirical sediment detachment equation.
Detachment Velocity Exponent	none	1.0 - 2.0	An exponential constant in the empirical sediment detachment equation.
Initial Sediment Depth	m	≥ 0	initial depth of sediment
Clay	%	0 - 100	fraction of clay in the river bottom sediment
Silt	%	0 - 100	fraction of silt in the river bottom sediment
Sand	%	0 - 100	fraction of sand in the river bottom sediment

Initial Concentration

Figure 5.24 presents the tab for **Initial Conc.**. The initial concentrations of various water quality constituents can be entered into the spreadsheet in the units specified.



Initial Conc.	
Temperature, C	20
Ammonia, mg/l N	0.02
Aluminum, mg/l	0.1
Calcium, mg/l	3
Magnesium, mg/l	1
Potassium, mg/l	2
Sodium, mg/l	5
Sulfate, mg/l S	5
Nitrate, mg/l N	0.2
Chloride, mg/l	2
Phosphate, mg/l P	0.005
Org. Carbon, mg/l	2
Inorg. Carbon, mg/l	25
Silica, mg/l Si	4
Copper, mg/l Cu	0
Fec. Coli.. #/100 ml	100

Figure 5.24
River Input Dialog - Initial Concentrations.

Observed Data

Figure 5.25 shows the tab for **Observed Data**. This is used to link between an observed data file to the river segment. The observed data file can be for hydrology with ORH extension or for water quality with ORC extension.

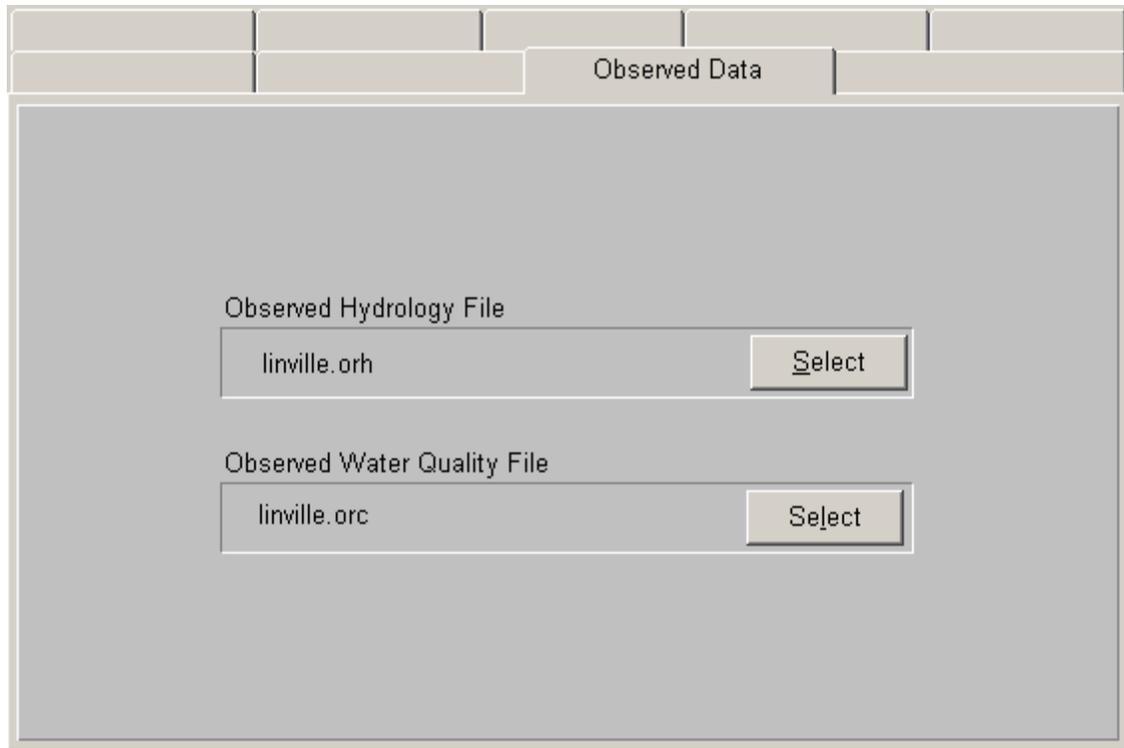


Figure 5.25
River Input Dialog - Observed Data.

To select an observed hydrology (flow, depth) or water quality file, click on the corresponding **Select** button. The observed data files can be edited through the data module as described in the **Update and Recalibration** chapter of this report.

CE-QUAL-W2

Figure 5.26 shows the tab for **CE-QUAL-W2**. This is used to have WARMF simulation output link directly to input files for CE-QUAL-W2.

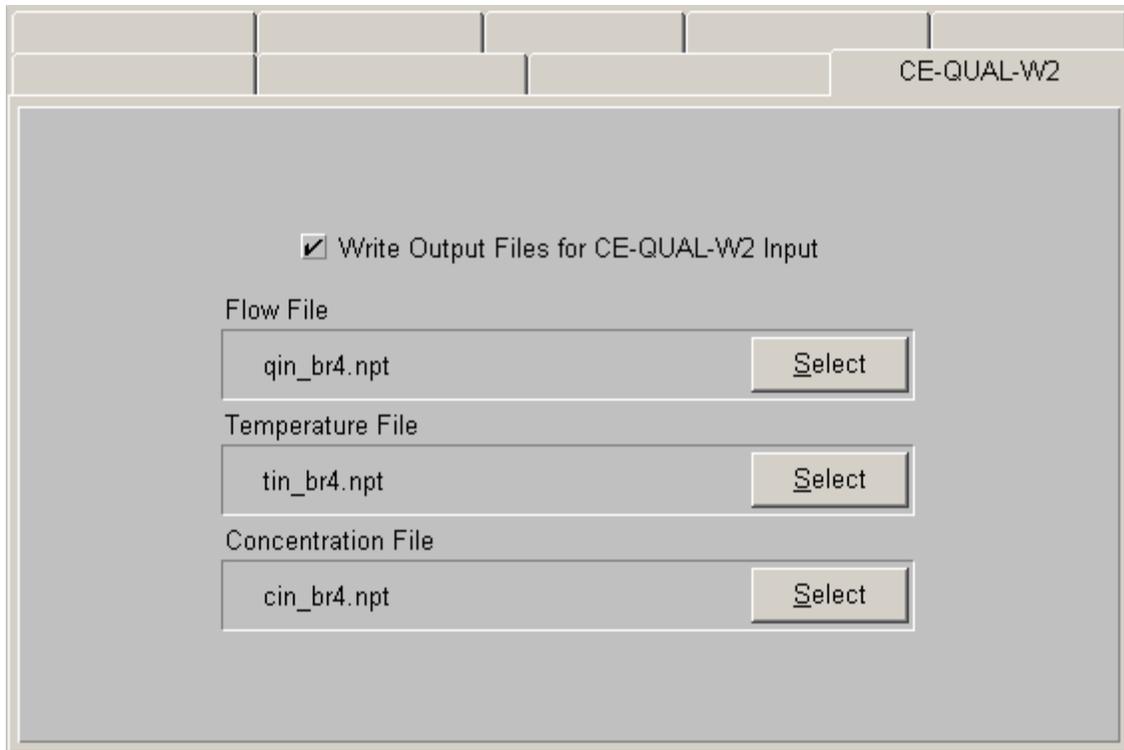


Figure 5.26
River Input Dialog – CE-QUAL-W2.

To have the simulation output for this river segment saved in the format for CE-QUAL-W2 branch inflow or tributary inflow input files, check **Write Output Files for CE-QUAL-W2 Input**. Then click each **Select** button to choose the names of the flow, temperature, and concentration files.

Reservoir Coefficients

To edit reservoir coefficients, double-click on a specific reservoir segment on the Map. Figure 5.27 shows the input dialog for Lake Norman.

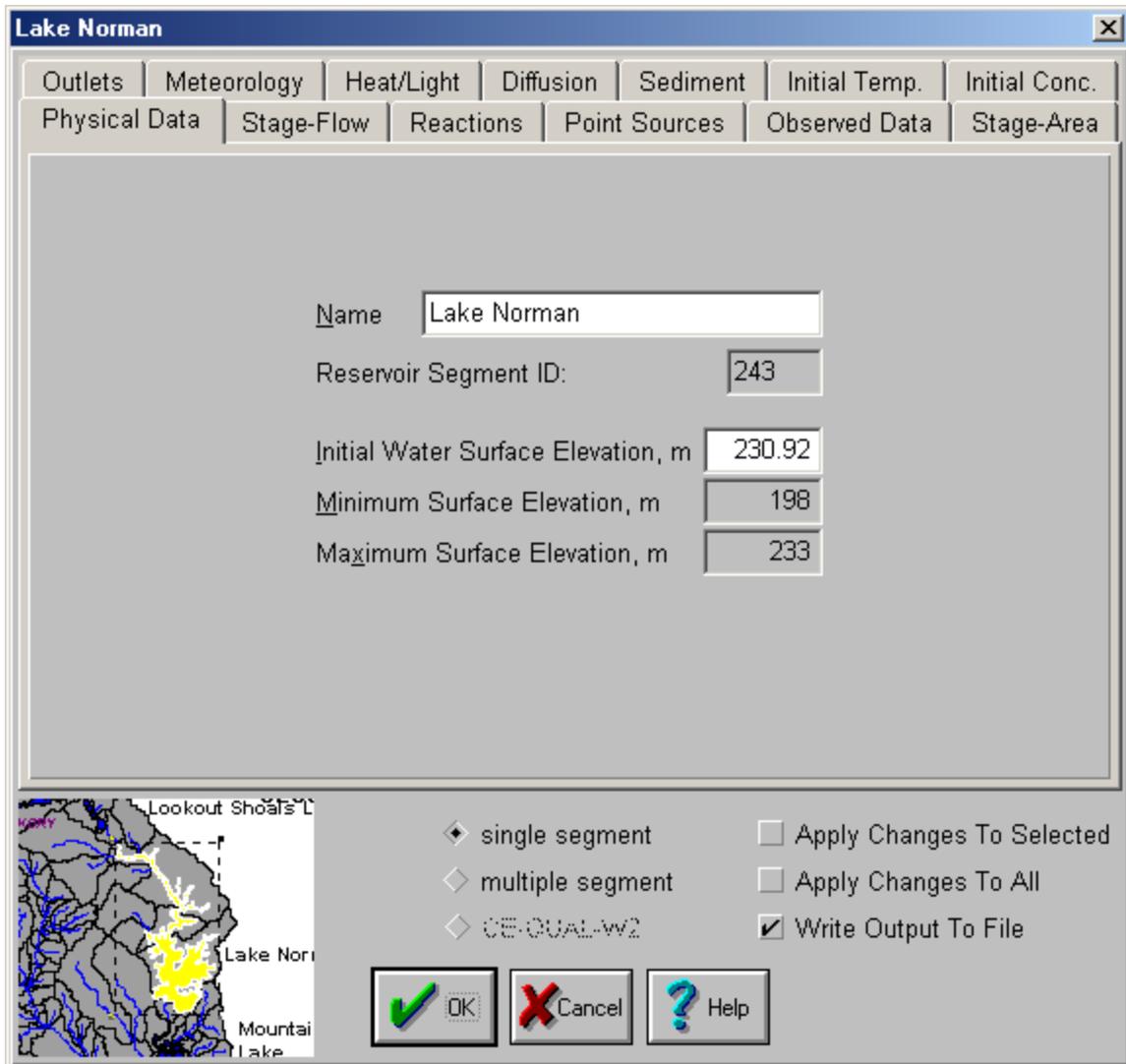


Figure 5.27
Reservoir Input Dialog - Physical Data.

The name of the reservoir segment is shown in the **Name** box. The identification number of the reservoir segment is shown in the **Id Number** box. The user can type the name of the lake in the name box, but cannot change the identification number of the reservoir used internally by WARMF.

The image in the lower left corner is a shrunken copy of the Map. Note that the reservoir segment being edited is highlighted in this window. There are tabs with various categories of coefficients for the reservoir segment. The user can activate a category of coefficients by pointing and clicking at its tab. Only one category of coefficients can be activated at a time. Below the coefficient categories, the user may select whether to simulate the water body as a **Single** or **Multiple** segments, or with **CE-QUAL-W2**. Single segment method is for reservoirs that can be stratified vertically, but mixed horizontally. For a long and narrow reservoir, it may

be more appropriate to divide the reservoir into multiple segments, each of which can be stratified vertically but mixed horizontally. WARMF is also capable of simulating reservoirs with CE-QUAL-W2. Refer to the CE-QUAL-W2 manual (Cole et. al. 2000) for information about its coefficients.

The **Apply Changes to Selected** box is used to apply changes made to all selected reservoir segments. The **Apply Changes to All** button is used to apply all changes made to the coefficients in the dialog to all reservoir segments in the river basin. The **Write Output to File** button is used to save the time series of simulation results for the reservoir segment. When this button is not checked, the output will not be available for later use.

To save the changes made when closing the dialog, click **OK**. To ignore changes, click **Cancel**.

Physical Data

Figure 5.27 is the dialog for **Physical Data**. Table 5.10 provides the definition of physical data for reservoirs.

Table 5.10
Physical Data for Reservoirs.

Variable	Units	Range	Description
Initial Water Surface Elevation	M		surface elevation at the beginning of simulation
Minimum Surface Elevation	M		the elevation of dead storage capacity
Maximum Surface Elevation	M	> min surface elevation	elevation of water over the spill way

Stage-Flow Curve

Figure 5.28 is the input dialog for the stage-flow curve of the reservoir spillway:

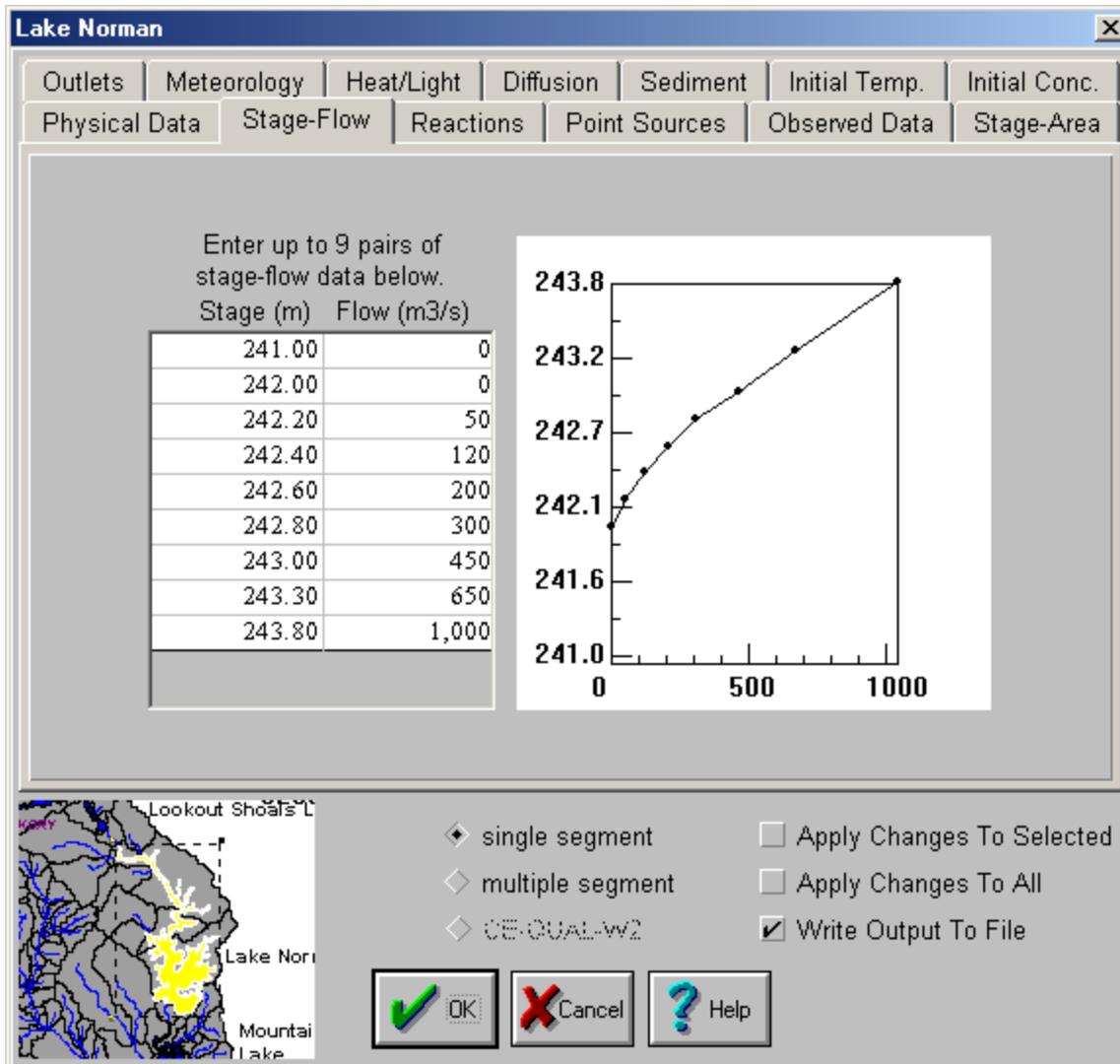


Figure 5.28
Reservoir Input Dialog – Stage-Flow Curve.

The stage-flow curve defines the spillway performance when spill is calculated automatically by WARMF.

Reactions

Figure 5.29 shows the dialog box for reaction rate coefficients. The reaction parameters involved are similar to those used in the river model, described in the previous section. Table 5.11 provides a description of the coefficients associated with **Reactions**.

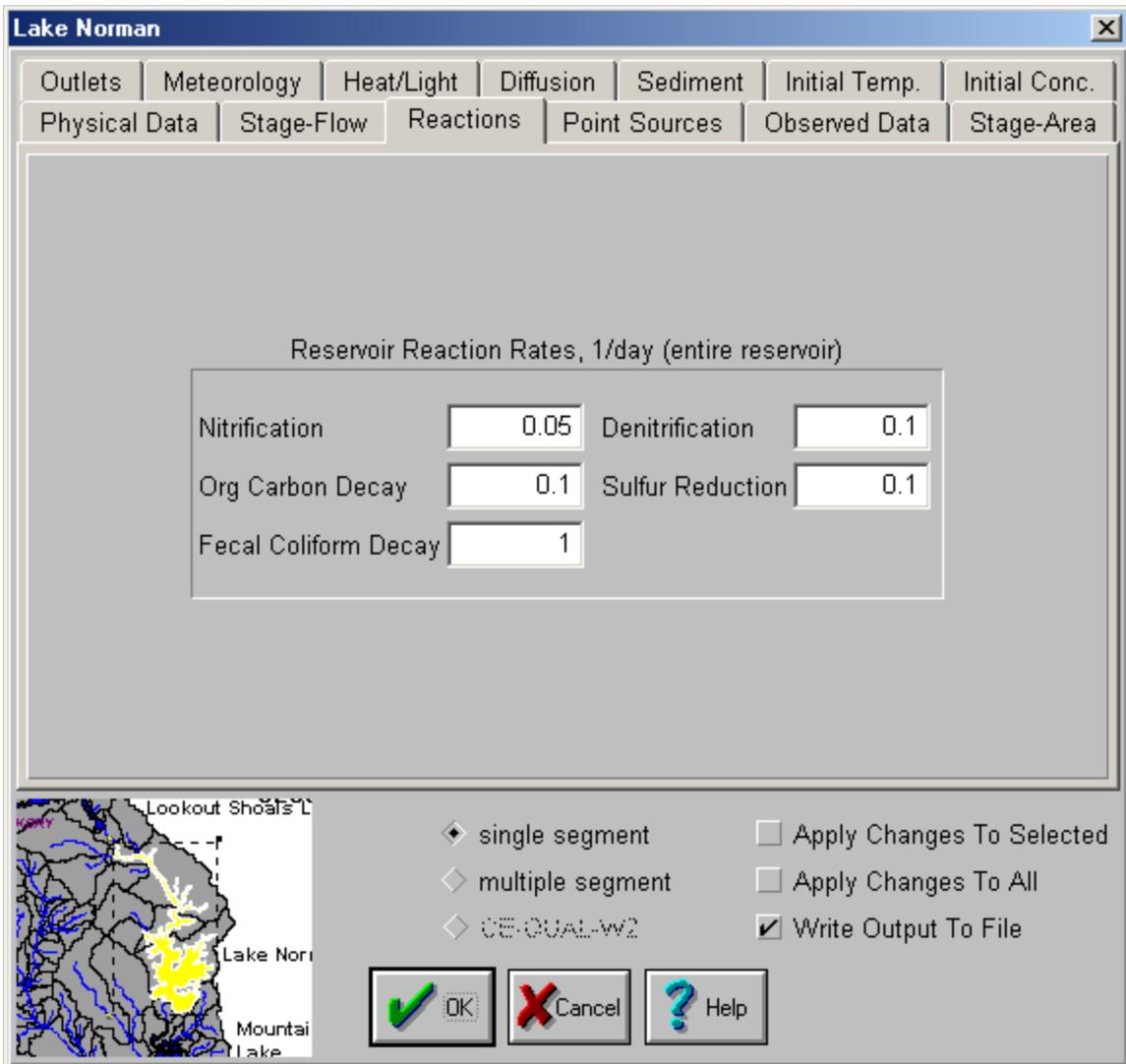


Figure 5.29
Reservoir Input Dialog – Reactions.

Table 5.11
Reactions Data for Reservoirs.

Variable	Units	Range	Description
Nitrification Rate	1 / day	0.1 - 1	Nitrification rate at 20 °C
Organic Carbon Decay Rate	1 / day	0.1 – 1	Organic carbon decay rate at 20 °C
Fecal Coliform Decay Rate	1 / day	0.1 – 1	Fecal coliform decay rate at 20 °C
Denitrification Rate	1 / day	0.1 – 1	Denitrification rate under anoxic conditions at 20 °C
Sulfur Reduction Rate	1 / day	0.1 - 1	Sulfate reduction rate under anoxic conditions at 20 °C

Point Sources

Figure 5.30 is the input dialog to assign the point source files to a reservoir segment. WARMF stores all point source files in the same directory. To add a point source to the reservoir segment, simply press the **Add** button. WARMF will show all point source files. Click on a specific discharge to add. To remove a point source discharge from the river segment, select the point source file and press the **Remove** button.

Each discharger has a separate file that contains date, flow, and pollutant loadings. The data point can be as little as only one for the entire period or as frequent as daily. The model uses a step function to apply the pollutant loadings to the stream segment.

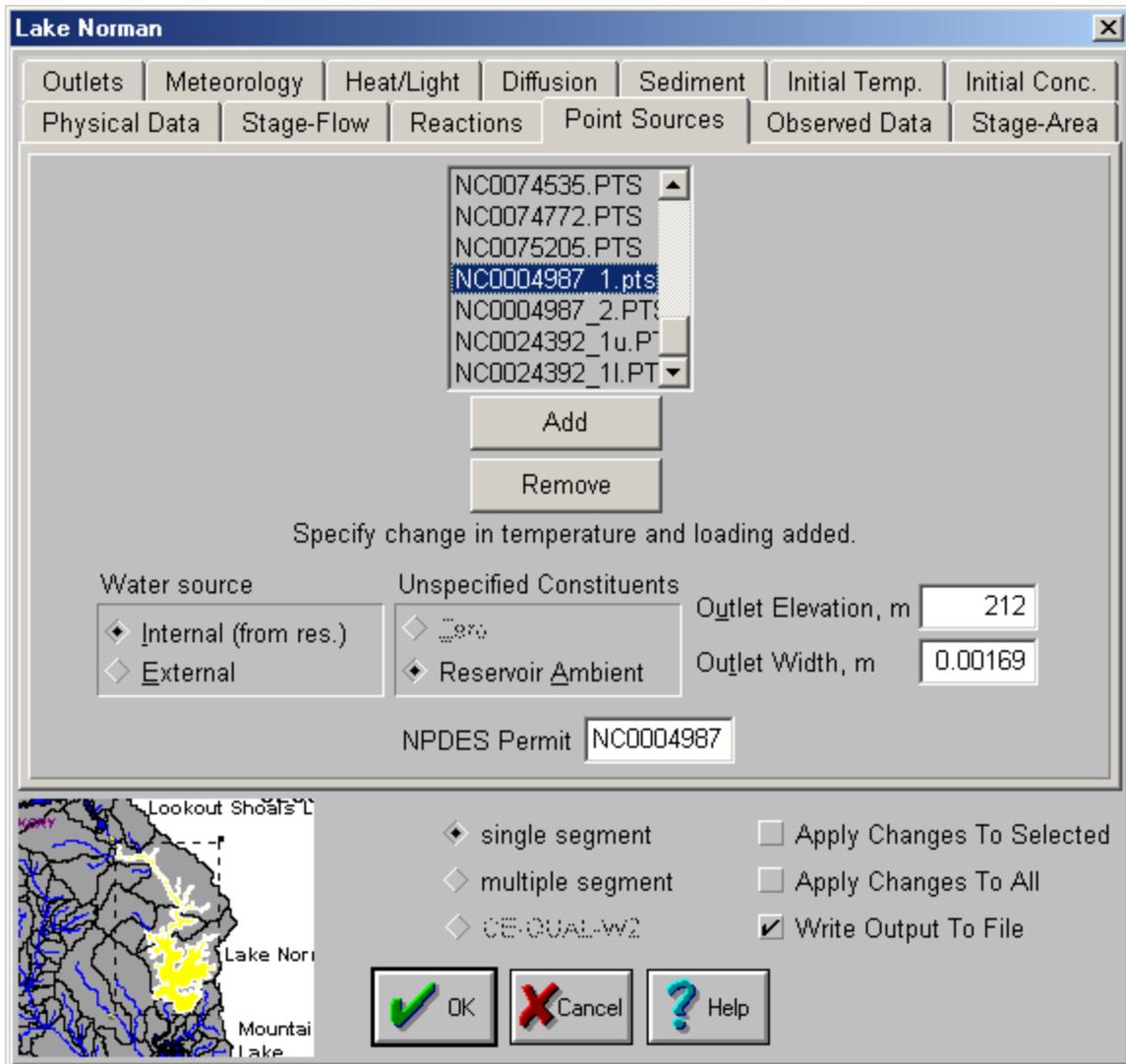


Figure 5.30
Reservoir Input Dialog – Point Sources.

A reservoir segment can accept multiple point source discharges. WARMF accepts each discharge separately and puts them into the reservoir segment. The location of point sources can be seen on the watershed map by selecting **View/Point Sources** from the main menu. To view point source data, double click on the white dot for a specific discharger. Each point source file contains date, flow, and pollutant loading data. There is an issue of whether to enter the permitted loading or the actual loading. For the calibration and base case, we recommend to use actual loading. The permitted loading can be used in scenario evaluation.

Below the point source list, there is a line, **“water source information corresponds to selected point source”**. It invites user to point and click at a point source on the list to find out its water source. When a source is selected, for example, the two boxes below the line become activated. If the water is from external source, the line changes to **“specify temperature and total loading”**. It means that the data in the point source file is the actual loading.

Point source load from a sewage treatment plant or an industrial facility is from an external source. A thermal discharge, on the other hand, is from an internal source, because the power plant withdraws water from the stream segment within the basin, adds heat or other chemical constituents, and discharges it again. For the internal source discharge, the line underneath the spreadsheet changes to “**Specify changes in temperature and loading added**”. In other words, the numbers in the point source file represent the increase of pollution loads for temperature and other water quality constituents. All internal point sources to reservoirs must have the elevation and width of the reservoir outlet (point source inlet).

Observed Data

Figure 5.31 is the input dialog for **Observed Data**. Each reservoir can have an observed hydrology file assigned to it. Click on **Select** to choose the file. Each reservoir segment can have an observed water quality file. Click its **Select** button to choose the file name.

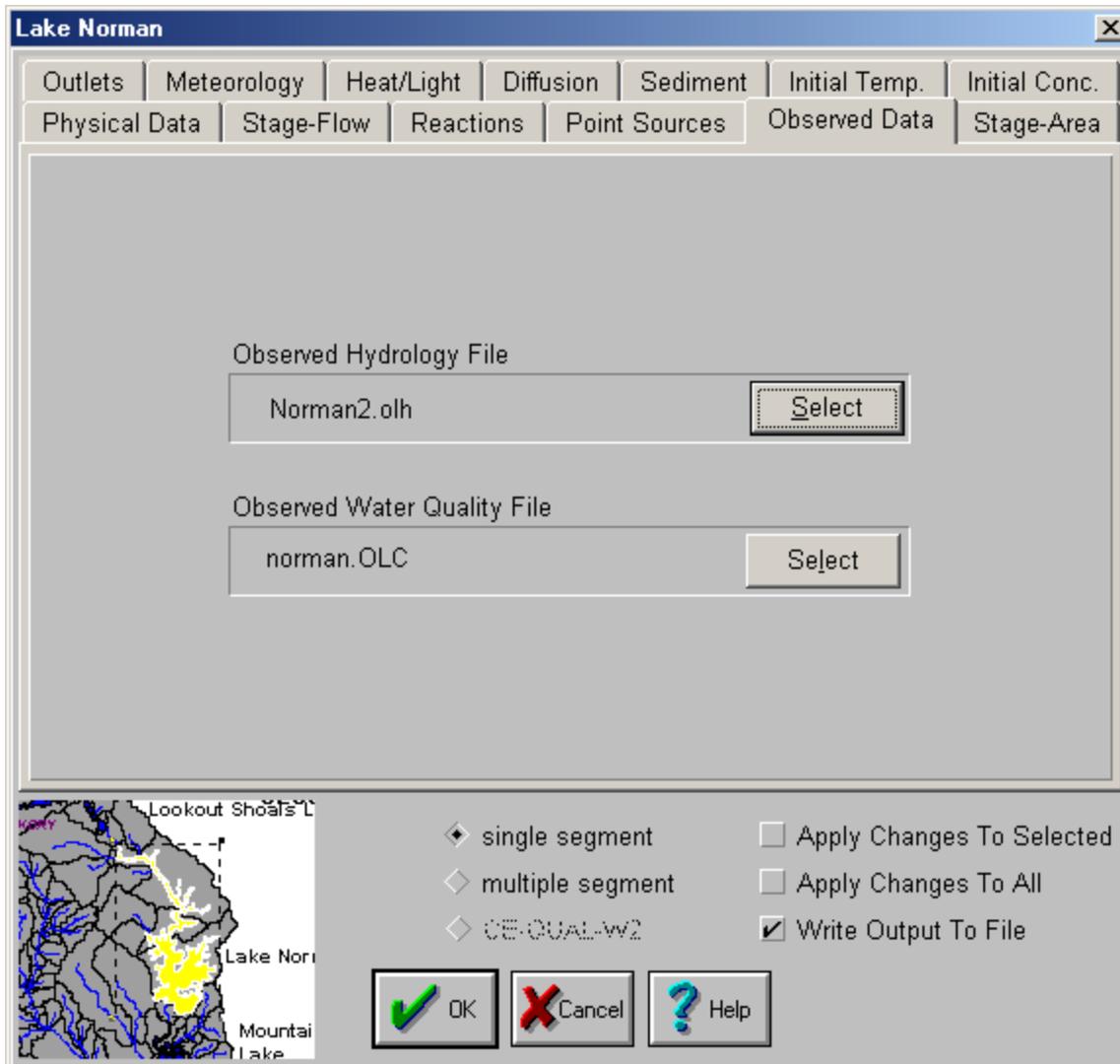


Figure 5.31
Reservoir Input Dialog – Observed Data.

Stage-Area Curve

Figure 5.32 is the dialog for the stage-area curve of the reservoir.

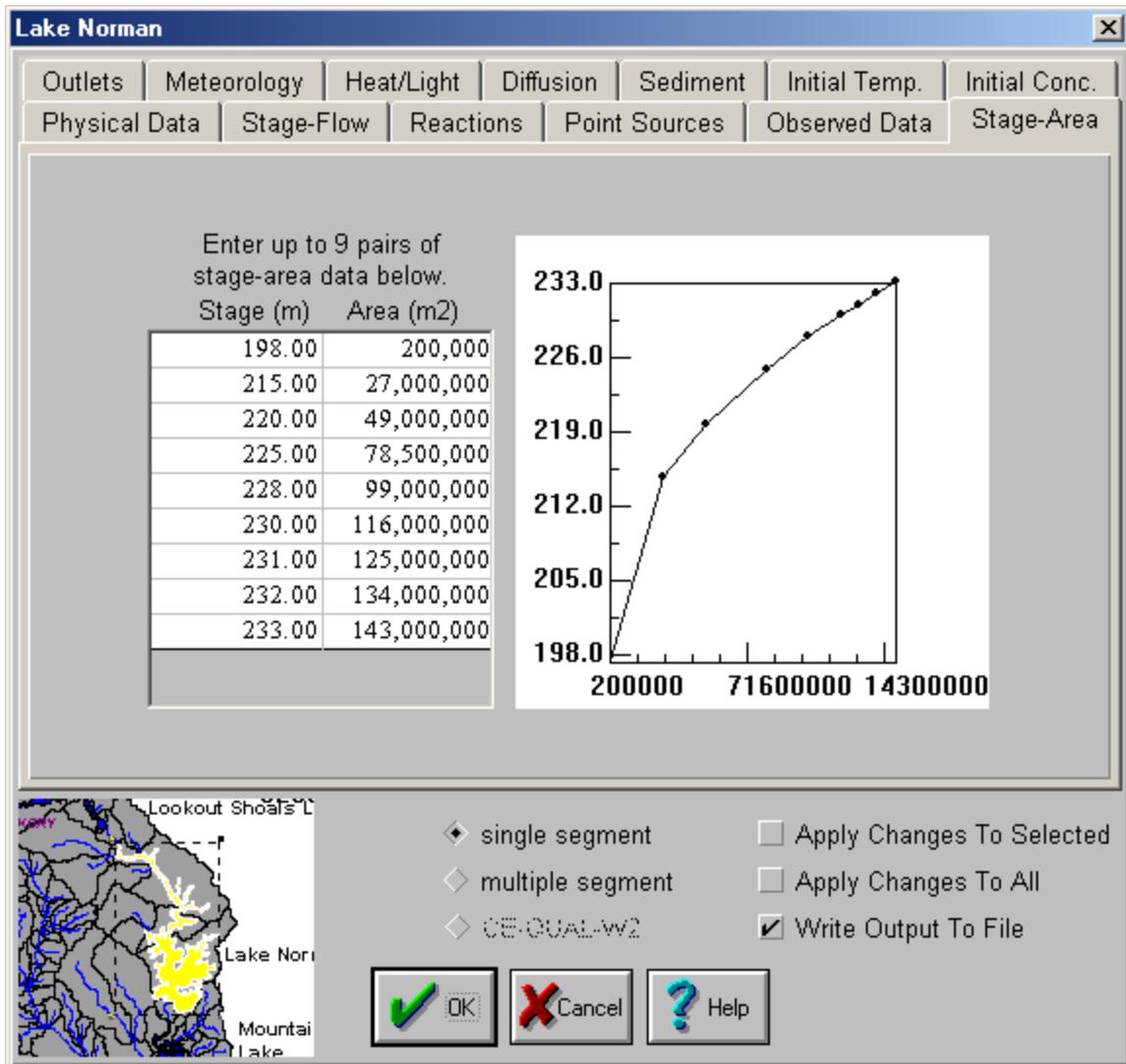


Figure 5.32
Reservoir Input Dialog - Stage-Area Curve.

The stage-area curve of the reservoir is described by 9 pairs of stage-area data. The surface elevation is in the left column and the surface area is in the right column. The graph for the stage-area relationship is updated as data is entered. When the reservoir is simulated as a **single segment**, only one stage-area curve is needed. If the reservoir is simulated as **multiple segments**, a stage-area curve must be entered for each segment.

Outlets

Figure 5.33 is the dialog for **Outlets**. Table 5.12 provides the definition of physical data for reservoirs.

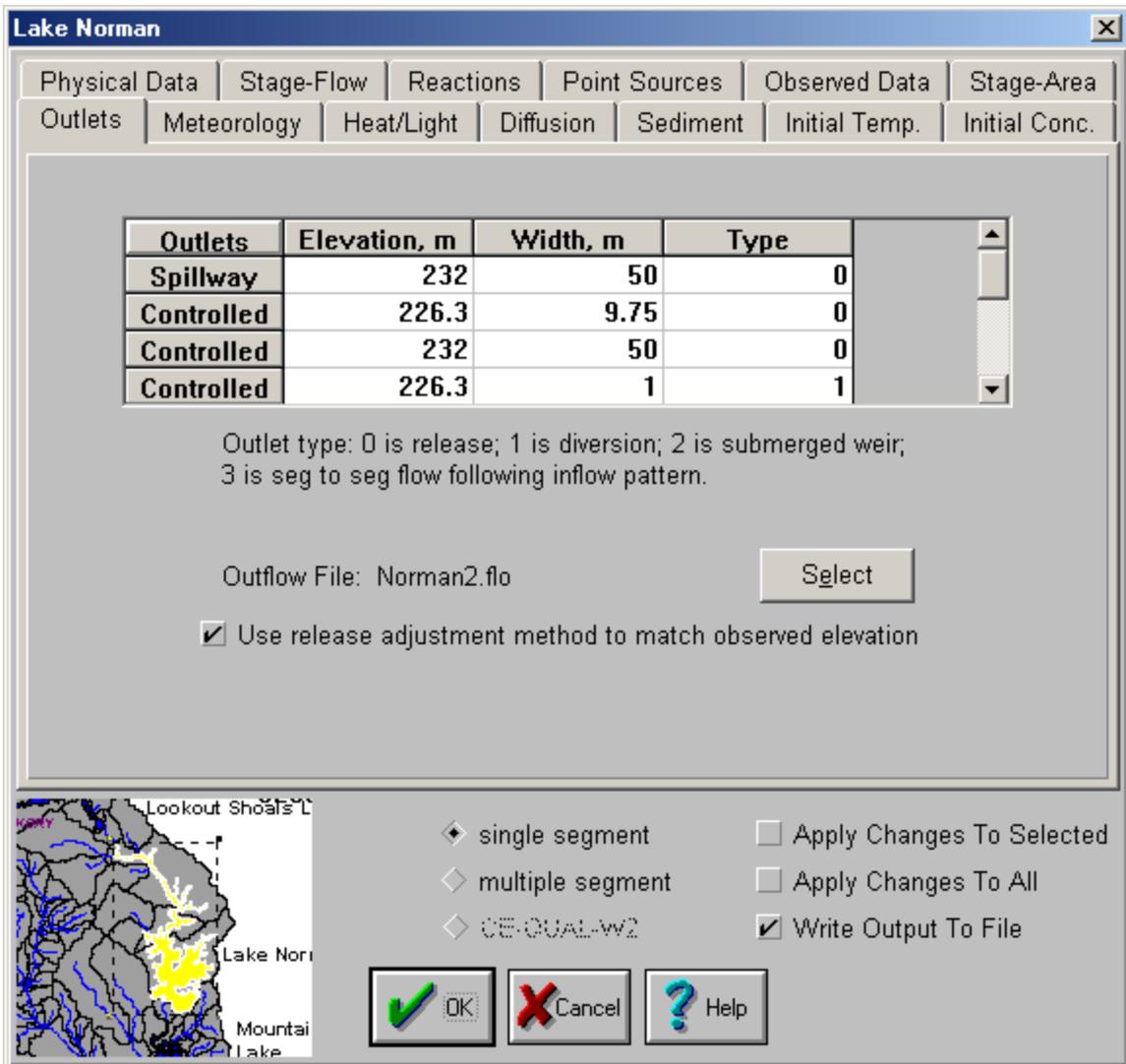


Figure 5.33
Reservoir Input Dialog - Outlets.

Table 5.12
Outlets Data for Reservoirs.

Variable	Units	Range	Description
Outlet			name of outlets
Outlet elevation	m		elevation of the outlet
Outlet width	m		width of the outlet
Outflow type			0 - for releases at a specified depth; 1 - for diversion; 3 - withdrawal from full depth
Spillway			the structure for water to spill over the top
Diversions			water is removed from the river basin
Outflow File			contains data of daily reservoir releases and flow diversions from each outlet

A reservoir can have multiple outlets. The first outlet is a spillway. Each outlet has its own elevation. WARMF withdraws water from the strata near the outlet elevation. WARMF is designed to operate with the daily input of reservoir releases from each outlet other than the spillway as specified in the outflow file. If spill data is available, that can be specified as an additional outlet with a column in the outflow file. The spillway algorithm built into WARMF calculates the spill when the water level is higher than the spillway. This can be de-activated by setting a very high spillway elevation in order to avoid double accounting when the spill data is available.

The outflow file contains daily flow release data. It is an ASCII (text) file with a FLO extension. Each line contains the data of day, month, year, and flow in m³/s for each outlet. The outflow file can be viewed and modified in the **Data Module** under managed flow.

In general, WARMF can simulate the unimpaired flow, which is controlled only by natural processes, with a reasonable accuracy. When the flow is modified by man-made diversions and flow releases, the accuracy of the flow simulation is dictated by the accuracy of the managed flow data. By default, WARMF calculates the reservoir surface elevation given the outflow. If **Use release adjustment method to match observed elevation** is checked, however, WARMF adjusts the prescribed outflow to match the given surface elevation.

Meteorology

Figure 5.34 is the input dialog for **Meteorology**. WARMF requires the assignment of a meteorological station to each reservoir. Push **Select** button for a pull down list of meteorological stations. Click on a nearby station on the list. The name of file that contains

meteorological data for the station will appear in the meteorological file box. In this example, the file is GASTONIA.MET. Table 5.13 provides the definition of meteorological data for reservoirs.

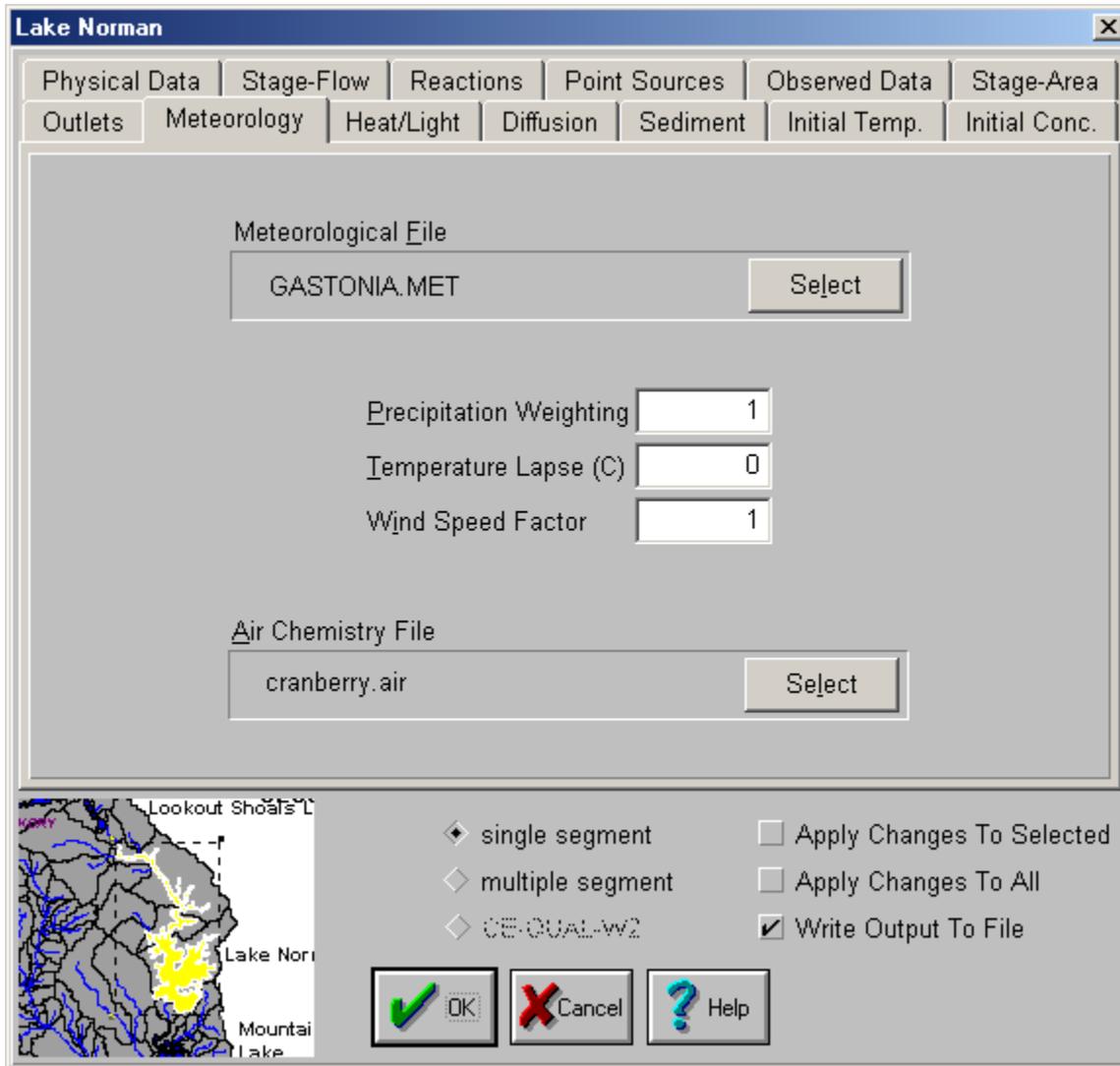


Figure 5.34
Reservoir Input Dialog - Meteorology.

Table 5.13
Meteorology Data for Reservoirs.

Variable	Units	Range	Description
Meteorological File			File with weather data
Precipitation Weighting	None	0.6 – 1.4	Precipitation multiplier to account for orographic effects
Average Temperature Lapse	°C	-4 – 4	Amount by which the reservoir is colder than the weather station
Wind Speed Factor	None	1 – 2	Wind speed multiplier to account for unobstructed path of wind over lake surface
Air Chemistry File			File containing air/rain chemistry data

Heat / Light

Figure 5.35 is the input dialog for **Heat / Light**. Table 5.14 provides the definition of heat and light data for reservoirs.

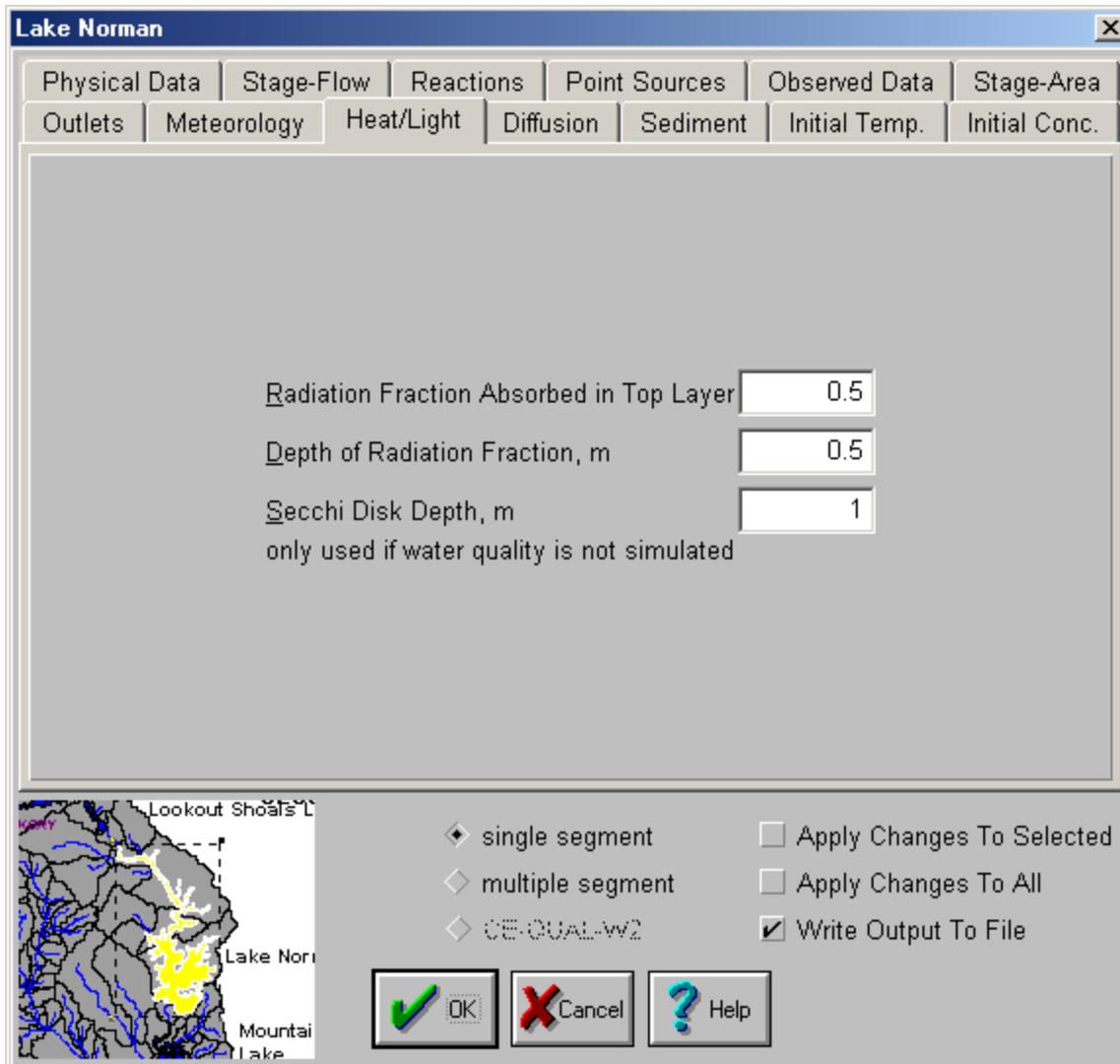


Figure 5.35
Reservoir Input Dialog – Heat / Light.

Table 5.14
Heat / Light Data for Reservoirs.

Variable	Units	Range	Description
Radiation Fraction Absorbed in Top Layer	None		Portion of radiation absorbed in the specified depth of water
Depth of Radiation Fraction	M		Depth at which the above radiation is absorbed
Secchi Disk Depth	M		Secchi disk depth (used only when water quality simulation is turned off)

Diffusion Coefficients

Figure 5.36 is the input dialog for diffusion coefficients. There are two basic methods for estimating reservoir diffusion. One is to estimate the diffusion rate as a function of wind speed. The other is to estimate the diffusion rate as a function of the density gradient in the water column. This dialog shows the empirical coefficients needed to perform the calculations. By assigning appropriate coefficients, it is possible to direct WARMF to use one of the two methods or to calculate diffusion using both methods and then use the larger value. To use only the wind mixing method, set **Max. Diffusion Coefficient** in the density gradient coefficients to 0. To use only the density gradient method, set **Max. Diffusion Coefficient** in the wind mixing method to 0. When using both methods, it is best to set **Min. Diffusion Coefficient** to 0. Table 5.15 provides a description of the coefficients associated with **Diffusion**.

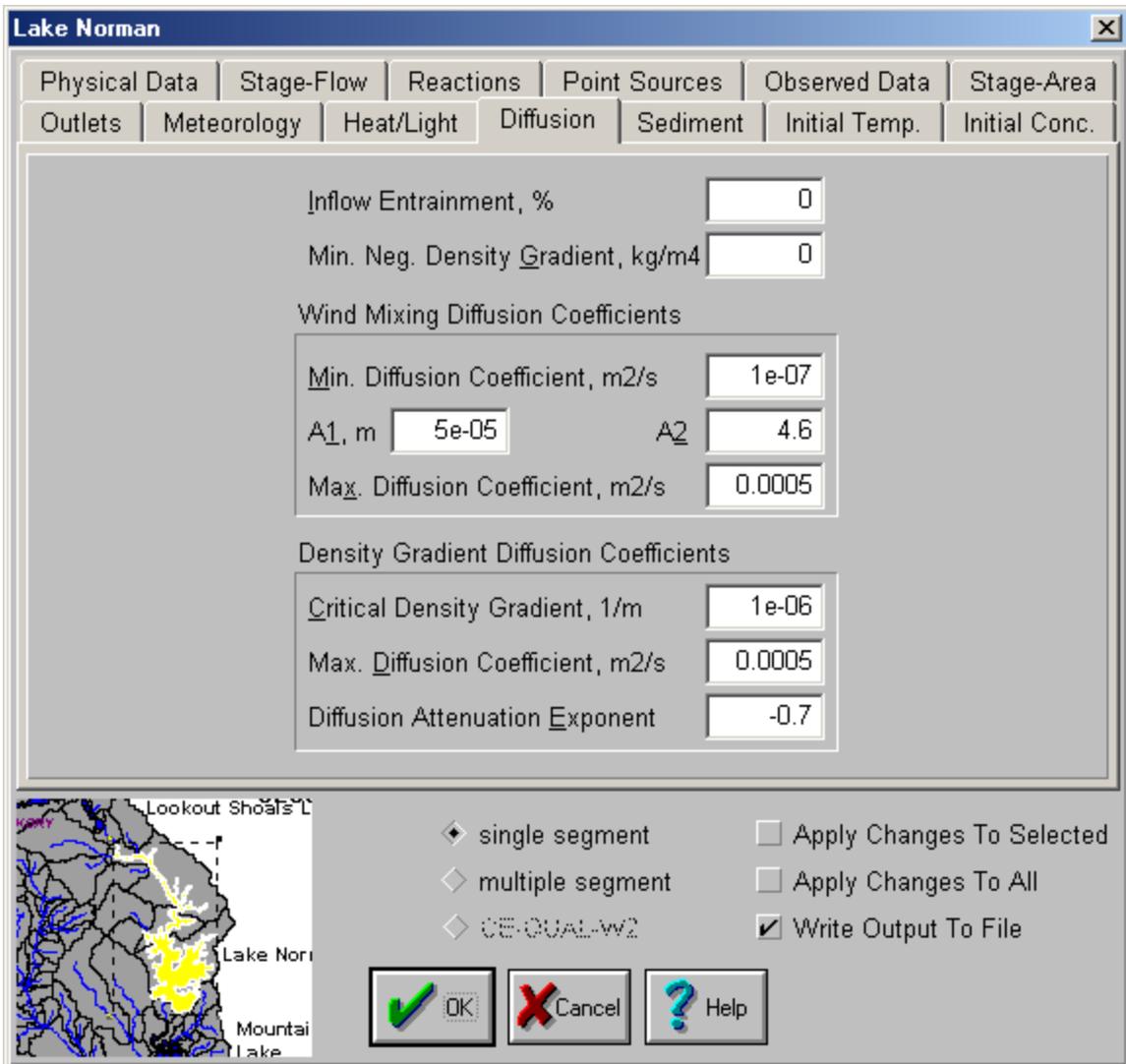


Figure 5.36
Reservoir Input Dialog - Diffusion.

Table 5.15
Diffusion Data for Reservoirs.

Variable	Units	Range	Description
Inflow Entrainment	1 / m	0 - 1	fraction of ambient water entrained into the inflow
Min. Negative Density Gradient	kg / m ⁴	≤ 0	smallest density gradient before overturn
<i>Wind Method</i>			
Min. Diffusion Coefficient	m ² / s	1.0e ⁻⁷ - 5.0e ⁻⁵	minimum diffusion coefficient at calm wind
A1	m	1.0e ⁻⁴ - 5.0e ⁻⁵	wind/diffusion proportionality constant
A2	none	4.6	factor to attenuate wind with depth
Max. Diffusion Coefficient	m ² / s	5.0e ⁻⁴	maximum diffusion coefficient at strong wind
<i>Gradient Method</i>			
Critical Density Gradient	1 / m	1.0e ⁻⁶ - 5.0e ⁻⁶	density gradient to impede diffusion at thermocline
Max. Diffusion Coefficient	m ² / s	1.5e ⁻⁴ - 1.0e ⁻³	maximum diffusion coefficient
Diffusion Attenuation Exponent	none	-0.7 - -1.0	attenuation exponent of density gradient with respect to diffusion coefficient

Sediment

Figure 5.37 shows the dialog box for rate coefficients. The reaction parameters involved are similar to those used in the river model, described in the previous section. Table 5.16 provides a description of the coefficients associated with **Sediment**.

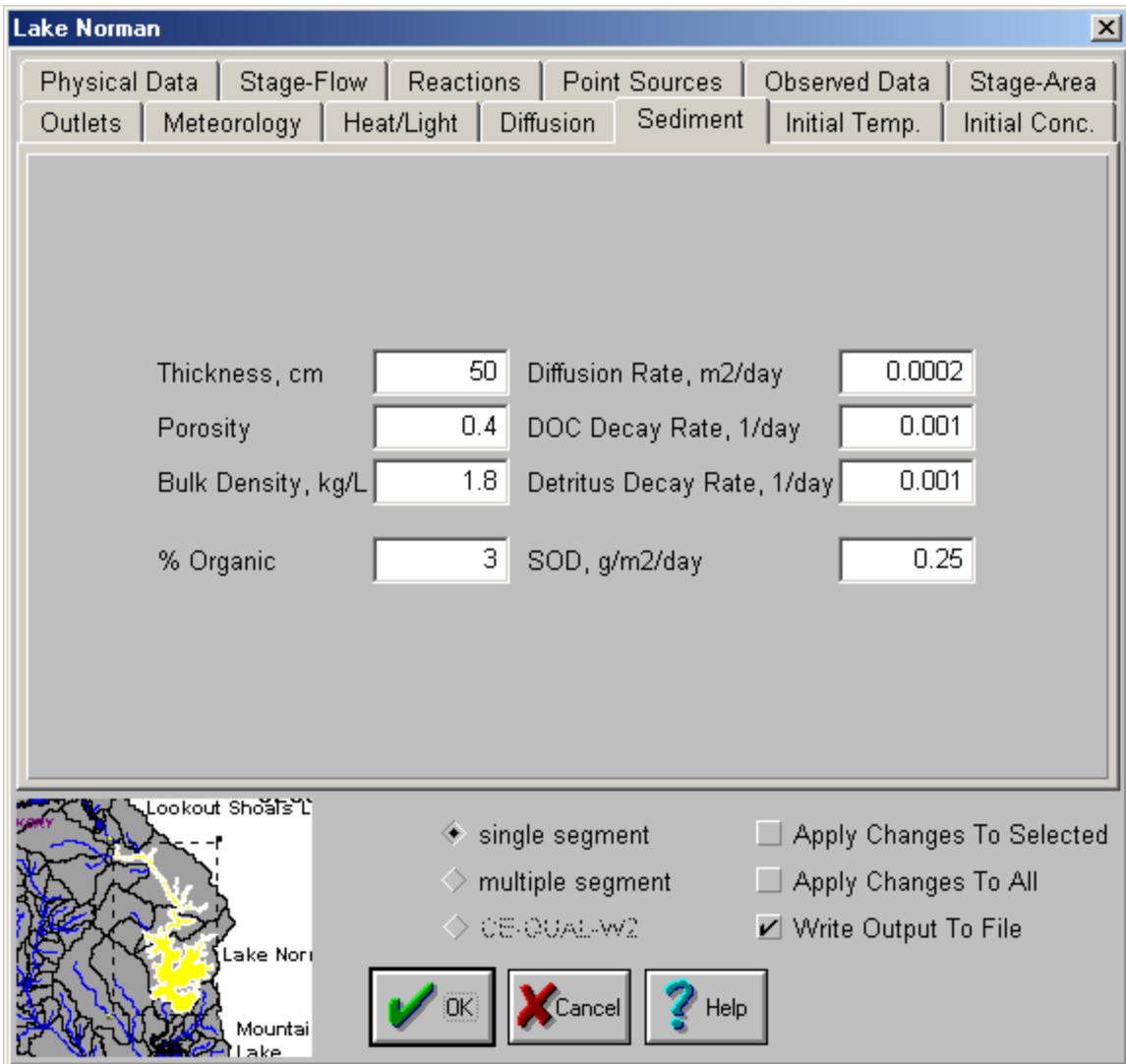


Figure 5.37
Reservoir Input Dialog –Sediment.

Table 5.16
Sediment Data for Reservoirs.

Variable	Units	Range	Description
SOD	g/m ² /d	0.1 – 2.0	Sediment oxygen demand in lake bottom
Bulk Density	kg / l	1.6 – 2.0	Bulk density of lake bottom sediment
Porosity	none	0.4	Porosity of lake bottom sediment
Detritus Decay Rate	1 / day	0.001	Decay rate of settled detritus
Thickness	m	> 0	Thickness of lake bottom sediment
% Organic	%	3	Percentage of organic matter in lake bottom sediment
Diffusion	m ² /d	0.0002	Diffusion rate of constituents out of the lake bottom sediment
Organic Carbon Decay	1 / day	0.001	Decay rate of organic carbon in the lake bottom sediment

Initial Temperature

Figure 5.38 is the dialog for initial temperature.

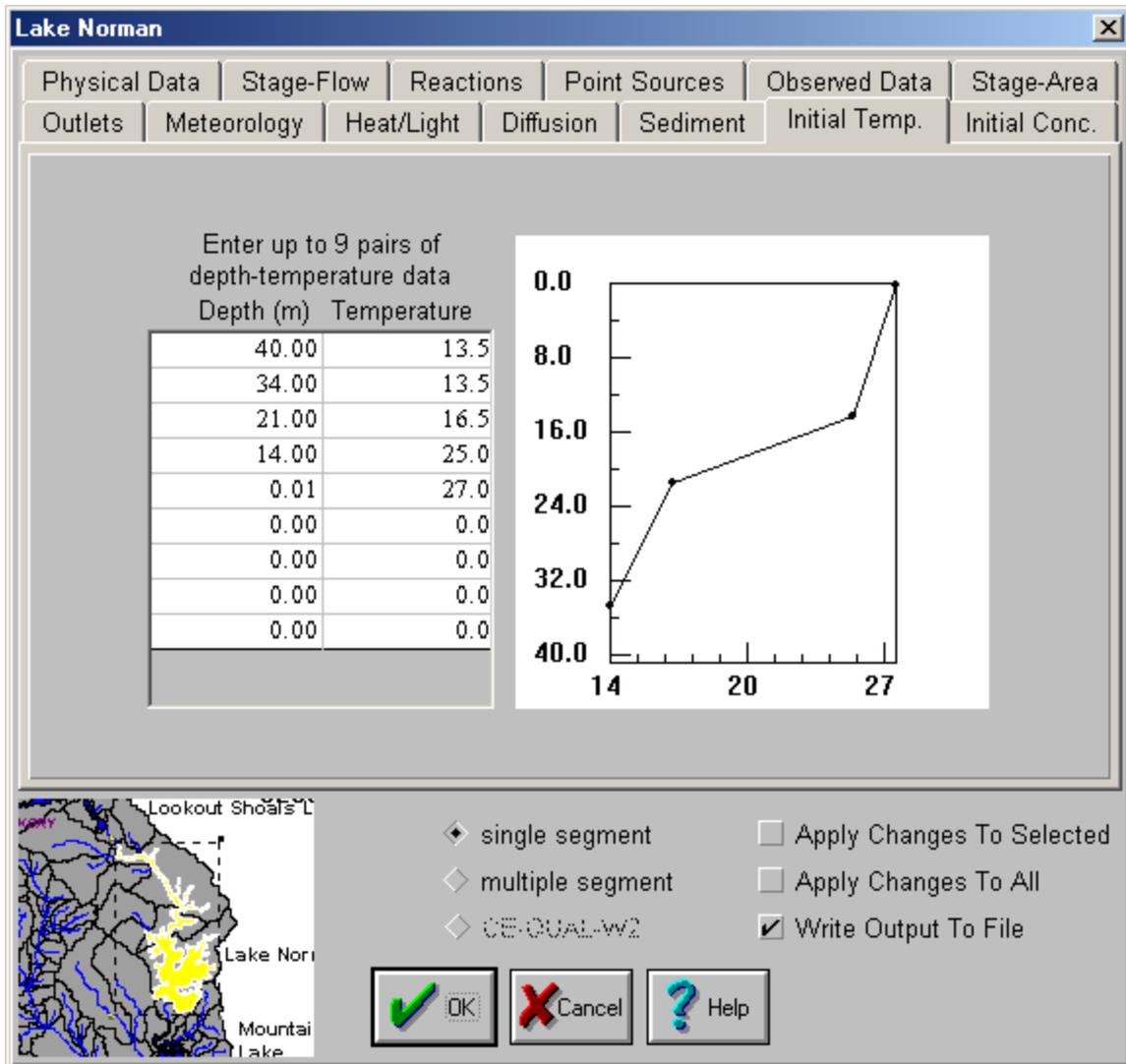


Figure 5.38
Reservoir Input Dialog - Initial Temperature.

The initial depth-temperature curve can be entered as 9 pairs of data points. **Depth** (not elevations) is in the left column and the temperature is in the right column. The depth-temperature curve will update itself as data is entered in the spreadsheet.

Initial Concentrations

Figure 5.39 shows the dialog box for initial concentrations. It is noted that only a single value is used to specify the initial concentration. For that reason, it is recommended that the model simulation be started in late fall, when the lake water is almost vertically mixed. During this time, the lake may have a slight thermal stratification but little chemical stratification. The initial temperature profile is set separately elsewhere in the reservoir input dialog.

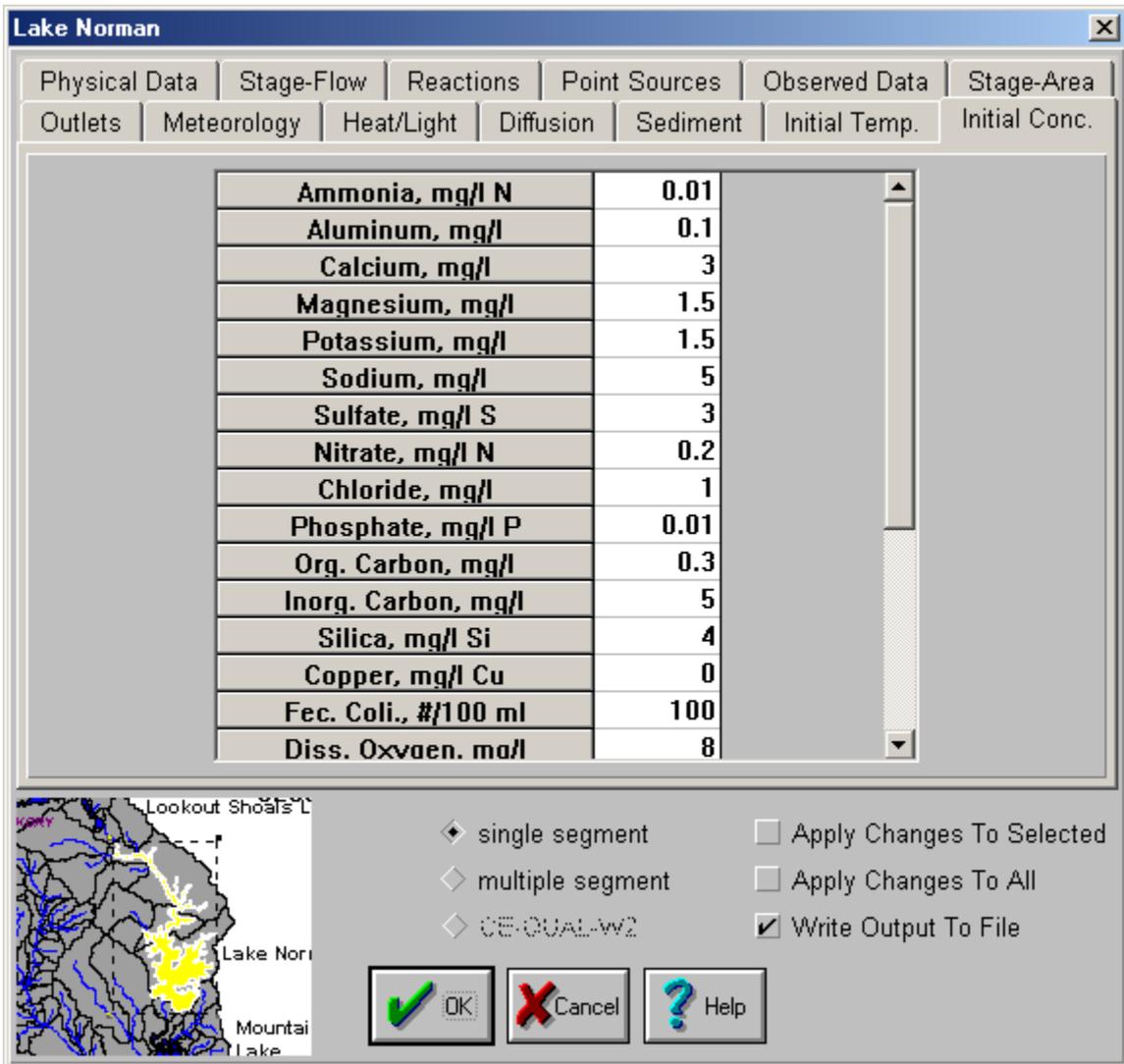


Figure 5.39
Reservoir Input Dialog - Initial Concentrations.

System Coefficients

System coefficients are those applicable to the entire watershed rather than a specific land catchment, river segment or reservoir segment. To edit system coefficients, double-click in the Map Window, but outside the Map. Figure 5.40 shows the dialog for system coefficients.

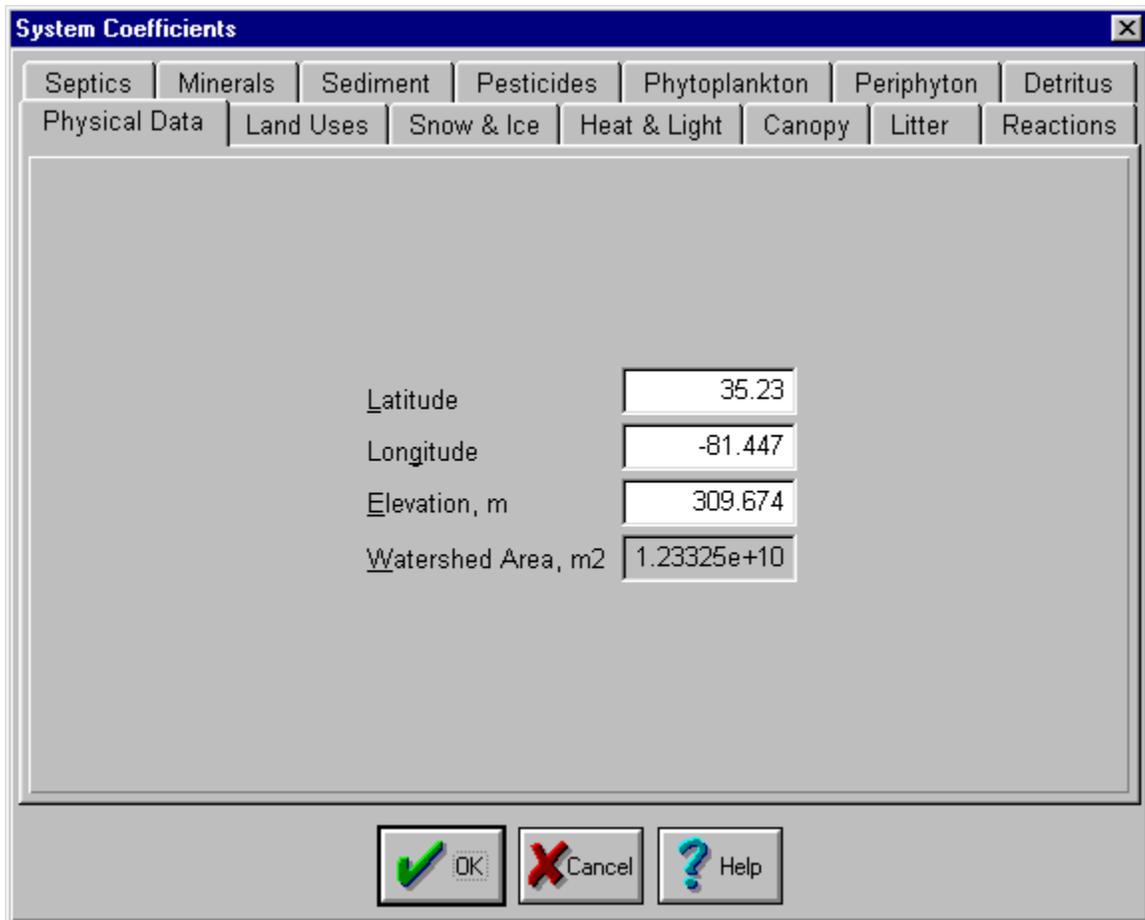


Figure 5.40
System Coefficients Dialog - Physical Data

The system coefficients are divided into categories, each of which is made visible by clicking on its tab: **Physical Data**, **Land Uses**, **Snow & Ice**, **Heat & Light**, **Canopy**, **Litter**, **Reactions**, **Septics**, **Minerals**, **Sediment**, **Pesticides**, **Phytoplankton**, **Periphyton**, and **Detritus**.

Physical Data

Figure 5.40 is the input dialog for systemwide physical data. The parameters include latitude, longitude, and elevation. The latitude is measured in degrees north of the equator. The watershed basin in southern hemisphere should have negative latitude. The longitude is also measured in degrees east of the Prime Meridian. The elevation is measured in meters above mean sea level. Table 5.17 provides a description of the coefficients associated with **Physical Data**.

Table 5.17
Systemwide Physical Data.

Variable	Units	Range	Description
Latitude	degrees	-90 – 90	Latitude north of the equator of the center of the watershed's north-south extents
Longitude	degrees	-180 – 180	Latitude east of the prime meridian of the center of the watershed's east-west extents
Elevation	M		Representative elevation of the watershed above mean sea level
Watershed Area	m ²	> 0	Area of the watershed (can not be edited)

Land Use

Figure 5.41 is the dialog for coefficients that can vary according to land use. By pushing the pull down arrow, WARMF will provide a list of coefficients. One by one, the user can select a coefficient and view its values for different land uses.

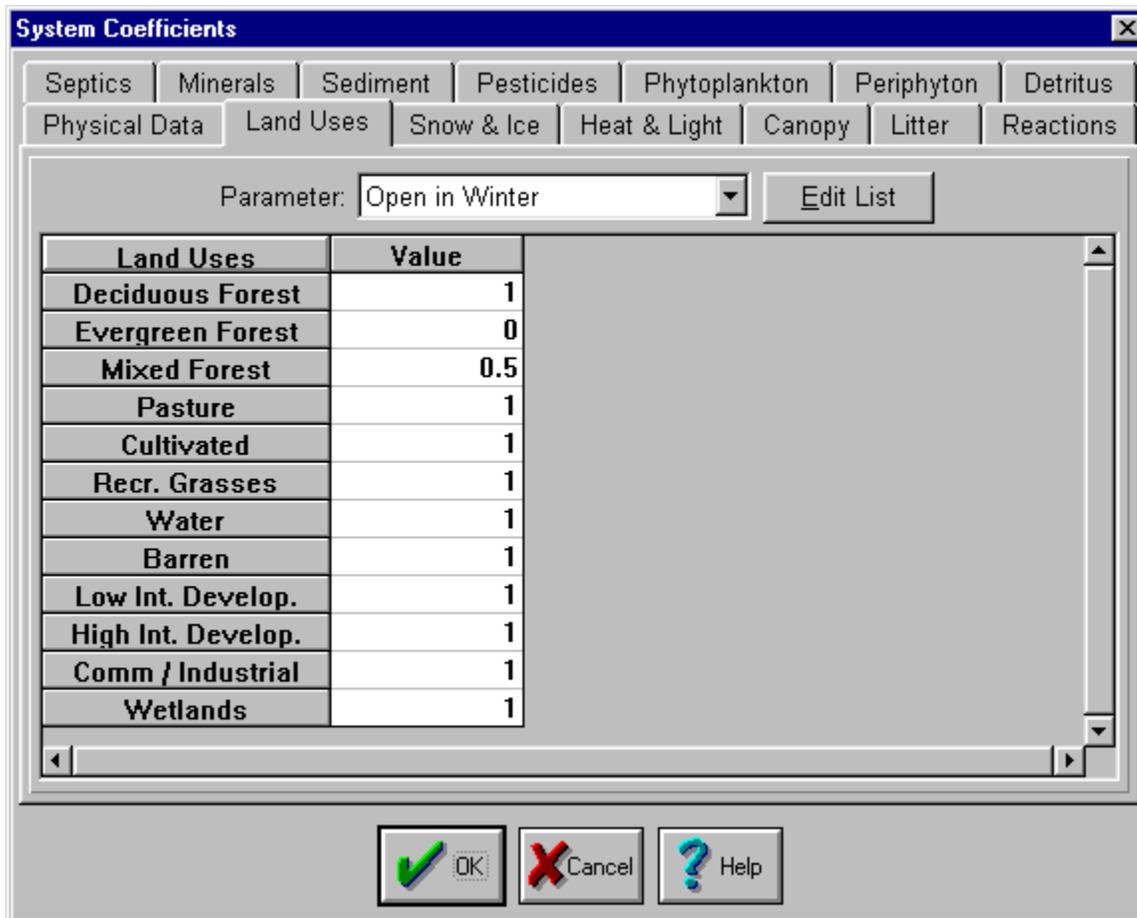


Figure 5.41
System Coefficients Dialog - Land Use

The example dialog shows the values of **Open in Winter** for each land use. This coefficient represents the fraction of land not shaded by vegetation in the winter. For deciduous forest area, the value is close to 1. For coniferous forest area, the value can be zero. For a mixed forest land, the value can be a half (0.5).

The user can click on the pull down arrow to select other parameters for evaluations. Table 5.18 provides a list of parameters and their typical values for various land uses. Many of these coefficients are used to calculate terms such as atmospheric deposition to the canopy and the uptake of nutrients from soils by vegetation.

Table 5.18
Land Use Parameters.

Variable	Units	Range	Description
Open in Winter	None	0 - 1	fraction of land not shaded by the coniferous canopy in the winter
Cropping Factor	None	0.1 - 0.8	a coefficient for erosivity based on vegetation cover
Rainfall Detachment Factor	g / cm ³	0.108 for exposed soil	a coefficient to calculate soil detachment as a function of rainfall intensity on exposed soil
Flow Detachment Factor	kg / m ⁴	usually 0.9	a coefficient to calculate soil detachment as a function of overland flow
Fraction Impervious	None	0 - 1	fraction of the land covered by an impervious surface that water cannot infiltrate
Interception Storage	Cm	0 - 0.3	precipitation intercepted by tree canopy
Long Term Growth	none	1.0 - 1.2	long term annual growth factor of tree
Leaf Growth Factor	none	1.0	annual growth factor for leaf
Productivity	kg / m ² / yr	0 - 1.2	productivity of vegetation on land
Active Respiration	day ⁻¹	0 - 1.0e ⁻⁷	respiration expended on growth metabolism
Maintenance Respiration	day ⁻¹	0 - 6.0e ⁻⁸	respiration expended on maintenance metabolism
Dry Collection Efficiency	none	usually 0.6	collection efficiency when canopy is dry
Wet Collection Efficiency	none	usually 0.9	collection efficiency when canopy is wet
Leaf Weight / Area	g / cm ²	0.005 - 0.01	leaf weight per unit leaf area
Canopy Height	m	0 - 50	height of the canopy
Stomata Resistance	s / cm	1 - 3	stomata resistance to SO _x uptake
Leaf Area Index	none	0 - 15	ratio of leaf area to ground area
Annual Uptake Distribution	none	0 - 0.3	monthly allocation of annual growth

Variable	Units	Range	Description
Litter Fall Rate	kg / m ² / month	0 - 0.2	leaf fall in each month
Exudation Rate	day ⁻¹	0 - 2.0e ⁻⁵	amount of mass secreted by the vegetation to its canopy in each month
Leaf Composition	mg / g dry wt	0 - 20	chemical composition of leaves
Trunk Composition	mg / g dry wt	0 - 1	chemical composition of tree trunk

When the **Edit List** button in Figure 5.41 is pushed, Figure 5.42 will appear. This is the dialog to edit the land use list.



Figure 5.42
Dialog to Add / Remove Land Use on the List.

This step is performed before importing land use ArcView shape file. The editing of land use categories is an initial step in model setup. When there is an update of land use data, some old land uses can be removed and some new land uses can be added through this dialog.

To add a land use, click on the **Add** button and enter the name of the new land use when prompted. The order of land uses can be changed with the **Move Up** and **Move Down** buttons, and land uses can be deleted with the **Remove** button.

Snow & Ice Coefficients

Figure 5.43 shows the dialog for system wide snow and ice coefficients. These are coefficients used to calculate snow pack accumulation, snow melt rate, constituent concentrations within the snow pack, and parameters affecting lake ice cover.

Table 5.19 provides a description of the system wide snow coefficients.

The screenshot shows a software dialog box titled "System Coefficients" with a close button (X) in the top right corner. The dialog has a tabbed interface with the following tabs: Septics, Minerals, Sediment, Pesticides, Phytoplankton, Periphyton, Detritus, Physical Data, Land Uses, Snow & Ice (selected), Heat & Light, Canopy, Litter, and Reactions. The "Snow & Ice" tab contains several input fields for coefficients:

Parameter	Value
Snow Formation and Melting Temperatures	
Formation (C)	0
Melting (C)	-2
Melting Rates	
Open Area, (cm/C/day)	0.2
Forested Area, (cm/C/day)	0.15
Rain Induced, (cm/cm/day)	0.008
Snow Field Capacity, %	5
Solute Fraction in Ice	0.1
Snowmelt Leaching	4
Snow Nitrification, 1/day	0
Sublimation Rates	
Open Area, (cm/day)	0.005
Forested Area, (cm/day)	0.005

At the bottom of the dialog are three buttons: "OK" (with a green checkmark icon), "Cancel" (with a red X icon), and "Help" (with a blue question mark icon).

Figure 5.43
System Coefficients Dialog – Snow & Ice.

Table 5.19
Systemwide Snow & Ice Coefficients.

Variable	Units	Range	Description
Snow Formation T	°C	0 – 3	temperature at which snow forms
Snowmelt T	°C	0 – 3	temperature to initiate snow melt
Open Area	cm / °C / day	0.05 - 0.1	snowmelt per degree above melting temperature per day in deciduous forest, grassland, farms, and urban areas
Forested Area	cm / °C / day	0.05 - 0.1	snowmelt per degree above melting temperature per day in coniferous forest
Rain Induced	cm / cm / day	0.0039	snowmelt induced by rain
Snow Field Capacity	%	> 0	Moisture field capacity of snow
Solute Fraction	None	0.1	Fraction of solutes retained in ice
Snowmelt Leaching	None	0 – 4	snowmelt leaching coefficient
Snow Nitrification	1/day	0	Nitrification rate in snow
Open Area Sublimation	cm / d	0.005	Open area snow sublimation rate
Forested Area Sublimation	cm / d	0.005	Forested area sublimation rate

Heat & Light Coefficients

Figure 5.44 shows the dialog for system wide heat and light coefficients. These are coefficients relating to the transmission of heat and light.

Table 5.20 provides a description of the system wide heat and light coefficients.

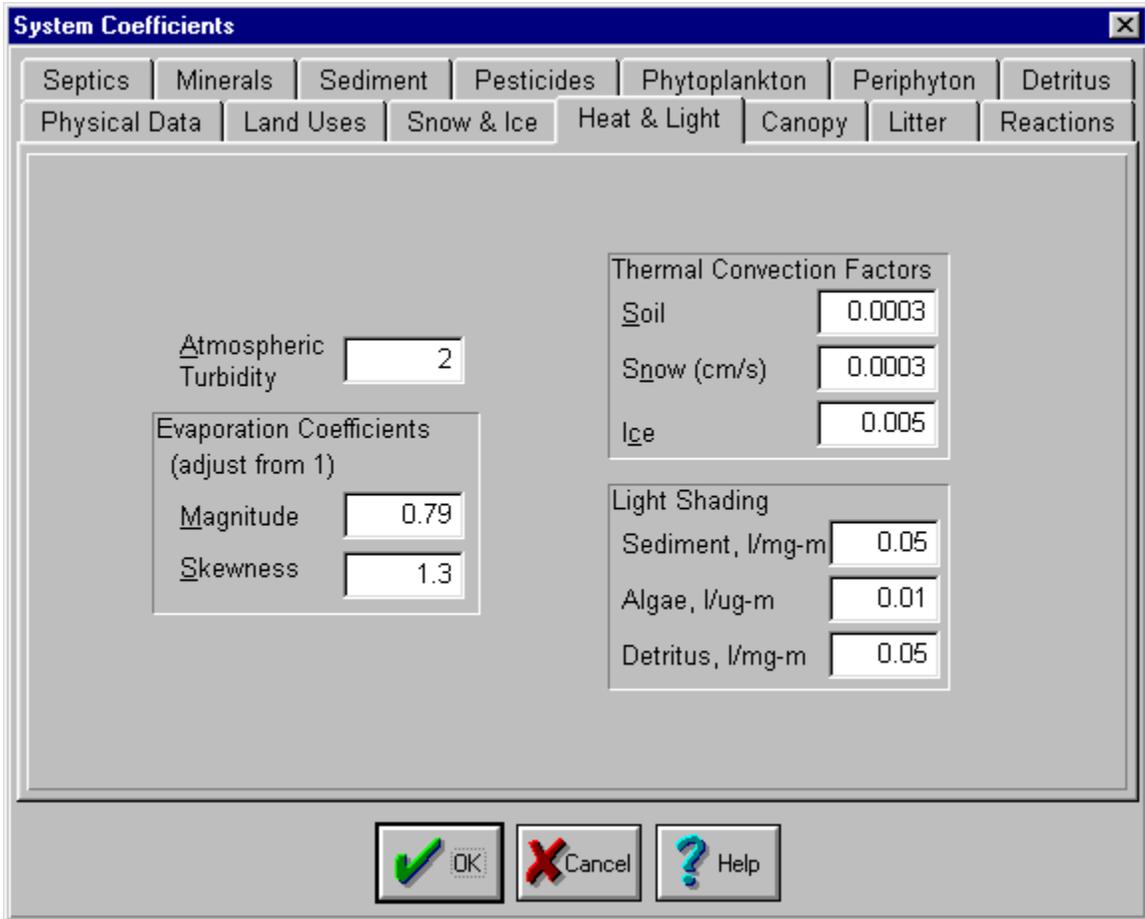


Figure 5.44
System Coefficients Dialog – Heat & Light.

Table 5.20
Systemwide Heat & Light Coefficients.

Variable	Units	Range	Description
Atmospheric Turbidity	None	2 – 5	Relative turbidity of the atmosphere
Magnitude	None	0.6 - 1	Scaling factor for evaporation
Skewness	None	0.6 – 1.4	The degree of variation in evaporation between seasons
Soil Thermal Convection Factor	cm/d	0.0003	Rate at which soil temperature equilibrates with the atmosphere
Snow Thermal Convection Factor	cm/d	0.0003	Rate at which the soil surface temperature equilibrates with the atmosphere through snow
Ice Thermal Convection Factor	cal/cm/s/°C	0.005	Heat transfer rate through ice cover
Snow Thermal Convection Factor	cm/d	0.0003	Rate at which the soil surface temperature equilibrates with the atmosphere through snow
Ice Thermal Convection Factor	cal/cm/s/°C	0.005	Heat transfer rate through ice cover
Snow Nitrification	1/day	0	Nitrification rate in snow

Canopy

Figure 5.45 presents the input dialog for canopy. These are coefficients for interactions between canopy and atmosphere. They describe the rates at which the dry particles and aerosols in the air settle to the canopy surface and the ammonia accumulated on the canopy surface get nitrified to nitrate, etc. The variable names and their ranges of values are presented in Table 5.21.

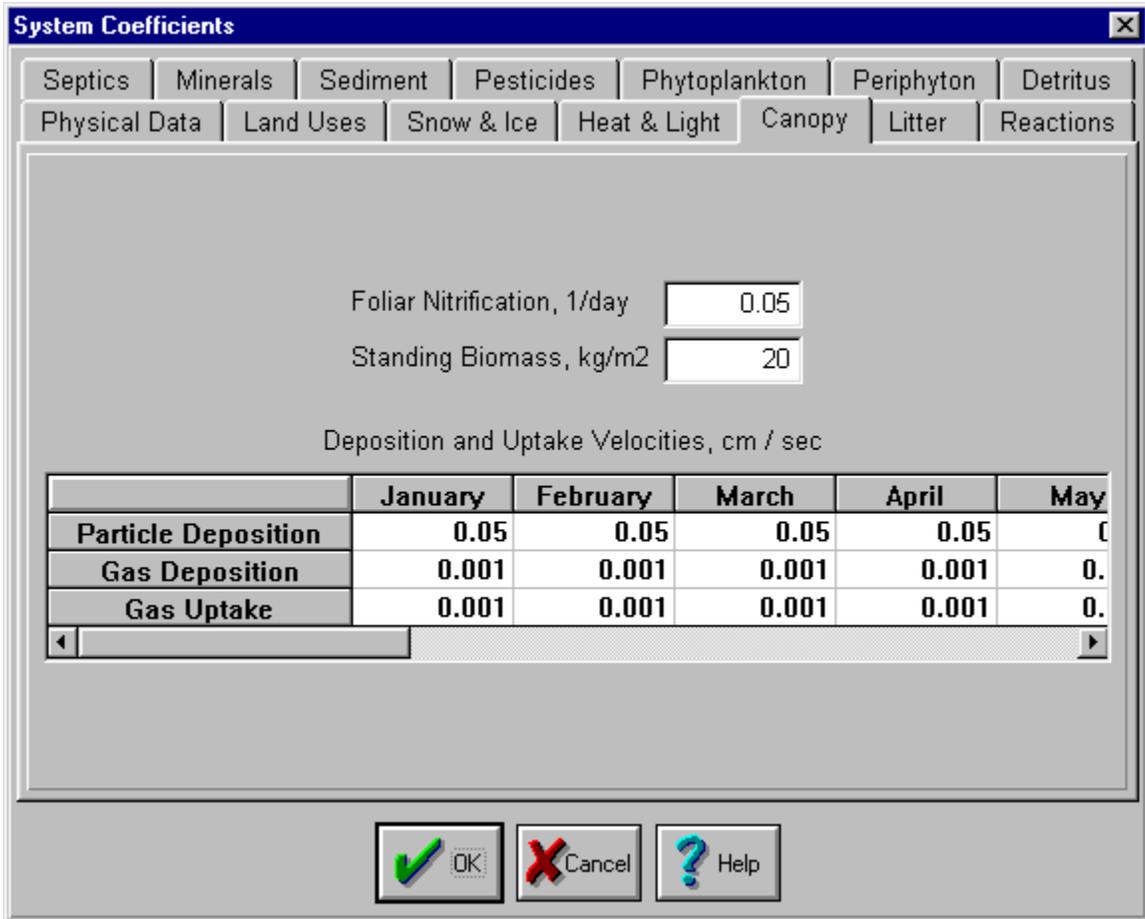


Figure 5.45
System Coefficients Dialog - Canopy.

Table 5.21
Canopy System Coefficients Data.

Variable	Units	Range	Description
Foliar Nitrification	day ⁻¹	0.4	Nitrification rate of ammonia deposited to canopy surface
Standing Biomass	kg/m ²	10 – 25	Biomass of tree canopy
Particle Deposition	cm/s	0.2 – 0.8	Settling velocity of dry atmospheric particles to the canopy surface
Gas Deposition	cm/s	0 – 0.5	Settling velocity of aerosol (NO _x and SO _x) to the canopy surface
Gas Uptake	cm/s	0 – 0.5	Uptake rate of NO _x and SO _x by the canopy

Litter

Figure 5.46 presents the input dialog for litter. These coefficients describe the rates at which coarse litter is broken down to fine litter, fine litter is decomposed to humus, ammonia is nitrified to nitrate, nitrate is denitrified to nitrogen gas, etc. The names, definitions, and ranges of parameter values are described in Table 5.22.

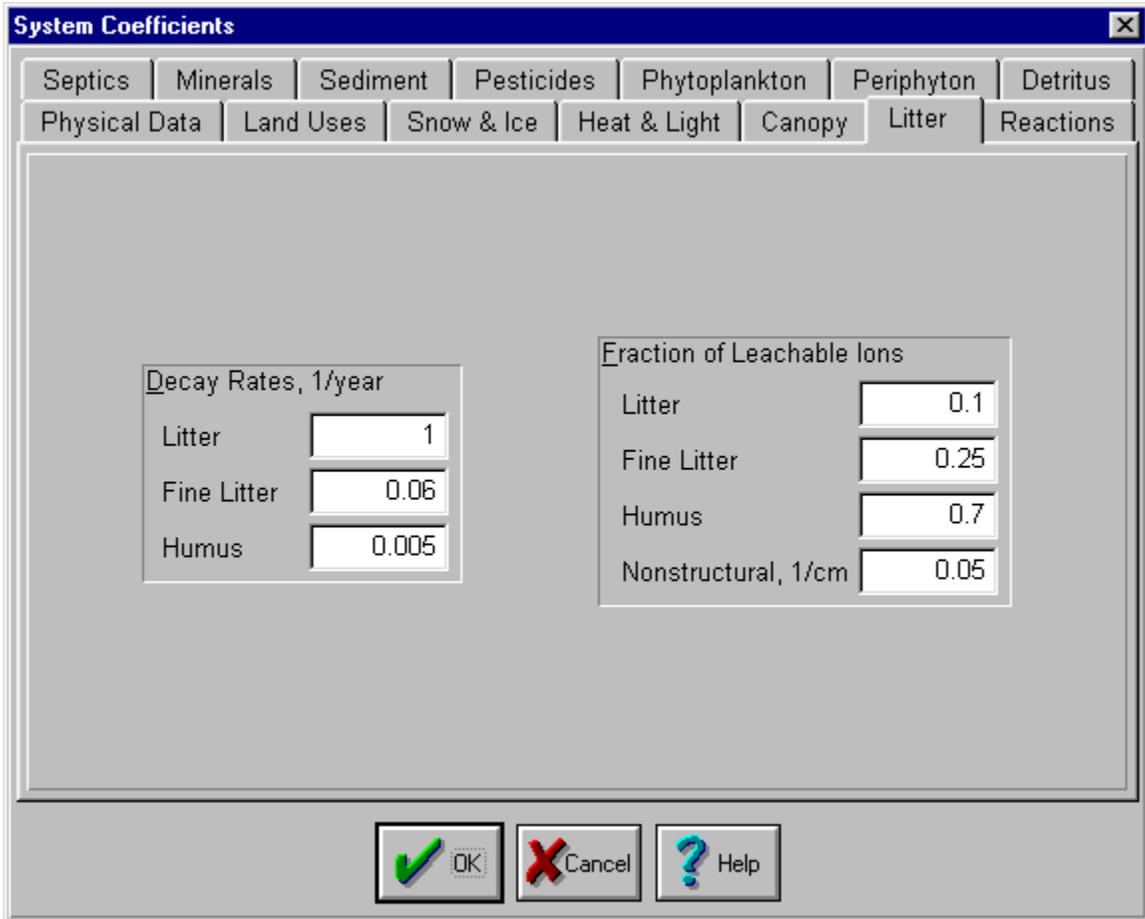


Figure 5.46
System Coefficients Dialog - Litter.

Table 5.22
Litter System Coefficients Data.

Variable	Units	Range	Description
Litter Decay Rate	year ⁻¹	1 – 2	Coarse litter to fine litter
Fine Litter Decay Rate	year ⁻¹	0.06	Fine litter to humus
Humus Decay Rate	year ⁻¹	0.005	Humus to organic acid
Litter Leachable	None	0 – 0.2	Labile fraction of coarse litter
Fine Litter Leachable	None	0.2 – 0.7	Labile fraction of fine litter
Humus Leachable	None	0.2 – 0.7	Labile fraction of humus
Nonstructural Leachable	cm ⁻¹	0.05	Leachable nonstructural part of litter

Reactions

Figure 5.47 presents the input dialog for coefficients related to system reactions. Currently, the only input coefficient in this dialog is anoxic limit. This is the dissolved oxygen concentration below which anoxic reactions will occur. The names, definitions, and ranges of parameter values are described in Table 5.23.

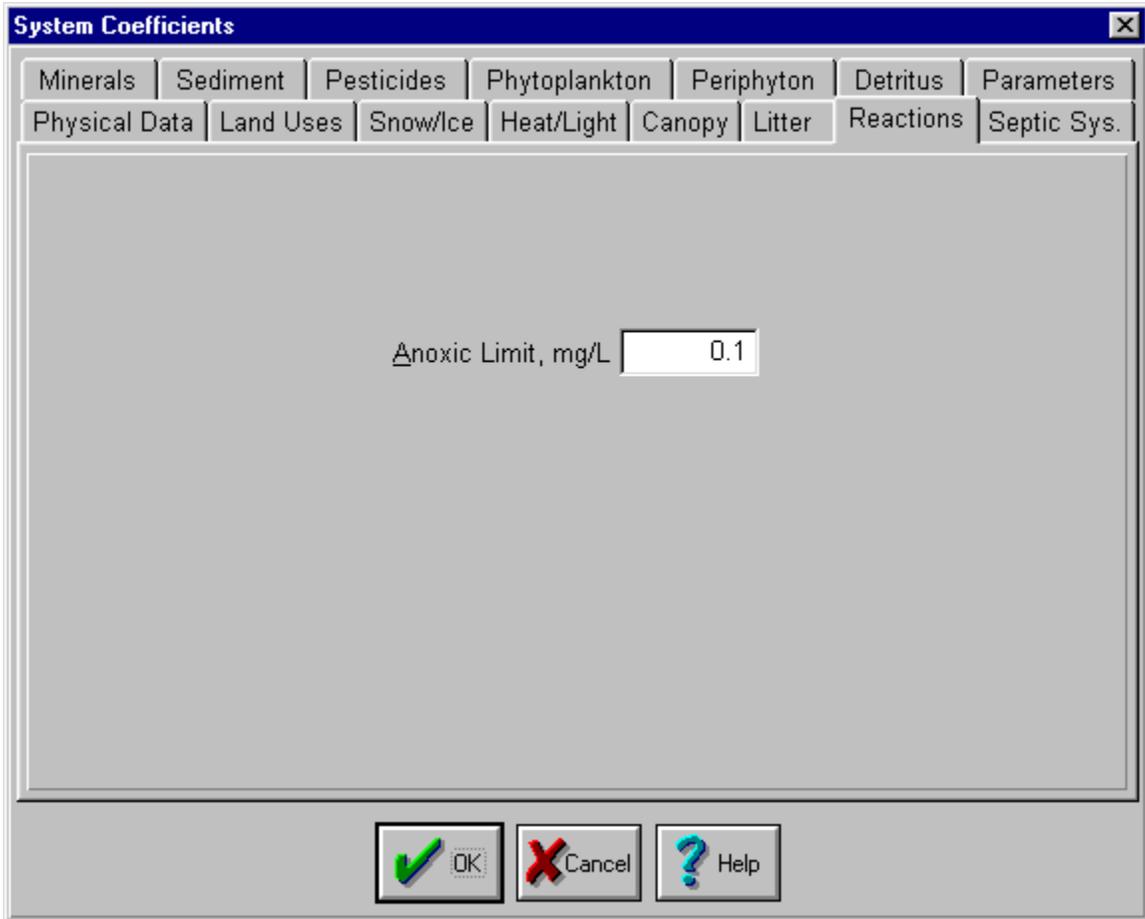


Figure 5.47
System Coefficients Dialog - Reactions.

Table 5.23
Reactions System Coefficients Data.

Variable	Units	Range	Description
Anoxic Limit	mg/l	> 0	Dissolved oxygen concentration below which anoxic reactions occur

Septics

Figure 5.48 shows the input dialog for septic systems and pesticides coefficients. WARMF groups septic systems into 3 different types: Standard, Advanced Treatment, and Failing. For each type, discharge quality concentrations are specified. Another input is a per capita flow rate from the septics. Several septic tank parameters are also specified in catchment input including:

population served by septics, proportion of standard, advanced and failing septics and the discharge soil layer.

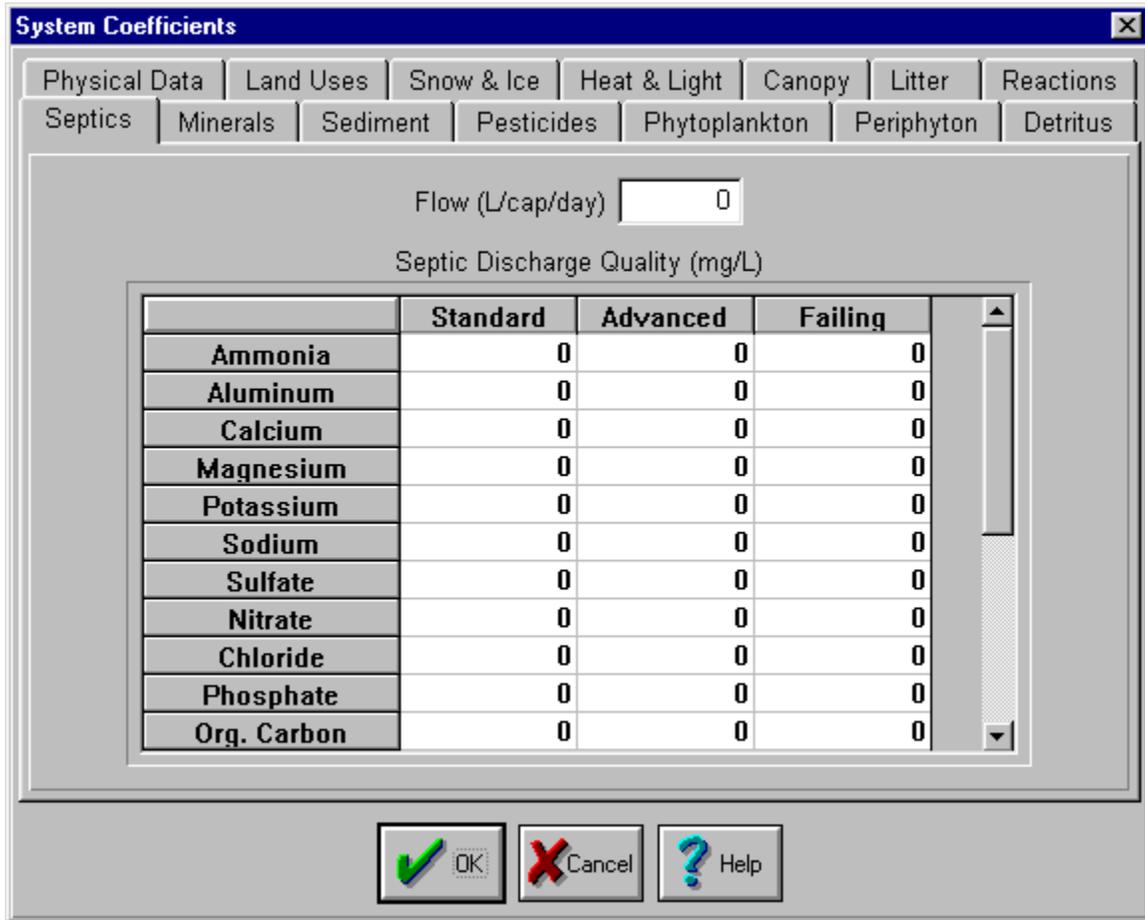


Figure 5.48
System Coefficients - Septics.

Minerals

Figure 5.49 is the input dialog for **Minerals**. The coefficients describe the mineral and their weathering by-products. When a mineral is selected under **Select**, the coefficients applicable to that mineral are shown. Pyrite is the mineral that contains iron bisulfide. Weathering of pyrite and leaching of its by-products by the ground water produces acid mine drainage. When pyrite is selected in the mineral list, the dialog contain information about the pyrite weathering rate, the rate dependency of pyrite oxidation with respect to pH, oxygen consumed per mole of pyrite oxidation, and the molar by-products, i.e. sulfate, iron, and acid (negative alkalinity).

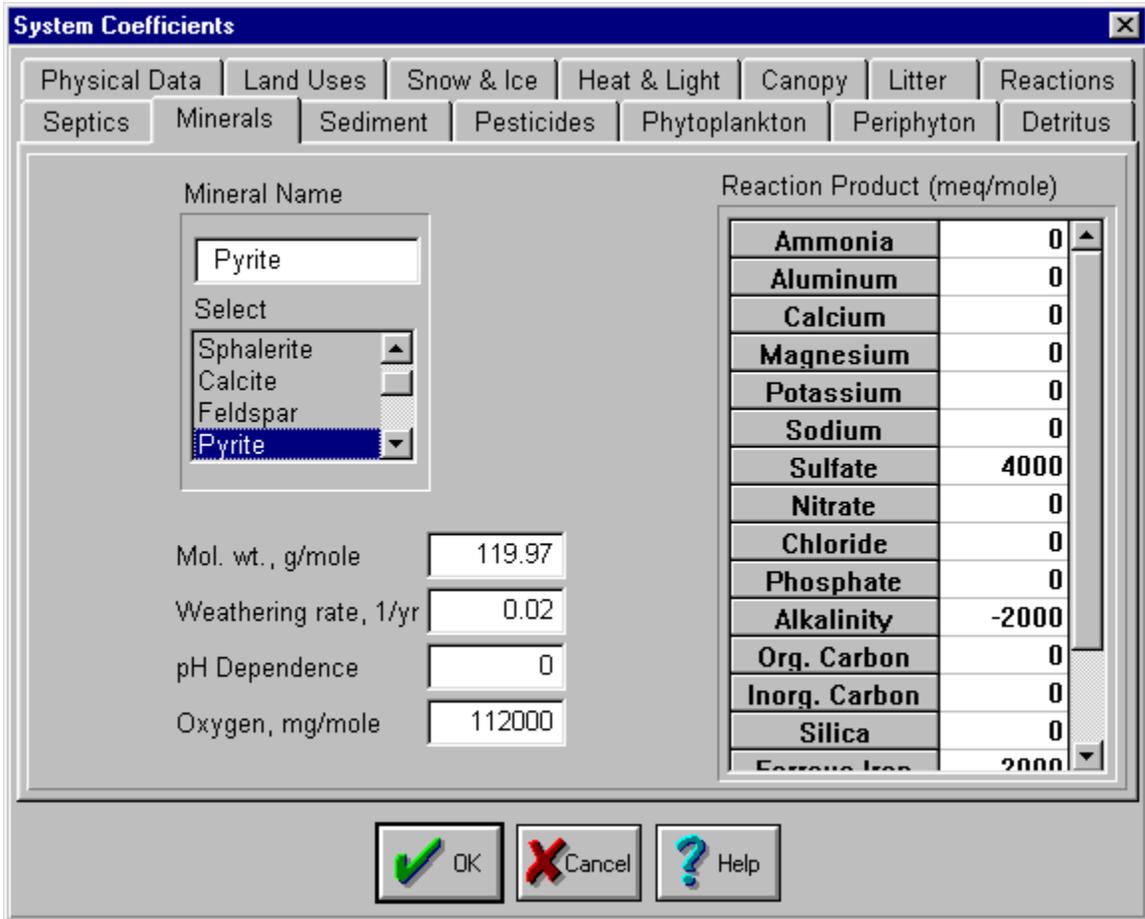


Figure 5.49
System Coefficients Dialog - Minerals.

Sediment

Figure 5.50 is the input dialog for sediment. The coefficients describe the particle size, specific weight, and settling velocity of clay, silt, and sand which make up the suspended sediment. Parameter names and their range of values are described in Table 5.24.

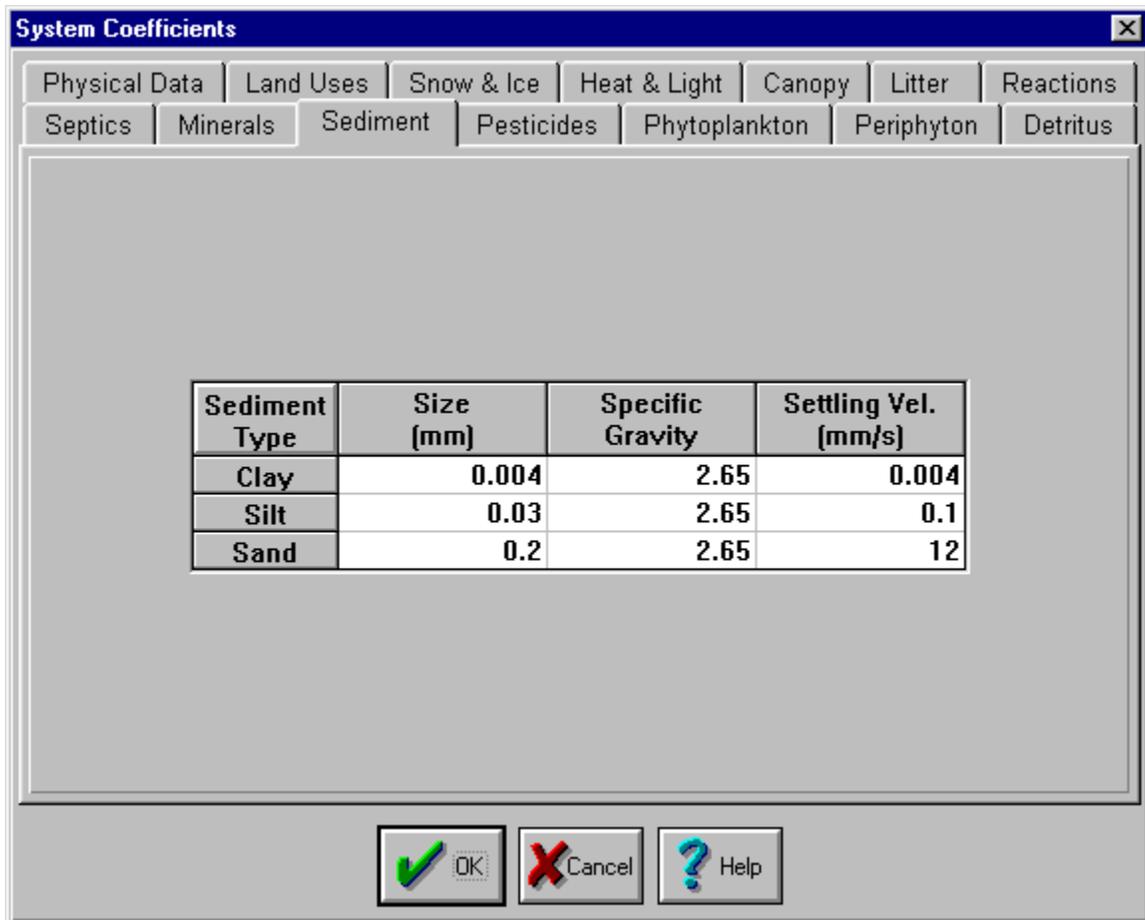


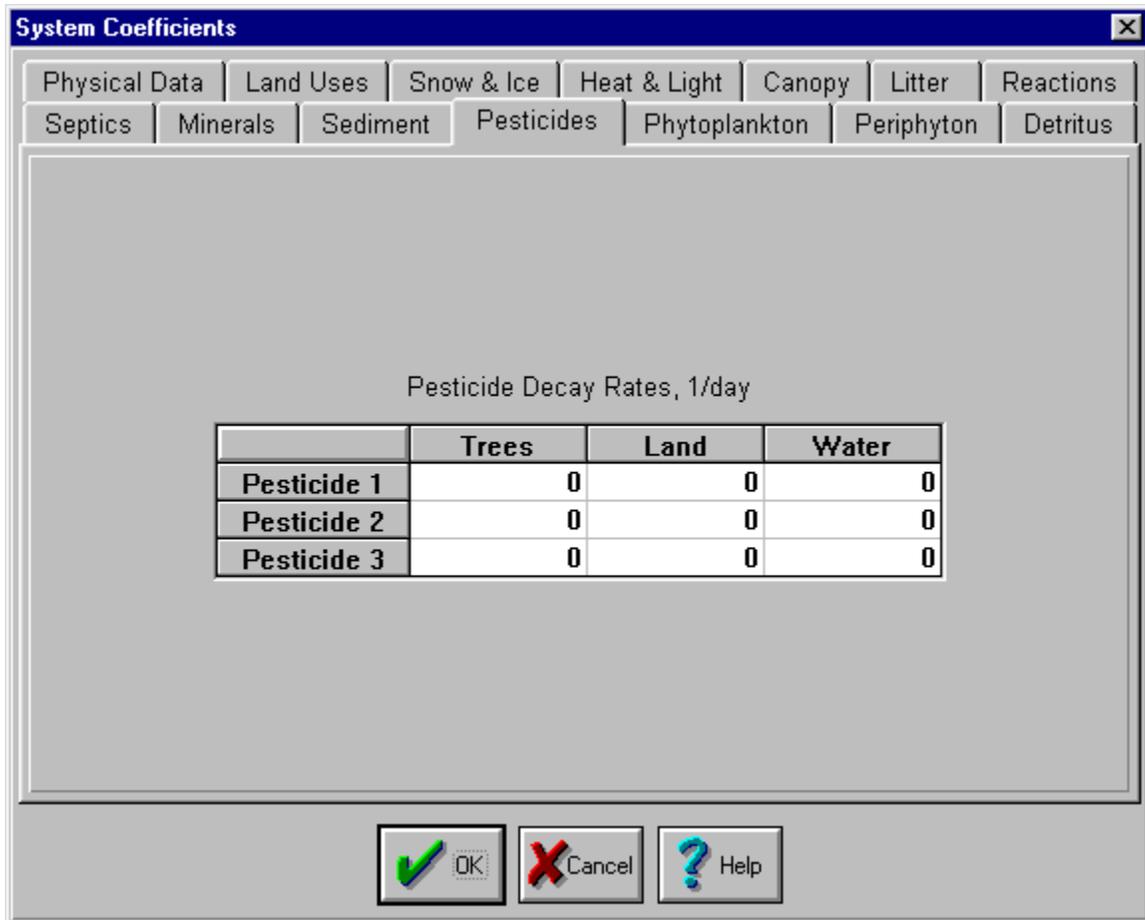
Figure 5.50
System Coefficients Dialog – Sediment.

Table 5.24
Sediment Data for System Coefficients.

Variable	Units	Range	Description
Particle size	Mm	0.001 - 1	Diameter of sediment particles
Specific Gravity	None	2.65	Density of sediment particles relative to water
Settling Velocity	mm / s	0 - 50	Settling velocity of the sediment particles

Pesticides

Figure 5.51 shows the input dialog for pesticide coefficients. As shown, WARMF simulates three different types of pesticides. The pesticide spray can land on the tree canopy or the soil. Pesticides that land on the tree canopy can be washed down to the soil as a part of the throughfall. Each pesticide can have different decay rates on the canopy, in the soil, and in the water. The model assumes that pesticides are adsorbed to the soil particles and are transported together with the soil particles.



System Coefficients

Physical Data | Land Uses | Snow & Ice | Heat & Light | Canopy | Litter | Reactions
Septics | Minerals | Sediment | Pesticides | Phytoplankton | Periphyton | Detritus

Pesticide Decay Rates, 1/day

	Trees	Land	Water
Pesticide 1	0	0	0
Pesticide 2	0	0	0
Pesticide 3	0	0	0

OK Cancel Help

Figure 5.51
System Coefficients - Pesticides.

Phytoplankton

Figure 5.52 shows the dialog for systemwide phytoplankton coefficients. They are used to calculate the growth, mortality and succession of three types of algae, typically diatoms, green, and blue-green algae.

System Coefficients

Physical Data | Land Uses | Snow & Ice | Heat & Light | Canopy | Litter | Reactions
 Septics | Minerals | Sediment | Pesticides | **Phytoplankton** | Periphyton | Detritus

Name: BlueGreen

Select: BlueGreen, Diatoms, Green Algae

Temperature Range, C:
 Lower: 15
 Upper: 40
 Optimum: 22

Half Saturation Constants:
 Nitrogen, mg/l: 0.01
 Phosphorus, mg/l: 0.005
 Silica, mg/l: 0.05

Maximum Growth, 1/day: 1
 Respiration Rate, 1/day: 0.15
 Mortality Rate, 1/day: 0.05
 Settling Rate, m/day: 0.1
 Light Sat., W/m²: 110
 Chl-a/Carbon: 0.02

OK Cancel Help

Figure 5.52
System Coefficients Dialog - Phytoplankton.

The coefficients are displayed for each type of algae. To select an algae type, click on one of the three listed under **Select**. The algae type will be highlighted and the name of the selected algae will appear in the **Name** box. The parameter values in the entire dialog are for the selected algae. Table 5.25 provides a description of the phytoplankton coefficients.

Table 5.25
Systemwide Phytoplankton Coefficients.

Variable	Units	Range	Description
Maximum Growth	day ⁻¹	1.5 - 2.5	maximum growth rate under optimum nutrients, light and temperature
Respiration Rate	day ⁻¹	0.05 - 0.25	respiration rate of algae
Mortality Rate	day ⁻¹	0.02 - 1.0	total mortality rate of algae
Settling Rate	m/day	0 - 2.0	settling rate of algae
Lower T	°C	0 - 15	lowest temperature tolerance
Upper T	°C	25 - 45	highest temperature tolerance
Optimum T	°C	15 - 35	optimum temperature for algae
Chl-a / Carbon	None	0.01 - 0.03	chlorophyll-a to carbon ratio of algae
Nitrogen	mg/l	0.01 - 0.03	half saturation constant for nitrogen
Phosphorus	mg/l	0.001 - 0.005	half saturation constant for phosphorus
Silica	mg/l	0 - 0.10	half saturation constant for silica
Light Saturation	W/m ²	50 - 200	saturating light intensity for growth

Periphyton

Figure 5.53 is the input dialog for periphyton. Periphyton is algae which grows on the rock at the river bottom. Its coefficients are similar to those of phytoplankton (Table 5.26). Being attached, periphyton rely on an optimum flow velocity to bring in nutrients to sustain its growth. The names, definitions, and ranges of the parameter values are presented in Table 5-25.

System Coefficients		X	
Physical Data	Land Uses	Snow/Ice	Heat/Light
Minerals	Sediment	Pesticides	Phytoplankton
Canopy	Litter	Reactions	Septic Sys.
Periphyton	Detritus	Parameters	
Maximum Growth, 1/day	<input type="text" value="3"/>		
Endogenous Respiration Coefficient	<input type="text" value="0.0267"/>		
Endogenous Respiration Exponential Coefficient	<input type="text" value="0.0776"/>		
Photorespiration Fraction	<input type="text" value="0.075"/>		
Mortality Rate, 1/day	<input type="text" value="0.2"/>		
Fraction Recycled of Grazed and Scoured Periphyton	<input type="text" value="0"/>		
Spatial Limit Half Sat., g/m ²	<input type="text" value="20"/>		
Spatial Limitation, Intercept	<input type="text" value="1"/>		
Scour Regress. Coeff 1/day	<input type="text" value="0.0007"/>		
Scour Regress. Exp. 1/m	<input type="text" value="2"/>		
		Half Saturation Constants	
		Nitrogen, mg/l	<input type="text" value="0.025"/>
		Phosphorus, mg/l	<input type="text" value="0.005"/>
		Velocity, m/s	<input type="text" value="0.25"/>
		Light Sat., W/m ²	<input type="text" value="220"/>
		Chl-a/Carbon	<input type="text" value="0.03"/>
		Ammonia Preference Coeff	<input type="text" value="20"/>
		<input type="button" value="OK"/> <input type="button" value="Cancel"/> <input type="button" value="Help"/>	

Figure 5.53
System Coefficients Dialog - Periphyton.

Table 5.26
Systemwide Periphyton Coefficients.

Variable	Units	Range	Description
Maximum Growth	day ⁻¹	1.5 - 2.5	Periphyton growth rate at the optimum conditions of nutrients, space, light and temperature
Endogenous Respiration Coefficient	None	0.0267	Coefficient (α) used to calculate the endogenous respiration where Endogenous Resp = $\alpha e^{\beta \text{Temp}}$
Endogenous Respiration Exponent	None	0.0776	Coefficient (β) used to calculate the endogenous respiration where Endogenous Resp = $\alpha e^{\beta \text{Temp}}$
Photorespiration Fraction	None	0.05 - 0.15	Fraction of photosynthetic productivity that is oxidized by photorespiration
Mortality Rate	day ⁻¹	0.02 - 1.0	Periphyton mortality rate
Spatial Limit Half Saturation	g/m ²	0.1 - 0.2	Half saturation constant for crowding
Spatial Limitation, Intercept	None	0.1	Intercept of the Michael-Menden equation for crowding effect
Lower	°C	0 - 15	Lower temperature range
Upper	°C	25 - 45	Upper temperature range
Optimum	°C	15 - 35	Optimum temperature range
Chl-a / Carbon	None	0.01 - 0.03	Chlorophyll-a to carbon ratio
Nitrogen	mg/l	0.01 - 0.03	Half saturation constant for nitrogen
Phosphorus	mg/l	0.001 - 0.005	Half saturation constant for phosphorus
Velocity	m/s	0.25	Half-saturation constant for flow velocity
Light Saturation	W/m ²	50 - 200	Saturated light intensity

Detritus

Figure 5.54 is the input dialog for detritus. The coefficients are for the settling and decay rates of detritus (dead algae). The coefficients and their ranges are shown in Table 5.27.

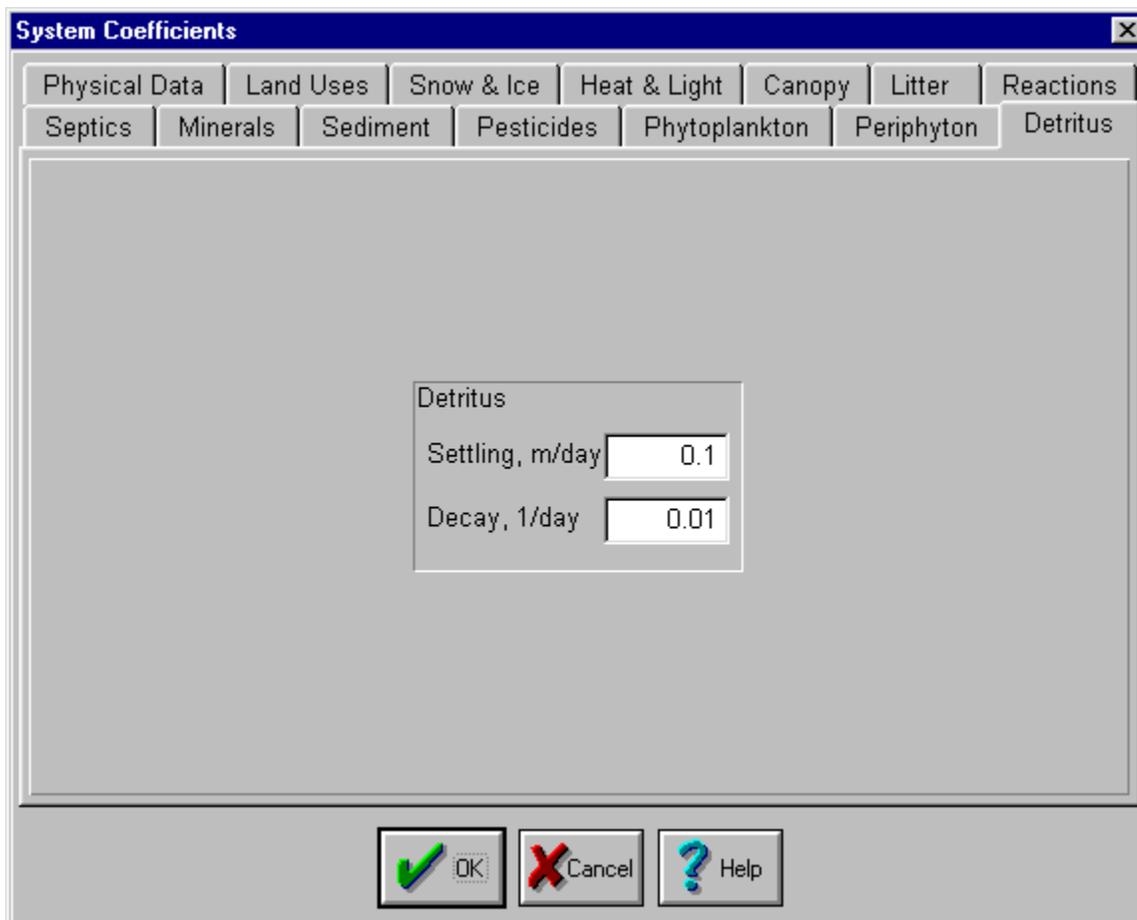


Figure 5.54
System Coefficients Dialog – Detritus.

Table 5.27
Detritus Data for System Coefficients.

Variable	Units	Range	Description
Detritus Settling	m/d	> 0	Settling velocity of detritus
Detritus Decay	1/day	> 0	Decomposition of detritus

Parameters

Figure 5.55 is the input dialog for parameters. The top of the dialog has several options: Names, Output Control, Physical Data, Hydroxide Solubility, Sulfate Solubility, Multipliers,

Composition, and Reaction Products. The coefficients for all the categories and their ranges are shown in Table 5.28.

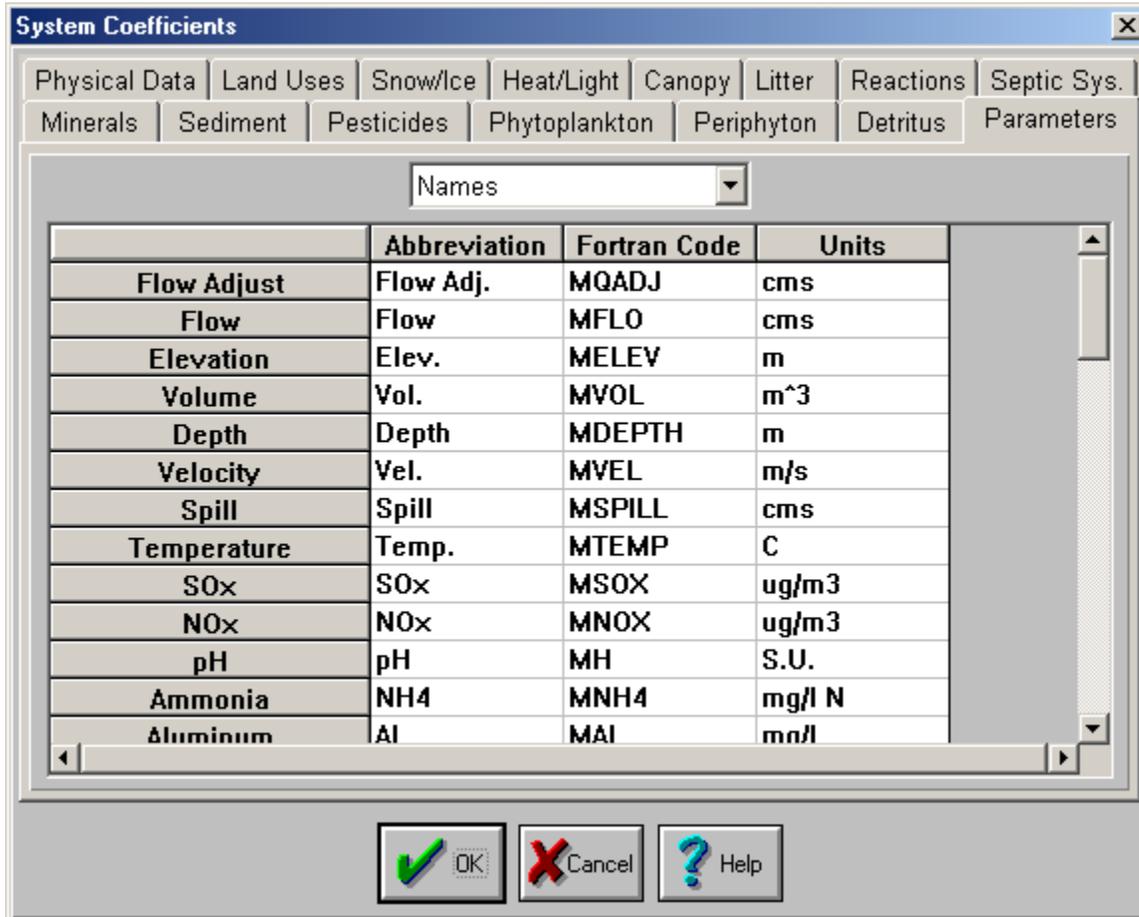


Figure 5.55
System Coefficients Dialog – Parameters.

Table 5.28
Parameter Data for System Coefficients.

Variable	Units	Range	Description
Names:			
Abbreviation			Abbreviation of the parameter name
Fortran Code			Parameter code recognized by simulator
Units			Units used in the graphical user interface
Output Control:			
Master			Switch to save output for the constituent
Catchments			Switch indicating this constituent applies to catchment output
Rivers			Switch indicating this constituent applies to river output
Reservoirs			Switch indicating this constituent applies to reservoir output
Loading			Switch indicating this constituent applies to loading output
Physical Data:			
Charge		-1, 0, or 1	Sign of the ionic charge of the parameter
Equivalent Weight	g/eq	> 0	Conversion between equivalents used in the simulator and units used in the GUI
Solubilities:			
Solubility Product	Varies	>0 or blank	Molar solubility product for precipitate or complex ion
Cation Valence		>0 or blank	Valence of the listed ion in precipitate or complex ion
Anion Valence		>0 or blank	Valence of hydroxide or sulfate in precipitate or complex ion
Multipliers:			
Point Source		≥ 0	Multipliers for point source loading
Nonpoint Sources		≥ 0	Multipliers for nonpoint source loading
Atmos. Deposition		≥ 0	Multipliers for atmospheric deposition
Composition	eq/eq	≥ 0	Multipliers for each parameter which when added together compose another parameter
Reaction Products	eq/eq	≥ 0	Reaction product for each parameter for each reaction

6

ENGINEERING MODULE – RUN AND OUTPUT

Run

The user can initiate a model run from three places: **Scenario** menu of the **Engineering Module**, **TMDL Module**, and **Consensus Module**. The purpose of multiple launching points is for convenience. After the preparation of a scenario case, a condition for TMDL calculation, or a revision of management alternative for consensus, there is quick access to starting a simulation.

In Chapter 3, a description of the **Simulate** button was made in both **TMDL** and **Consensus** modules. In Chapter 4, the **Run** item was mentioned in the **Scenario** section. In all those sections, the report only provides a brief discussion. This section provides a more complete description of running simulations.

Run Conditions

Figure 6.1 shows the dialog to specify conditions to control the model simulation. The first item is the beginning and ending dates. The three numbers for month, day, and year are separated by slashes. To change a number, move the cursor to the specific slot and click. Then use the up and down arrows to change the value. The day, month, or year can also be entered directly with the keyboard.

The second item is the time step in hours. The default time step is 24 hours or daily. To change the time step, click in the box and enter a new number. Please note that the program will expect meteorology and reservoir release data for each time step.

The third item is parameters to simulate. Hydrology is always simulated, but water quality constituents are optional. Optional items may be turned on and off by toggling with the mouse on the check box (☑). Simulations of hydrology alone run very fast. Simulations for the complete suite of water quality may take five times as long. The sediment, pesticides, fertilizers, and point sources options do not have a large impact on simulation time. They should be checked if input data is available.

The fourth item is the regions of the river basin to include in the simulation. It is not required to simulate the entire watershed every time. However, the entire watershed must be simulated at least once for WARMF to generate the boundary conditions between regions. WARMF will

automatically save the results for the interface points. After that, any subwatersheds can be turned off to save time by unselecting subwatersheds from the list.

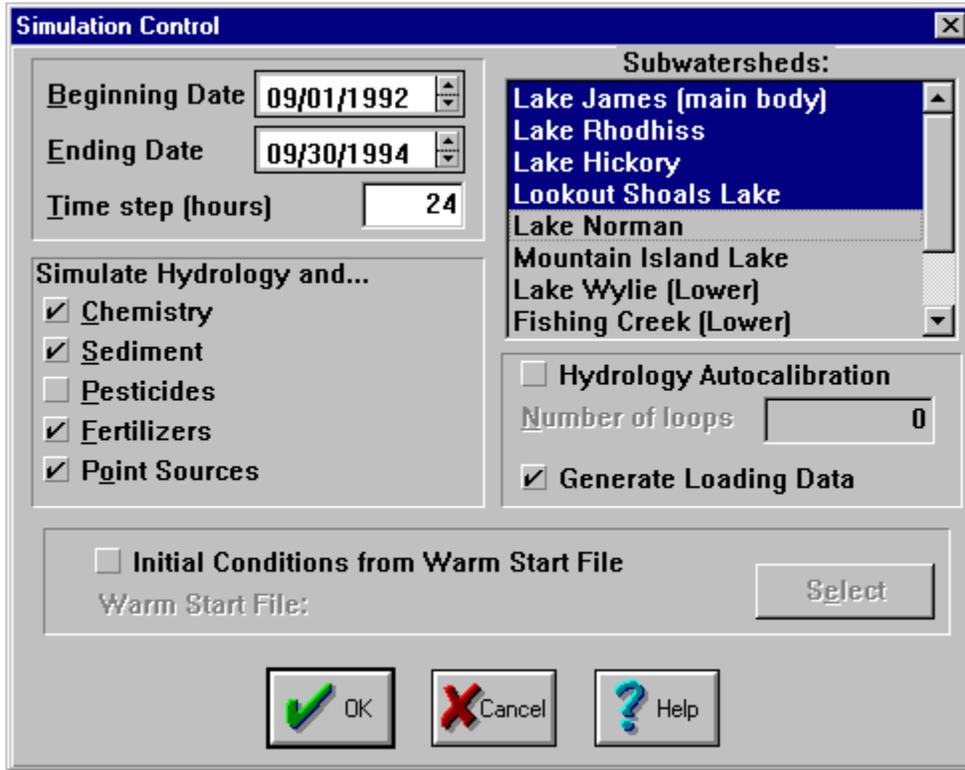


Figure 6.1
Dialog for Run Conditions

To see the subwatershed boundaries, select **Subwatersheds** from the **View** menu. As stated previously, the natural break point for subwatersheds is at reservoirs or lakes. Additional break points can be set on river segments. Please read the section on **View/Subwatersheds** for details. WARMF provides an autocalibrator for hydrologic simulation. There is no autocalibrator for water quality simulation. **Hydrology Autocalibration** can be activated by clicking on the check box.

This dialog only allows the users to specify the number of loops to iterate. For the autocalibrator to work, the user must have already set the autocalibration coefficients under the **Edit** menu. The users can select which regions of the watershed and which variables to adjust during the autocalibration.

By setting specific region to calibrate, the user can focus on different areas of the watershed, one at a time. It is best to work from the most upstream subwatersheds to the downstream subwatersheds.

Another option is **Generate Loading Data**. If this option is selected, point and nonpoint loading for each constituent are calculated for display in GIS maps. If this option is not selected, WARMF will still simulate hydrology and water quality for each catchment, river, and reservoir.

To account for future growth in the TMDL process, WARMF can run under one land use scenario for a few years (i. e. scenario A) and then run under a new projected land use for a few years (i. e. scenario B). This is possible with the **Warm Start** option. For scenario A, WARMF saves the final results in a warm start file with a **WST** extension. This file provides the initial conditions for scenario B. When making run for scenario B, turn the **Warm Start** option on and select the name of the warm start file from scenario A. For the program to work, it is important that the ending date of the first scenario is exactly one day prior to the starting date of the second scenario.

After all options are selected, click OK to start the simulation.

Progress of Simulation

During the simulation, a window will appear to show the progress. As stated previously, WARMF performs simulation for subwatershed regions, one at a time. Figure 6.2 shows that the program is working on subwatershed #1. The simulation is on day 99 out of a total of 760 days, or 13%. However, the river basin has a total of 11 subwatershed regions. In term of total simulation, the completion is only 1%.

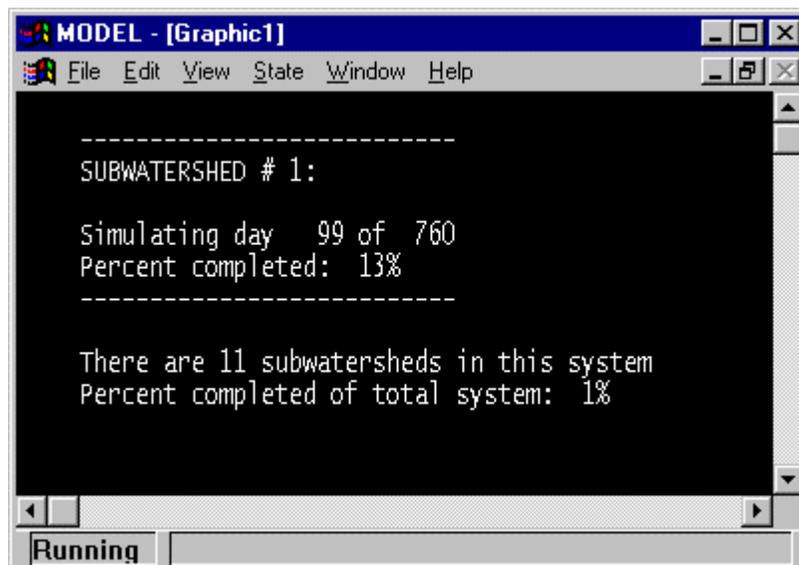


Figure 6.2
Progress of Simulation

WARMF will perform the simulation in the background, so the user is free to perform other tasks with the computer. Care should be taken, however, to avoid opening files in use by the simulation. When a simulation is successfully completed, the following dialog will appear (Figure 6.3):

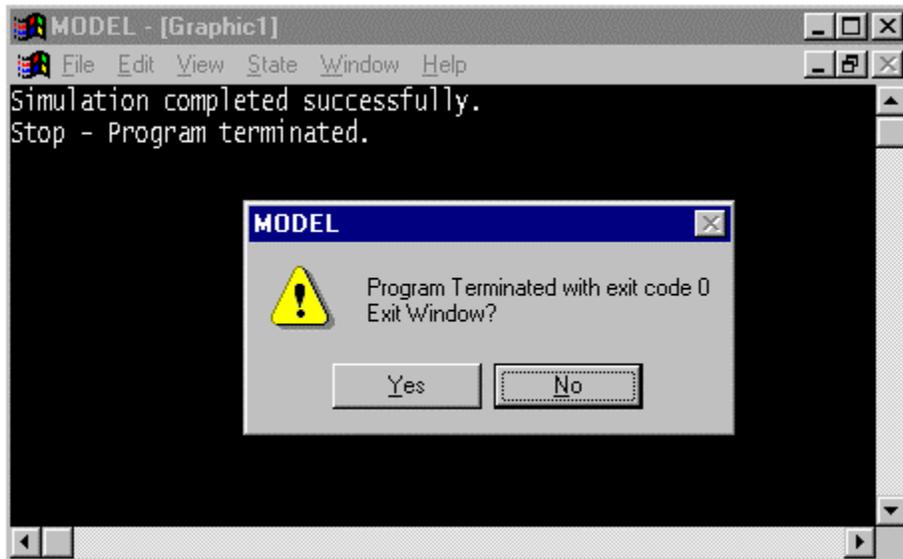


Figure 6.3
Completion Window

After clicking on Yes, the window will disappear and the user can view simulation output.

Output

Output of WARMF can be viewed from three modules (**Engineering**, **Consensus**, and **TMDL**) as well. The **Engineering** module provides scientific details of the model simulation. The **Consensus** and **TMDL** modules only provide information of interest to stakeholders, i.e. the GIS maps for the bar charts of point and nonpoint loadings from various regions of the watershed; the GIS maps for the source contribution of pollutants to a given location in the watershed; and the GIS maps showing the compliance or noncompliance with water quality criteria in various parts of the watershed.

The dialogs to display pollution loads and water quality conditions have been described in the consensus and TMDL modules of the documentation report (1). This section will describe only the dialogs for the **Mode/Output** menu of the **Engineering** module.

WARMF must be put into the **Output** mode to view output. To go to the **Output** mode, choose **Mode** on the menu and select **Output**.

Output Types

In the **Engineering** module, the user can view four types of output: **time series output**, **profile output**, **mass output**, and **spatial output**. Time series output shows simulation results and observed data for one location over the time period of the model simulation. Profile output shows simulation results and observed data through the depths of a reservoir segment for a particular day. Mass output shows the total mass of a constituent in a reservoir over the time period of the model simulation. Spatial output shows simulation results over the entire watershed for a particular day. Time series results are available for all catchments, river segments, and reservoir segments. Profile and mass output results are available for all reservoir segments.

If observed data is available for the selected location, it will be plotted along with the simulation results. If observed data is not available, WARMF will plot only the simulation results.

Viewing Output

Time Series Output

With the GUI in the **Output** mode, double-click on any catchment, river segment, or reservoir segment to view the time series output. If **Write Output to File** has not been checked for the object chosen before a simulation run, there will be no output available for viewing. Below are example dialog boxes for a river segment (Figure 6.4) and a reservoir segment (Figure 6.5).

The legend of the plot is shown below the X-axis. Black circles represent observed data points. Observed data can be shown or hidden by toggling the **Show Observed** button in the lower left corner of the dialog. If no black circles are visible with **Show Observed** checked, it means that there is no observed data from the simulated time period. The output parameters are listed on the left side of the dialog. To view a parameter, simply click on its name on the list.

The output can be exported to a text file for external processing. This is done by clicking on **Create Text File**. There are two options for the text file. **This constituent, all scenarios** option will create a text file with a column for day, a column for each scenario showing the simulated results for the highlighted constituent, and a column for the observed data. **All Constituents** option will create a text file with a column for day and a column for each of the simulated constituent concentrations for a given scenario (e.g. BASE). To change scenarios, click on the down arrow and choose the scenario to be written to the text file. A default file name is provided (i.e. FLOW.DAT), which can be changed by typing over it.

Several Output plots can be viewed simultaneously. The dialogs can be moved around by dragging. To close the output dialog, click on the “X” in the upper right corner.

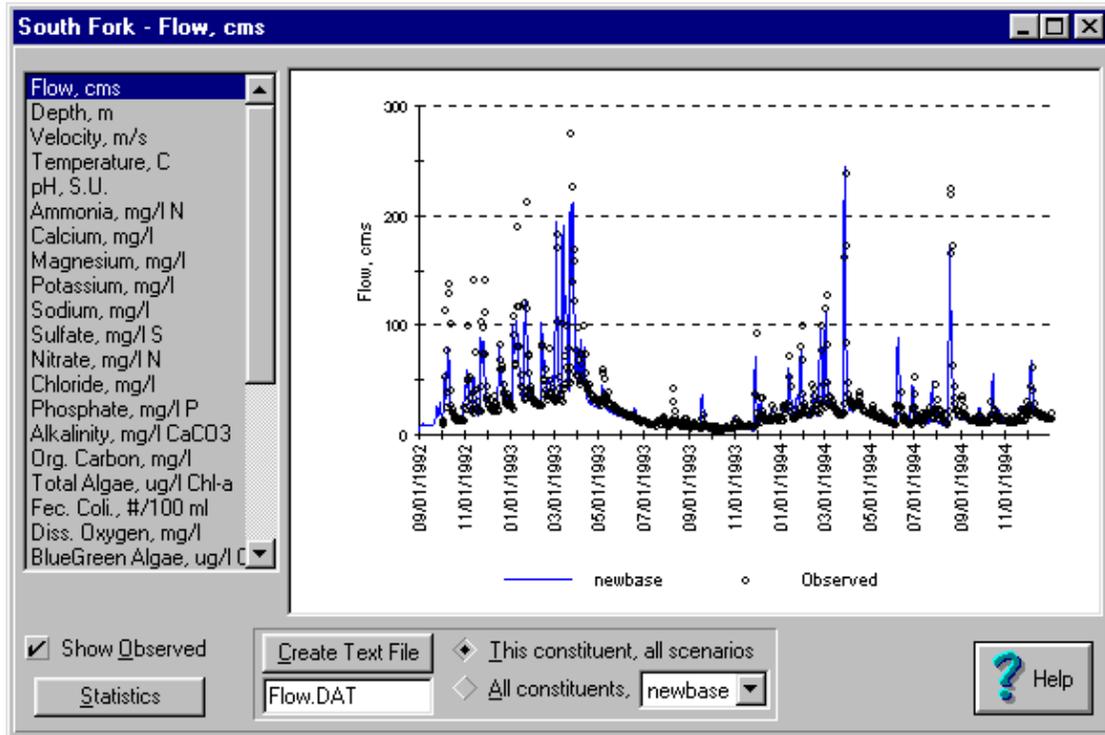


Figure 6.4
River Time Series Output Dialog.

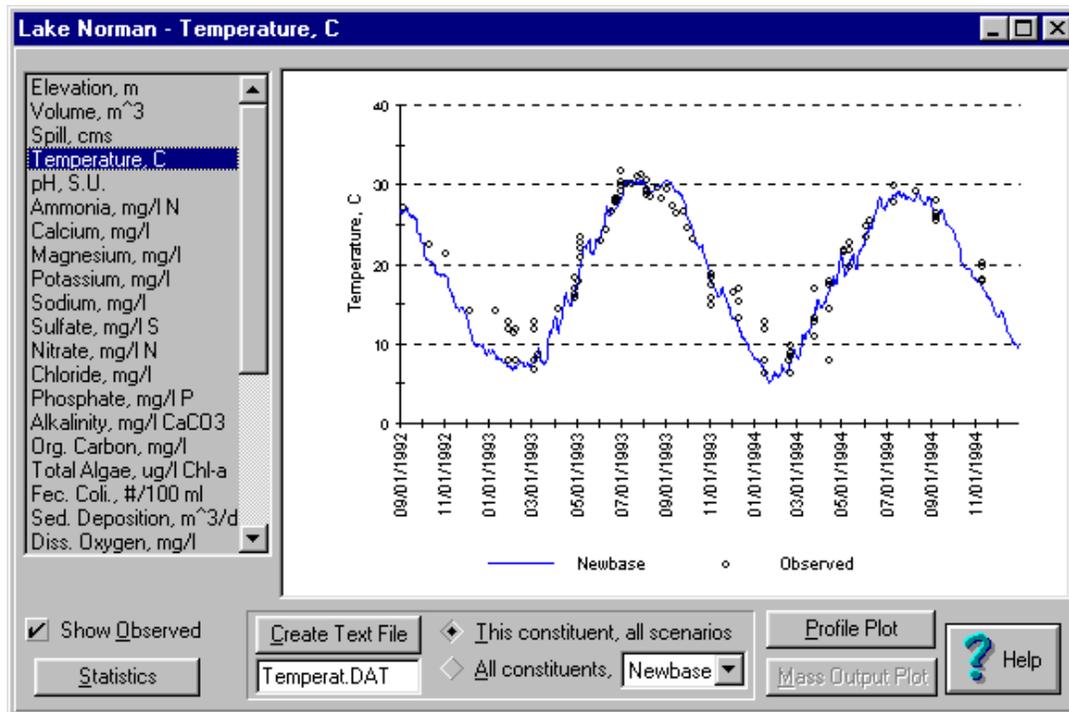


Figure 6.5
Reservoir Time Series Output Dialog.

Statistics

At the lower left hand corner of the time series plot (e.g. Figure 6.4 and Figure 6.5), there is the **Statistics** button. Pushing the statistic button will lead to the dialog shown in Figure 6.6. In this dialog, WARMF presents a comparison of the frequency distribution of simulated and observed values. The frequency distribution plot indicates whether the predicted and observed values are in the same range and same proportion. This comparison is important, because the water quality criteria must be met at a compliance level, rather than at a specific date.

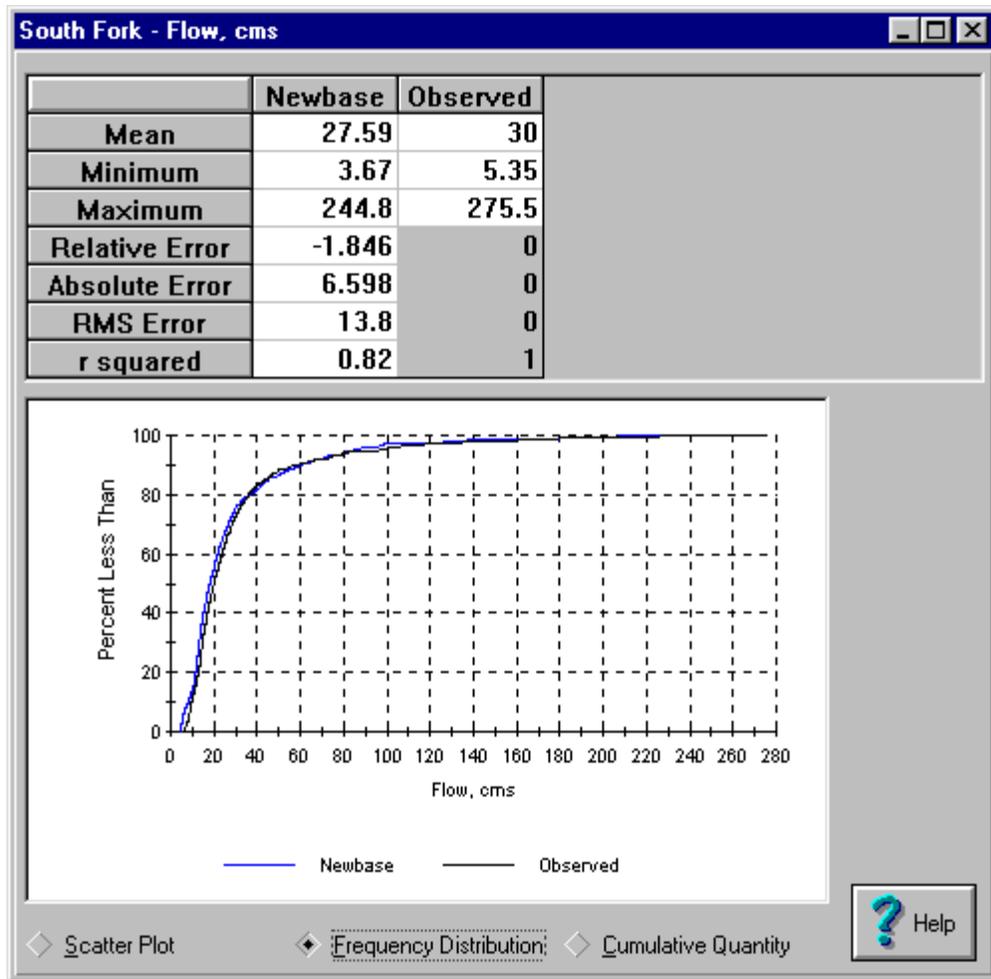


Figure 6.6
Frequency Distribution of Simulated and Observed Flows.

In the spreadsheet of Figure 6.6, the model result and observed data are compared for their mean, minimum, and maximum. **Mean** is the arithmetic average of all paired values over the entire period of simulation. The minimum and maximum of all paired values are also shown. These numbers indicate whether the model results are within the range of the observed data.

WARMF also calculates the relative, absolute, root mean square, and r-squared errors of the model results. In these calculations, the observed data is assumed to be 100% correct. The differences between simulated and observed values are errors.

Relative Error is the average of errors, i.e. the differences between simulated and observed values. The over prediction can cancel out the under prediction in this calculation. The relative error is a measure of model accuracy.

Absolute Error is the mean of the absolute value of the difference between simulated and observed values. In this calculation, the over predictions do not cancel out the under predictions. **Absolute error** is therefore a measure of model precision.

RMS Error, or "Root-Mean-Square" error, is calculated by taking the square root of the mean of the squared differences between simulated and observed values.

r-squared is the square of the correlation coefficient between simulated and observed values. A perfect correlation has **r-squared** of 1. It measures the percentage of variances in observed data that can be accounted for by the model simulation

At the left lower corner of the **Statistics** dialog, there is a diamond button for **Scatter Plot**. When this button is pressed, Figure 6.7 will appear. If there is a perfect correlation between the simulated and observed values, all data points will fall on the 45-degree line. The degree of scatter is a reflection of the statistics that the **r-squared** is 0.82. At the right lower corner of the **Statistics** dialog, there is a diamond button for **Cumulative Quantity**. When this button is pressed, Figure 6.8 will appear. The figure shows how well the model has simulated the cumulative amount of observed runoff for the gaging station.

WARMF is a dynamic model that uses the time series of meteorology, point source loads, etc. to calculate the time series of flow and water quality responses for so many locations in the river basin. It is very difficult to match both the timing and magnitude of the model predictions to the observed values.

WARMF presents various statistics for the user to evaluate the reliability of the model predictions. The user must bear in mind that there is no single statistical measure for the goodness of fit between two time series. If the simulated time series match the observed time series in magnitude, but off by one day, the errors can still be very large, even though they may not make any difference in TMDL calculations or management decisions. The calculation of error terms, discussed above, is based on the assumption that the measured values are 100% correct. This assumption may not necessary be correct.

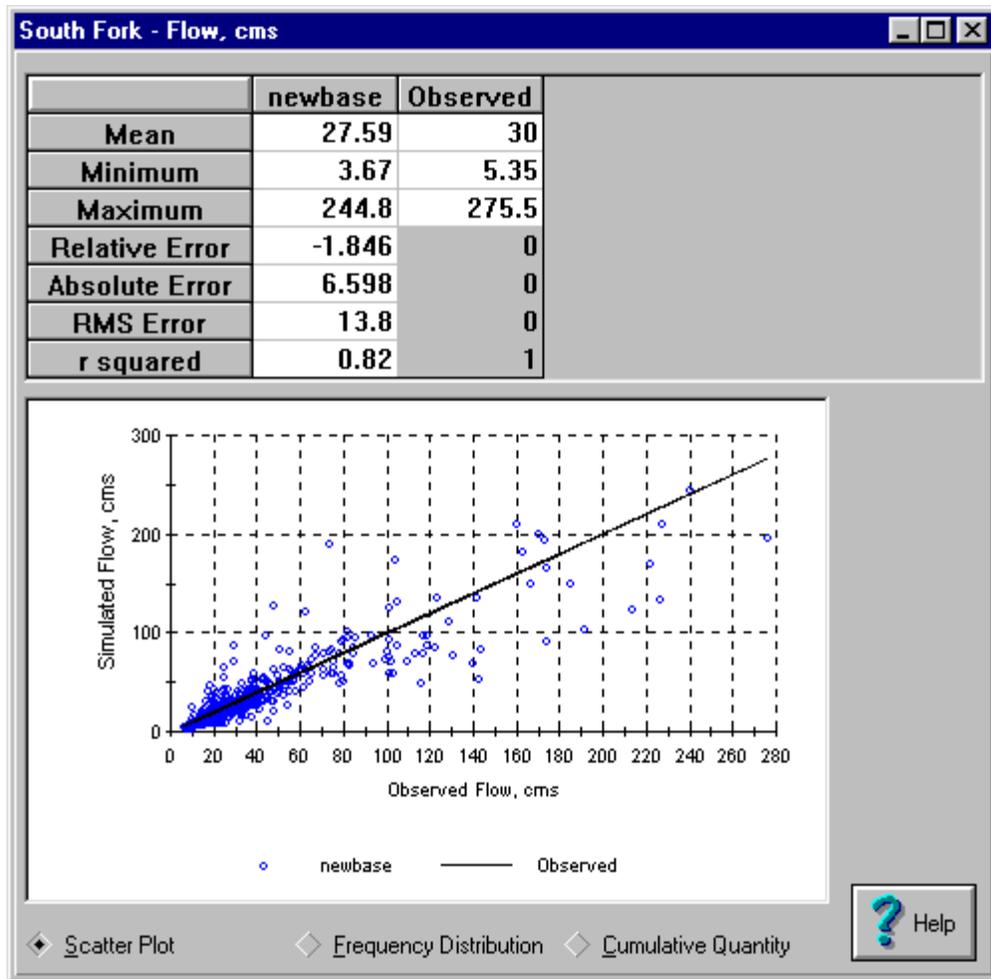


Figure 6.7
Scatter Plot of Simulated and Observed Flows.

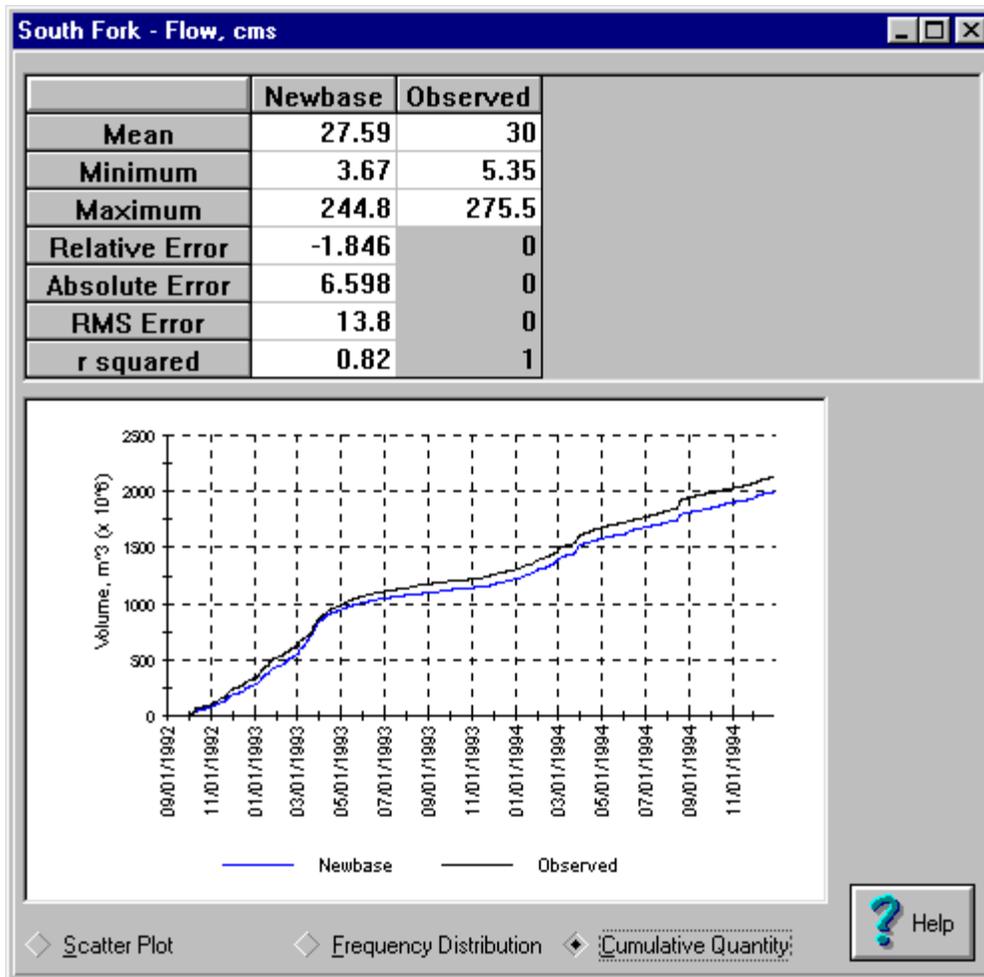


Figure 6.8
Cumulative Quantity of Simulated and Observed Flows.

Profile Output

To view a water quality profile of a reservoir, double-click on a reservoir segment. Select a parameter from the list on the left side of the dialog. Then click on **Profile Plot**. The dialog, shown in Figure 6.9, will appear:

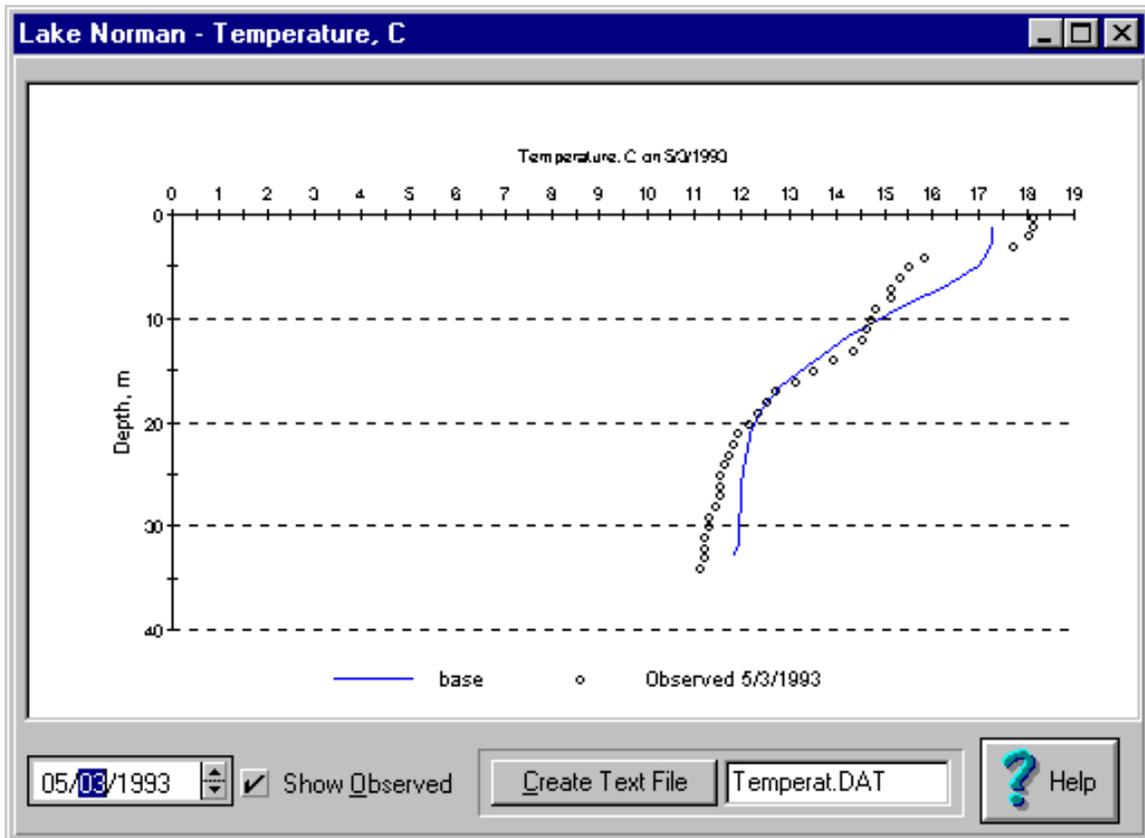


Figure 6.9
Profile Output Dialog.

The legend of the plot is displayed below the X-axis. Circles are for observed data and the line is for simulated results. The date of the observed profile is indicated in the legend. The date of the simulated profile is shown at the lower left corner of the dialog. Because observed profiles are available only for few dates, it is not possible to compare the simulated and observed profile at every date.

The user can change the simulation date to match the date of observed profile. To change the date of the simulated profile, click the mouse on either the day, month, or year field. Click on the up and down arrows to change date. By so doing, it is possible to see an animation of how the water quality profile changes seasonally. The day, month, or year can also be entered directly with the keyboard.

When **Show Observed** is checked but no data is shown, it means that there is no observed data. To evaluate the model output externally, click on **Create Text File**. The text file will contain columns for date, depth, observed and simulated data.

Multiple output plots (scenarios) can be opened for simultaneous viewing. The dialogs can be moved around on the screen by dragging. To close a dialog, click on the “X” in the upper left corner.

Mass Output

To view the total mass of a constituent in a reservoir, double-click on a reservoir segment when the GUI is in the **Output** mode. Select a water quality parameter in the list on the left side of the dialog and click on **Mass Output Plot**. Figure 6.10 appears:

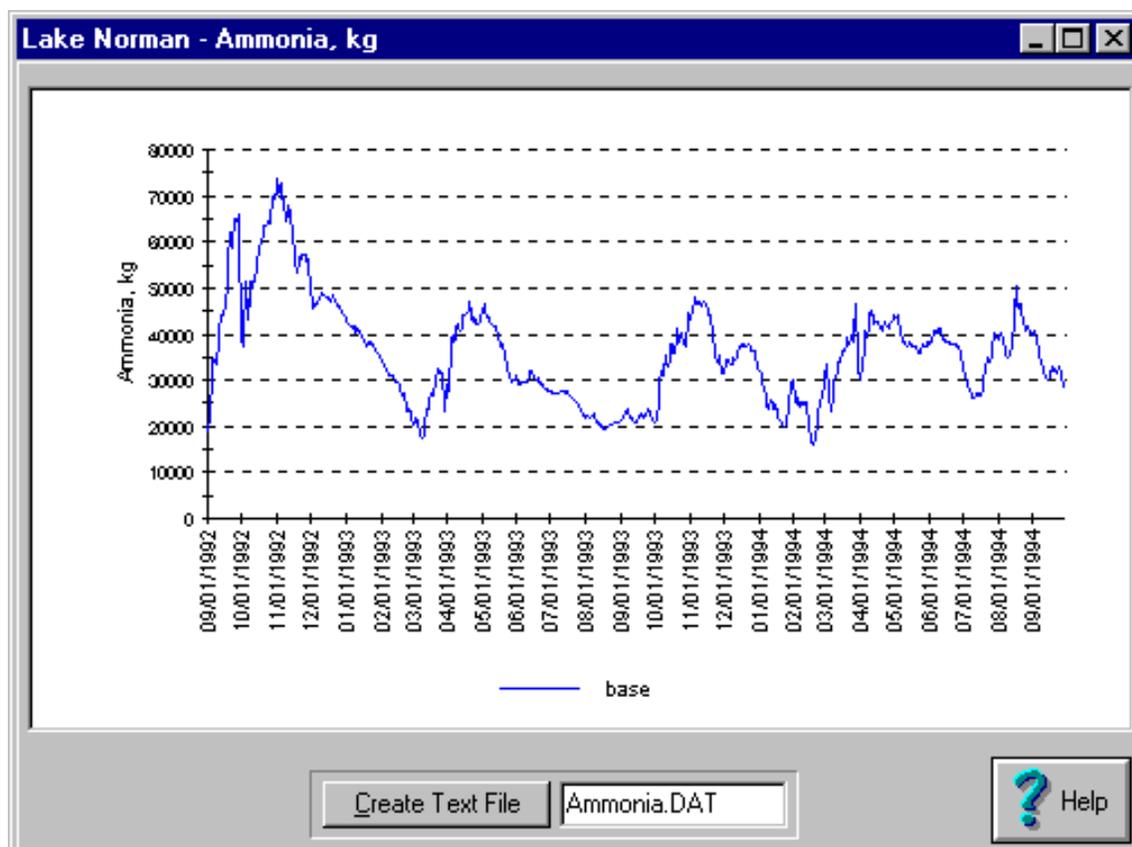


Figure 6.10
Mass Output Dialog.

The legend of the plot is displayed below the X-axis. To obtain the output in ASCII, click on **Create Text File**. The default text file name will be given based on the parameter selected (i.e. AMMONIA.DAT). This file name can be changed. Also, several output dialogs can be opened for simultaneous viewing. The dialogs can be moved around the screen by dragging. To close the dialog, click on the "X" in the upper right corner.

Spatial Output

To view spatial output of simulation results, double-click in the Map Window outside of the watershed boundary while the GUI is in the **Output** mode. Figure 6.11 is the dialog box that will appear:

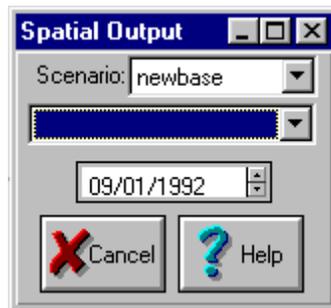


Figure 6.11
Spatial Output Dialog.

The dialog provides menu to select a scenario, a parameter and a date of spatial output. To select a scenario, push the pull down arrow for a list of scenarios and select one (e.g. BASE). To select a parameter, push the pull down arrow below for a list of parameters and select one (e.g. temperature). To select a date, click on the date and change it by the up and down arrow. Figure 6.12 shows the spatial output. The color of catchments, river segments, and reservoir segments reflects their temperature according to a scale shown on the Map Window.

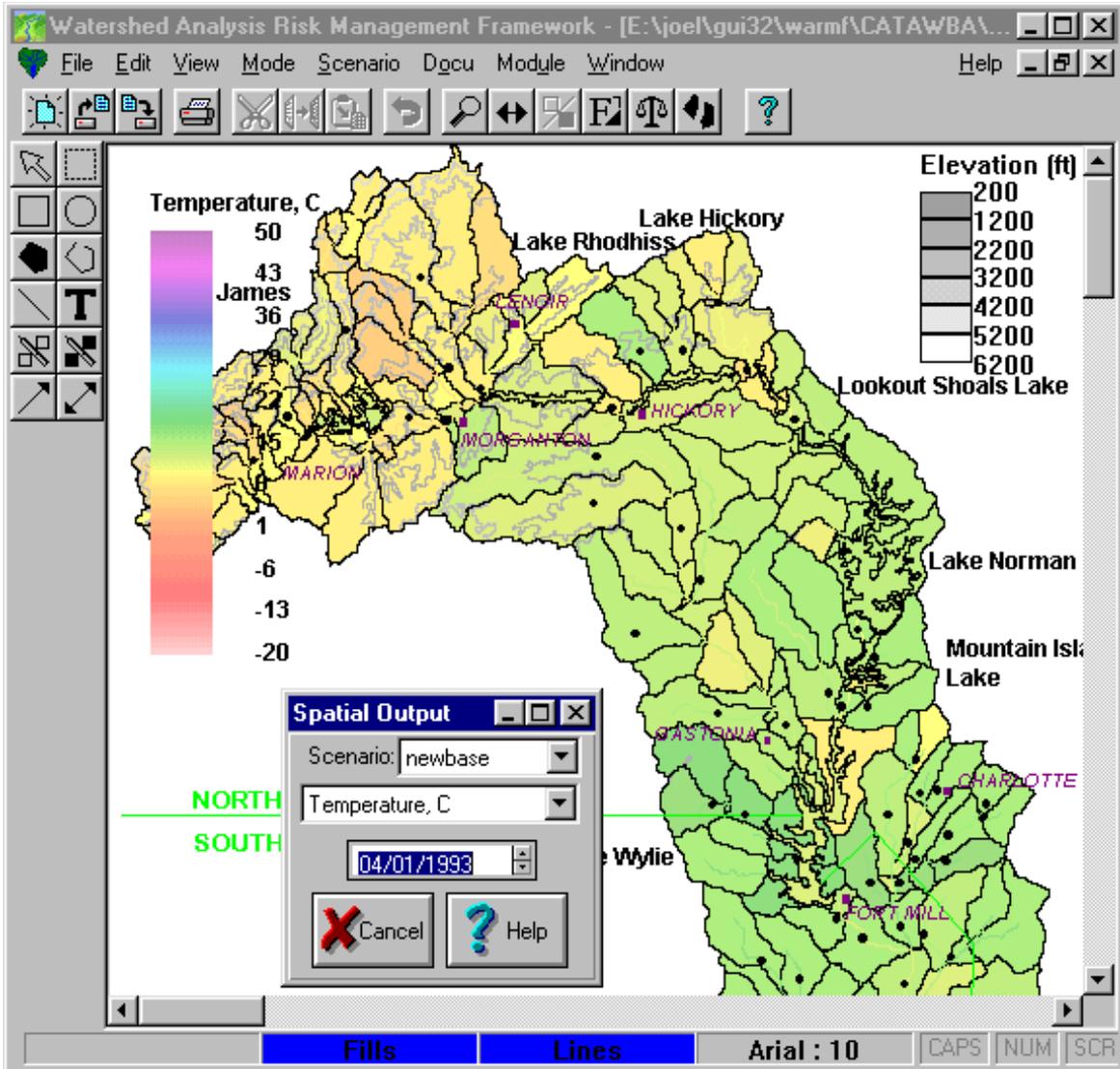


Figure 6.12
Spatial Output Display.

7

UPDATE AND RECALIBRATION

Introduction

The WARMF CD contains the database, simulation models, and graphical user interface. Continuous research in WARMF may result in improvements on the simulation models and graphical user interface. When it is warranted, a periodic update of WARMF may be issued. To the extent possible, the program update will be made in such a way that the program will continue to work with the old database. When an update of WARMF is furnished in a new CD, the user can follow the instructions to install the program. If there is a compatibility problem, the user should contact us, provide us the versions of new and old program, and explain the nature of the problem.

The database on the other hand can be updated when more data becomes available. Thus, the watershed managers can continue to use WARMF as a planning tool in the five years planning cycle of the TMDL process.

This chapter will describe the graphical user interface for extension of the database and/or further model calibration. It is assumed that the user already has a CD with an existing database.

Updating data will take 3 steps: compiling new data, recalling the existing database, and amending new data to the old database.

Adding New Data

New data can be added through the data module. There are two ways to access specific data in the **Data** module.

One way is to press **Module** in the menu bar from any module and select **Data Module** from the pull down list. WARMF will provide a list of data types, i.e. meteorology, point source, managed flow, etc. Select a data type to display the file names for existing data. Choose a file to update.

Another way is to press the **View** in the menu bar of the **Engineering** module, and select a data type. The stations with data for the data type are displayed as white dots on the basin map. Double-clicking on a specific white dot will retrieve the existing data file to update.

The method to go through the **Engineering** module is more intuitive than to go through the **Data** module. In the engineering module, the stations for the existing data are displayed as white dots

on the map. It is a matter of pointing and clicking at a white dot to retrieve the data file. In the data module, the user must learn the file name, which may be cryptic, for a specific station.

Extension of Meteorology Data

The first step is to compile daily meteorology data of precipitation (cm), minimum temperature (C), maximum temperature (C), cloud cover (%), dewpoint temperature (C), air pressure (mbar), and wind speed (m/s). The data source for the meteorology station is documented in the existing data file. The user can check the data source to get idea about where to obtain more recent data for the station. The data can generally be obtained either from the National Climatic Data Center (NCDC) or from a local Cooperative station.

For a higher order station, such as airports, the data for all parameters is usually available. For a lower order station, only precipitation and temperature data is available. In that case, the user may want to use the available precipitation and temperature data from the lower order station and the data of missing parameters from a nearby higher order station. It is necessary to have meteorology data for every parameter and every day of the simulation.

The second step is to retrieve the existing data. To do that, click on the **VIEW** menu and select **Meteorology Stations**. The available meteorology stations will be displayed as white dots on the basin map. If the white dots are too small to see, use zoom function to enlarge the map. Double click on a specific dot to retrieve the meteorological data for the station. The existing data will be displayed in a spreadsheet or a time series plot.

The third step is to amend new data to the existing database. To do that, click on **Table**, to put the database in **Table** mode. Click on **Add Blank Rows to End of File** to extend the length of the file. Scroll down to the new blank lines and enter the data. Data can be copied from an Excel spreadsheet using CTRL+C and CTRL+V commands. To insert individual rows, select a cell below which the new rows are to be add and push CTRL+INS. To delete a row, select the row and push CTRL+DEL.

Extension of Managed Flow Data

The first step is to compile new managed flow data. Managed flow data includes reservoir release data and diversion data and must be specified for every day of the simulation. The user can consult the data source in the existing database to get idea about where the data came from. Reservoir release data is usually available from the operator of the reservoir. If data is not available, but the river is gaged directly downstream of the dam, this river flow data can be used as reservoir release data. Diversion data is also usually available from the organization responsible for the diversion. In some cases, water may be diverted only during certain times of the year. For days with no diversion flow, the value should be set to zero. If data is available on a monthly (or yearly) basis, there is no need to repeat the value for every day in the file. Simply set the value for the first day it is valid and then leave the file blank until the day when the value changes. Missing data for a date can lead to a simulation error.

The second step is to recall existing data. To do that, click on **View** menu and select **Managed Flow**. The locations with managed flow data will appear as white dots in the basin map. If

needed, use the zoom function to enlarge the map. Double click on a specific white dot to retrieve the data file for the specific location.

The third step is to amend new data to the existing data file. Click on **Table** to place the data module in **Table** mode. Click on **Add Blank Rows to End of File** to extend the length of the file. Scroll down to the new blank lines and enter the data. Data can be copied from an Excel spreadsheet using CTRL+C and CTRL+V commands. To insert individual rows, select a cell below which the new rows are to be add and push CTRL+INS. To delete a row, select the row and push CTRL+DEL.

Extension of Air Quality Data

The first step is to compile new air quality data. Air quality data includes chemical constituent concentrations (mg/l) in precipitation and chemical constituent concentrations ($\mu\text{g}/\text{m}^3$) in the air. Monthly average data is used by WARMF.

The source of air quality data is documented in the existing database. The user is advised to check it to obtain idea about where to look for the more recent data. In general, rain chemistry data is available from the National Atmospheric Deposition Program. The aerosol chemistry data is available from the National Dry Deposition Monitoring Network. The monitoring stations are sparse. In most case, only one station within or near the basin may be available.

The second step is to retrieve the existing data. To do that, click on the **Module** menu, select **Data Module**, and then select **Air Quality**. Select **Table** to view the data in spreadsheet.

The third step is to add new data to the spreadsheet. To do that, click on **Add Blank Rows to End of File** to extend the length of the file. Scroll down to the new blank lines and enter the data. Be sure to add data for both the **Rain** and **Air** categories. Data can be copied from an Excel spreadsheet using CTRL+C and CTRL+V commands. To insert individual rows, select a cell below which the new rows are to be add and push CTRL+INS. To delete a row, select the row and push CTRL+DEL.

Point Source Load

The first step is to compile new point source data. Point source data includes flow, temperature, and loading data for each NPDES discharge. The data source is documented in the existing database. Consult it to get idea about where to obtain the new data. Generally, the data can be obtained from the state regulatory agencies, NPDES permit holders, or the EPA Permit Compliance System (PCS) database. The PCS database can be accessed via EPA's website.

The second step is to retrieve the existing database. To do that, click on the **View** menu from the **Engineering** module and select **Point Sources**. The locations of all point source dischargers will be shown as white dots on the basin map. If needed, use the zoom function to enlarge the map. Click at a white dot to retrieve the point source data at the specific location for update.

The third step is to add new data to the spreadsheet. To do that, click on **Add Blank Rows to End of File** to extend the length of the file. Scroll down to the new blank lines and enter the data. Data can be copied from an Excel spreadsheet using CTRL+C and CTRL+V commands. To insert individual rows, select a cell below which the new rows are to be add and push CTRL+INS. To delete a row, select the row and push CTRL+DEL.

Point source data can be entered for dates with irregular frequency. WARMF will use the flow and loading data for the starting date for each day of simulation until the next available date. In other words, it uses a step function approach for the point source load.

Update Land Use Data

It is desirable to update land use data on a periodic basis. WARMF can perform a model simulation under one land use condition and save the results as initial conditions for another simulation under the new land use conditions. WARMF does not have the capability to perform an interpolation of land use changes between two periods.

The best way to update land use data is to import a new ArcView shape file. Many state and local agencies have GIS departments that can prepare the ArcView shape files for historic or projected conditions. The shape file can be imported directly into WARMF to replace the old shape file. The import procedure is performed with the **File / Import / Land Use** function under the main menu. This function was described in an earlier section (**Catchment Coefficients**) of this report.

The new shape file may contain land use categories different from the old data. In this case, the list of land use categories must be updated before importing the ArcView shape file. The procedure to change the land use categories has been described earlier in the **System Coefficients** section of this report.

Extension of Observed Hydrology Data

The first step is to compile new observed hydrology data. The user can consult the data source documented in the existing database to get idea about where the old data came from. This may be the same source for new gaged flow data.

In general, daily stream flow data for most stations are obtained from the USGS website. Some stakeholders may have flow data measured for a specific location and period. For reservoirs, surface elevation and flow release data is usually compiled from the organization that operates the reservoir.

The second step is to retrieve the existing database. Two methods can be used. For method 1, click on **View** menu and select **gaging stations** in the pull down menu. The gaging stations will be shown as white dots in the basin map. If needed, use the zoom function to enlarge the map. Double click at a white dot to retrieve the observed hydrology data for the specific gaging station. For method 2, click on **Module** and select **Data** module. Click on down arrow for type of data and select **Observed Hydrology**. Click the down arrow of **File Name** to display available data files for the observed hydrology. Select a file for the gaging station to be updated.

The third step is to add new data. To do that, select Table mode to display the existing data in spreadsheet. Click on **Add Blank Rows to End of File** to extend the length of the file. Scroll down to the new blank lines and enter the data. Data can be copied from an Excel spreadsheet using CTRL+C and CTRL+V commands. To insert individual rows, select a cell below which the new rows are to be add and push CTRL+INS. To delete a row, select the row and push CTRL+DEL.

It is not necessary to have observed data for every day of simulations. The observed data is only used for comparing against model results.

Extension of Observed Water Quality Data

The first step is to compile new observed water quality data. Consult the data source documented in the existing database. The EPA STORET database may have an update of new water quality data for the same station. Stakeholder groups may have sponsored the collection of new water quality data to monitor the water quality improvement since the adaptation of a new TMDL plan. They can all be used to update observed water quality data.

The second step is to retrieve the existing database for update. Two methods can be used. For method 1, click on **View** menu and select **Water Quality Stations** in the pull down menu. The water quality stations will be shown as white dots in the basin map. If needed, use the zoom function to enlarge the map. Double click on a white dot to retrieve the observed water quality data for the specific station. For method 2, click on **Module** and select **Data** module. Click on down arrow for type of data and select **Observed Water Quality**. Click the down arrow of **File Name** to display available data files for the observed water quality. Select a file for the water quality station to update.

The third step is to add new data. To do that, select Table mode to display the existing data in spreadsheet. Click on **Add Blank Rows to End of File** to extend the length of the file. Scroll down to the new blank lines and enter the data. Data can be copied from an Excel spreadsheet using CTRL+C and CTRL+V commands. To insert individual rows, select a cell below which the new rows are to be add and push CTRL+INS. To delete a row, select the row and push CTRL+DEL.

Model Recalibration

As the new data is entered into WARMF, the user may wish to recalibrate the model to the new and better data. It is advisable for the user to first run the model without recalibration. If the results are good, it can be considered as a verification of the model.

For example, the model might initially use the annual average values of point source loads. As the point source data is improved to the monthly averages or weekly averages, the user may see the improvement in model prediction without the recalibration.

In most situations, model coefficients as contained in the CD have been calibrated with available data, which was limited. In any model application, there is always room for improvement. To adjust the model coefficients based on newer and better data can help improve WARMF on a continuous basis.

Through a model review, some potential users may discover that the application of WARMF is very data intensive. They have raised a legitimate question: do we have enough data to start a project using WARMF? The answer is affirmative for two reasons. First, WARMF can be started with input data that is readily available through Internet. Second, WARMF can grow with the improved data. There is no need to wait at the beginning.

Calibration is still a combination of art and science. It would be impossible to develop an autocalibration algorithm for a dynamic and multiple parameter model like WARMF. An autocalibrator has been developed for the hydrologic module, where a limited number of coefficients are adjusted in a logical sequence. Even for that, the application is carefully monitored by experienced modelers. Water quality calibration must be performed by experienced modelers also.

WARMF contains multiple parameter models involving numerous coefficients. A systematic approach must be used to calibrate the models. The idea is to calibrate the models according to a hierarchical order of parameters. For example, WARMF can be calibrated sequentially for hydrology, temperature, sediment, conservative constituents, nutrients, algae, and dissolved oxygen. In each step, a smaller but manageable group of coefficients can be adjusted to achieve the match between simulated and observed values.

Calibration Coefficients and Their Menu Paths

The calibration coefficients are parameters to adjust. There are only a few key coefficients to adjust for certain response variables. The menu path is the pathway to reach those key coefficients. They are discussed according to the hierarchical groups of response variables.

Hydrology and Temperature Calibration

The calibration coefficients for hydrology and temperature are grouped together because flow and temperature profiles are coupled in a stratified reservoir. In the case where a stratified reservoir is not involved, hydrology can be calibrated before temperature.

Following is a listing of the calibration coefficients and their menu paths for hydrology and temperature.

Menu path: Catchment coefficients / physical data category

- Detention storage
- Roughness

Menu path: Catchment coefficients / meteorology category

- Precipitation weighting factor
- Temperature lapse rate
- Altitude lapse rate

Menu path: Catchment coefficients / soil coefficients category

- Soil thickness
- Initial moisture
- Field capacity

- Saturation moisture
- Horizontal conductivity
- Vertical conductivity
- Initial soil temperature

Menu path: River coefficients / physical data category

- Manning's N

Menu path: River coefficients / reactions category

- Convective Heat Factor

Menu path: River coefficients / initial concentration

- Initial river temperature

Menu path: Reservoir coefficients / meteorology category

- Precipitation weighting factor
- Temperature lapse rate

Menu path: Reservoir coefficients / diffusion category

- Minimum negative density gradient
- Wind mixing diffusion coefficients
- Density gradient diffusion coefficients

Menu path: Reservoir coefficients / initial temperature category

- Initial temperature profile

Menu path: System Coefficients / physical data category

- Evaporation coefficients
- Thermal convection factors

Menu path: System Coefficients / land use category

- Fraction impervious

Menu path: System coefficients / snow category

- Snow formation temperature
- Snowmelt temperature
- Snowmelt rates

Sediment Calibration

Following is a listing of calibration coefficients and their menu paths for sediment:

Menu path: Catchment coefficient / erosion category

- Soil erosivity factor
- Sand, silt, and clay fractions of erodible soil

Menu path: Catchment coefficient / buffer zone category

- Percent buffered (length of buffer strip)
- Width of buffer strip
- Slope of buffer strip
- Roughness coefficient of buffer strip

Menu path: River coefficients / sediment category

- Detachment velocity factor
- Initial sediment depth
- Sand, silt, and clay fractions of river bed
- Vegetation factor
- Bank stability factor

Menu path: System coefficients /land use category

- Cropping factor
- Rainfall detachment factor
- Flow (velocity) detachment factor

Menu path: System coefficients / sediment category

- Particle size
- Specific gravity
- Settling velocity

Conservative and Non-conservative Constituents

Following is a listing of calibration coefficients and their menu paths for conservative and non-conservative substances:

Menu path: Catchment coefficients / fertilization category

- Fertilizer application rates including animal droppings, garbage, and automobile exhaust.

Menu path: Catchment coefficients / reactions category

- Ferrous ion oxidation rate

Menu path: Catchment coefficients / soil category

- Initial solution concentrations
- Initial adsorbed ions and cation exchange capacity of soil
- Mineral composition
- Surface mines and deep mines

Menu path: River coefficients/ reactions category

- Decay rates of various constituents
- Oxidation rate of ferrous to ferric iron

Menu path: Reservoir coefficients/ reaction category

- Decay rates of various constituents

Menu path: System coefficients / land use

- Collection efficiencies of aerosols
- Leaf area index
- Chemical composition of vegetation

Menu path: System coefficients /mineral category

- Mineral weathering rate coefficients
- Weathering by-products
- Equilibrium for pH

Nutrients, Algae, and Dissolved Oxygen

Following is a listing of calibration coefficients and their menu paths for nutrients, algae, and dissolved oxygen:

Menu path: Catchment coefficients /fertilization category

- Fertilizer application rates including animal dropping, garbage, and automobile exhaust.

Menu path: Catchment coefficients /soil category

- Initial solution concentrations
- Initial adsorbed ions and the CEC of soil

- Organic content in soil

Menu path: River coefficients /reaction category

- Sediment oxygen demand
- Nitrification rate
- Organic carbon decay rate

Menu path: Reservoir coefficients /reaction category

- Sediment oxygen demand
- Nitrification rate
- Organic carbon decay rate

Menu path: System coefficients / land use category

- Leaf area index
- Collection efficiencies of aerosol
- Chemical composition of vegetation

Menu path: System coefficients / algae and periphyton category

- Maximum algal growth rates
- Respiration, mortality, and settling rates
- Half saturation constants of nutrients
- Half saturation constants of light
- Chemical composition of algae
- Temperature tolerant ranges
- Chl-a/Carbon Ratio

Menu path: System coefficients/ nitrification category

- Foliar nitrification rate
- Soil nitrification rate.

Calibration Procedure

The basic procedure for calibration is by trial and error. WARMF provides a graphical user interface to facilitate such a process. The model calibration is performed through the engineering module. Calibration can proceed according to the following steps:

1. Under **Module** menu, select **Engineering**
2. Under **Scenario** menu, select **Manager**
3. Under the **Scenario** menu, make sure Base scenario is active. Open the **Scenario Manager**, push **Copy** button, and give a new scenario name (e.g. calib1).
4. Select **Open** to open the new scenario and click OK. Select the new scenario name (e.g. calib1) in the bottom of the scenario menu. Thus all changes made will be saved under the new scenario for comparison to the base case scenario.
5. Under **Mode** menu, select **Input**
6. Determine appropriate calibration coefficients and their menu paths.
7. Point and click at catchments, stream segments, or reservoir segments according to the menu paths.
8. Make appropriate adjustments of coefficients in the dialog. The adjustments can be made for as many locations and parameters as necessary.
9. Under **Mode** menu, select **Run**
10. Wait for the simulation to complete.
11. Under **Mode** menu, select **Output**
12. Point and click at a location in the watershed where there are observed hydrology and water quality data.
13. Select a parameter to display the plots of observed and simulated results for base case and new scenario (e.g. calib1).
14. Repeat the process until a good calibration is obtained.
15. If the results are satisfactory, click **Scenario Save** to save the new model coefficients under the new scenario name (e.g. calib1).

Some rules must be observed in the recalibration. If there are measured values for the calibration coefficients, use them directly. The adjustment of parameter values must be made within a reasonable range. The range of literature values can be found by pushing **Help** button.

It is also important to recognize that errors can come from different sources. They may include input data (meteorology, land use, etc.), model formulation, model coefficients, and observed data (hydrology and water quality). Model coefficients are not the only cause for a deviation from a perfect match.

A time series match is extremely difficult, because everything has to be lined up perfectly. In some of our simulation results, the simulated seasonal pattern appears to match the observed reasonable well by visual comparison. When the pairs of observed and simulated data for the same time are compared, the statistical correlation is very poor due to minor shifts in the time series.

A perfect match between simulated results and observed data should not be the only criteria to judge the performance of a model. A perfect match can be achieved by a very simple model with two lines of code: read the observed data and print it out as the answer. But, the model would not be useful.

The bottom line is whether WARMF, with the uncertainties of its model assumptions and the errors and uncertainties of its input data, can provide scientifically sound information for stakeholders to make a management decision. Sensitivity and uncertainty analyses to address this issue have been discussed in the documentation report of WARMF (1).

8

EXERCISES

Introduction

To help users become familiar with WARMF and its features, a set of exercises have been developed. Several of these exercises describe how to set up scenarios for hypothetical management plans, e.g. point source loading reduction, BMP(s) for nonpoint source loading, or water right purchase as a pollution trading scheme. One exercise shows how to set up TMDL runs using multiple Water Quality Limited Sections in the 303(d) list. One exercise demonstrates how to evaluate water quality due to projected future growth on a watershed. Another exercise looks at the Cost Sharing worksheet where point source dischargers share the cost of BMP(s) of nonpoint point source dischargers in exchange for a less stringent effluent limitation. The final exercise looks at the path to consensus. These are only a sample of the types of analyses that can be performed using WARMF.

The exercises are written in a cookbook format. The user can follow the procedure by clicking on the menus and buttons of the graphical interface.

Point Source Reduction

This exercise demonstrates the effect of making a global reduction in point source loading.

1. Under the **Scenario** menu, select **Scenario Manager**, select BASE, click on **Copy**, and give a new name (e.g. PTSRC). Use the **Open** button to open the new scenario and click OK. Make the new scenario active by selecting it from the list under the **Scenario** menu item.
2. Under the **Module** menu, select **Consensus**. Go to step 5. Click the pull down arrow for **Edit** box and select **Point Sources**. Push **Edit** button to display global load reduction factors for various pollutants. Reduce the point source loading by changing the weighting factors for each constituent. A value of 1.0 means no reduction and a value 0.4 means a 60% reduction. Click on **OK** to retain the changes. Click on **Scenario / Save**.
3. In the **Consensus** module, go to step 4 and click the **Simulate** button. Make sure the **Generate Loading Data** switch is on. Click OK to run the simulation with the existing setting for beginning date, ending date, etc. Wait for the simulation to complete.

4. When the simulation finishes, click on **Loading** to see how the reduction of point sources affects the overall loading.
5. Click on **Water Quality** and switch between scenarios and intended uses to see what affect the loading reduction had. Do some rivers and reservoirs change from red to green?

The exercise is for a global reduction of all point source dischargers. It may be desirable to make a load reduction for only a selected number of point source dischargers. This evaluation can be done through the **Engineering** module.

First prepare the data files for the proposed changes of specific point source dischargers. Follow step 1 describe above to create a new scenario. Under **Mode** menu, select **Input**. Double click on specific river segments or reservoirs that will receive modified point source discharges. Click on **Point Sources**. Use **Remove** to remove the old point source data file and use **Add** to assign the new point source data file. Click on **OK** and select **Scenario / Save**. After that follow steps 3, 4, and 5 described above.

Buffer Strips BMP

This exercise demonstrates the effect of buffer strips on nonpoint source loading and receiving water quality.

1. Under **Scenario** menu, select **Manager**. In the **Scenario Manager**, select BASE, click on **Copy**, and give a new name (e.g. BUFFER). Use the **Open** button to open the new scenario and click OK. Make the new scenario active by selecting it from the list under the **Scenario** menu item.
2. Under **Mode** menu, select **Input**. Point and click at one or more catchments where buffer strips are proposed. In the catchment dialog, select **Buffer Zone**. Make changes to the buffer zone coefficients: **Percent Buffered**, **Width**, **Slope**, and **Roughness**.
3. To modify the buffer strips for the entire watershed on a global basis, click on the **Apply to All Catchments**. To change several catchments as a group, hold down the **SHIFT** key while single clicking on the catchments. Double click on the last catchment to be included in the group while still holding the **SHIFT** key. Make the coefficient changes and then select **Apply to Selected Catchments**.
4. Under the **Scenario** menu, select **Save** to retain changes under the new scenario name. Under **Mode** menu, select **Run**, set simulation conditions, turn the **Generate Loading Data** switch on, and click OK to initiate the simulation. Wait for the simulation to complete.
5. In **Consensus** module, click on **Loading** in step 4 to see how the increase of buffer strips affects the overall loading.

6. In the **Consensus** module, click on **Water Quality** in step 4. Switch between scenarios and intended uses to see the effects of more buffer strips. Do some rivers and reservoirs change from red to green?

Cropping Factors for Agricultural Land

This exercise simulates the benefit of another BMP: to improve farming practices. The cropping factor, which ranges from 0.1 to 0.8, controls soil erosion and associated transport of phosphorus and pesticides from land to surface waters. A proper selection of crops and tillage practices can reduce the cropping factor for farmlands.

Under the **Module** menu, select **Engineering**. Push the **Scenario** menu and select **Manager**. In the **Scenario Manager**, select BASE, click on **Copy**, and give a new name (e.g. CROPFAC). Use the **Open** button to open the new scenario and click OK. Make the new scenario active by selecting it from the list under the **Scenario** menu item.

Push **Mode** in the menu bar and select **Input**. Double-click outside of the basin map to edit **System Coefficients**. Select **Land Use** with coefficient selector on the right column. Push the down arrow of Parameter box and select **Cropping Factor** from the list. Select land uses for **Cropland**, **Cultivated**, **Farm**, and **Orchard** and reduce their cropping factor by 50%. Click OK for the changes made.

Under the **Scenario** menu, select **Save** to retain changes under the new scenario name. Under the **Mode** menu, select **Run**, turn on the **Generate Loading Data** switch, and push **OK** to start the simulation. Wait for the simulation to complete.

Under the **Module** menu, select **Consensus**. Click on **Loading** in step 4 to see how the nonpoint source loading decreases.

Click on **Water Quality** and switch between scenarios and intended uses to see the affects of reduced cropping factors. Do some rivers and reservoirs change from red to green?

Atmospheric Deposition

This exercise simulates the effects of cleaner air. Cleaner air can reduce wet and dry atmospheric deposition to land. The deposited pollutants can be washed off to receiving waters.

1. Under the **Module** menu, select **Engineering**. Under the **Scenario** menu, select **Scenario Manager**. In **Scenario Manager**, select BASE, click on **Copy**, and give a new name (e.g. AIRDEP). Use the **Open** button to open the new scenario and click OK. Make the new scenario active by selecting it from the list under the **Scenario** menu item.

2. Under the **Module** menu, select **Consensus**. Go to step 5 and push the pull down arrow of Edit box and select **Atmospheric Deposition** from the list. Push the **Edit** button for a list of deposition factors for various air pollutants. Reduce their values by 50%, which will be made on both wet and dry depositions.
3. In the **Consensus** module, click **Simulate** button in step 4. Set the simulation conditions and turn the **Generate Loading Data** switch on. Click OK to start simulation and wait for the run to complete.
4. When the simulation finishes, click on **Loading** to see how the reduction of air deposition affects the overall loading.
5. Click on **Water Quality** and switch between scenarios and intended uses to see the effect of loading reduction. Do some rivers and reservoirs change from red to green?

Fertilizer Application

This exercise simulates the effects of fertilizer application. WARMF tracks the amount of fertilizer application to the land and subtracts the amount consumed by vegetation. The remainder can be washed off to a river segment.

WARMF uses the same procedure to track all pollutants that can be applied to land. For that purpose, the pollutant list expands from nitrogen and phosphorus of real fertilizer to such parameter as BOD, fecal coliform, and metals. They can be derived from animal wastes in pasture land. In urban land, they can be derived from lawn fertilizers, garbage in the streets, pet wastes, and unlawful dumping into storm sewers.

A reduction of nonpoint source load can be achieved by farmers, street sweepers, or pollution prevention promoters. WARMF can evaluate their effectiveness.

1. Under the **Scenario** menu, select **Scenario Manager**. In the **Scenario Manager**, select **BASE**, click on **Copy**, and give a new name (e.g. FERTILIZ). Use the **Open** button to open the new scenario and click OK. Make the new scenario active by selecting it from the list under the **Scenario** menu item.
2. Under **Module** menu, select **Consensus**. Push the pull down arrow for **Edit** box and select **Nonpoint Sources** from the list.
3. Push the **Edit** button for a global change of fertilizer applications. Push the pull down arrow of the land use box for a list of land uses. Select a land use (e.g. cultivated land, grassland, urban etc.) one at a time and reduce its monthly fertilizer applications by 50% for each pollutant. Check **Apply to all subcatchments** for a global change. Select **Scenario/Save** to retain changes.
4. Click **Simulate** button in step 4. Set the simulation conditions and turn the **Generate Loading Data** switch on. Click OK to start simulation and wait for the run to complete.

5. When the simulation finishes, click on **Loading** to see how the reduction of fertilization rates affects the overall loading.
6. Click on **Water Quality** and switch between scenarios and intended uses to see the effect of loading reduction. Do some rivers and reservoirs change from red to green?

If fertilizer applications are to be reduced only for a group of catchments, the evaluation must be performed through engineering module. For that evaluation, the first step of creating and activating a new scenario is the same as described in step 1. Under the **Module** menu, select engineering. Under the **Mode** menu, select **Input**. Click on a catchment and select **Fertilization**. Push the down arrow of land use box and select a land use to change its monthly fertilizer application rates for various pollutants.

To modify the fertilizer rates the entire watershed on a global basis, click on the **Apply to All Catchments** button. To change several catchments as a group, hold down the **SHIFT** key while single clicking on several catchments until they are selected. Double click on the last catchment to be included in the group while still holding the **SHIFT** key. Make the coefficient changes and then select **Apply to Selected Catchments**.

After that, follow steps 4, 5, and 6 to see the impact of fertilizer applications on nonpoint source loading and receiving water quality.

Water Rights Purchase

This exercise simulates the impact of purchasing water rights from farmers as a pollution-trading scheme.

In some river basins, large quantities of water are diverted for municipal and agricultural uses. This practice can not only reduce available dilution water but also increase nonpoint source load from farmlands. One possible management option is for the point source dischargers to purchase the water rights of some diversions and keep more water in the river. The goal of this purchase would be to increase the assimilative capacity of the river which could result in a higher allowance of point or nonpoint loading and/or improved water quality.

1. Create a new scenario for this exercise. Start with **BASE** as the active scenario. Go to **Scenario / Manager**, click on **Copy**, and give it a new name (such as **BUYWATER**). Use the **Open** button to open the new scenario and click **OK**. Make the new scenario active by selecting it from the list under the **Scenario** menu item.
2. Under the **Module** menu, select **Consensus**. Go to Step 5 and push the pull down arrow, and select **Diversion** from the list. Push the **Edit** button for a list of the diversions in the watershed. Decide which diversions will be removed or reduced. Adjust the factors accordingly. A factor of zero will remove the diversion completely. A factor of 0.5 will reduce the diversion by 50%. Click on **OK** and **Scenario/Save** to retain changes.
3. Turn the **Generate Loading Data** switch on. Select **Mode / Run** from the main menu and run a simulation for the entire watershed.

4. When the simulation finishes, click on **Loading** to see how the purchase of water rights affects the overall loading.
5. Click on **Water Quality** and switch between scenarios and intended uses to see the effect of the water rights purchase. Do some rivers and reservoirs change from red to green?

Nested TMDL

This exercise demonstrates the procedure to calculate a TMDL for multiple water quality limited sections (WQLS) on a watershed. The WQLS are locations that violate the water quality criteria for its intended uses. In WARMF, WQLS and control points mean the same thing. The TMDL calculation is made from the upstream to the downstream WQLS.

For the purpose of illustration, we will use Sugar Creek in Charlotte, North Carolina as an example. If your CD does not contain the database for Sugar Creek, please follow the procedure and apply it to your watershed system.

Figure 8.1 shows the map of three river sections that violated the intended use of warm water fish habitat. They are Upper Sugar Creek, McAlpine Creek, and Lower Sugar Creek. The first TMDL we will calculate is for Upper Sugar Creek.

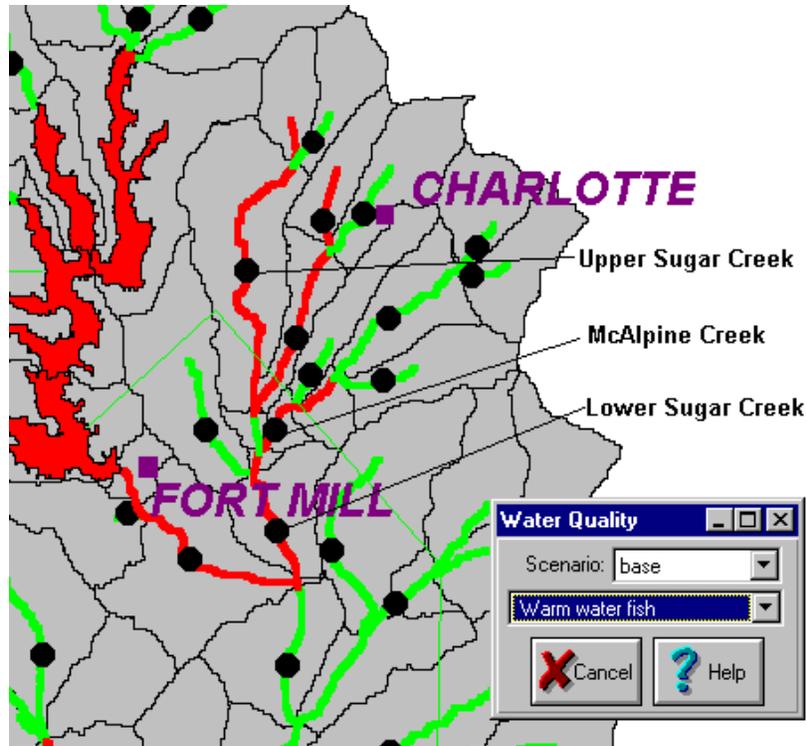


Figure 8.1
Map of Sugar Creek, NC.

The TMDL calculation will be carried out through TMDL module. However, the first step is to create a new scenario name for TMDL.

1. Under the **Scenario** menu, select scenario manager, select BASE, click on **Copy** and give it a new name (e.g. TMDL1). Make the new scenario (TMDL1) active.
2. Under the **Mode** menu, select **TMDL**. Push the down arrow of intended use box and select **Warm Water Fish**. Push down arrow of criterion box and select **min. 7-day mean Dissolved Oxygen, mg/l**. Push the down arrow of TMDL box and select **BOD** as the loading parameter to adjust.
3. Click on the **Control Point** button. The basin map will appear along with a dialog. Drag the dialog away if it covers the map section of interest. Follow the instruction in the dialog and click once on **Upper Sugar Creek**. The creek should be highlighted. Click OK on the dialog. The name, Upper Sugar Creek, should appear next to the control point button.
4. Set a level of either point or nonpoint source control. Let's use a nonpoint control level of 0.4 for the first TMDL calculation. The TMDL for point source load will be determined together with a 60% reduction in nonpoint source loading.
5. Push the pull down arrow of simulation name box and select TMDL1. Push the **Start** button and wait for the simulation to finish.

6. To view the results, click on **Loading** button to see how the loading is reduced from Base case to TMDL1. Click on **Water Quality** button to see if Upper Sugar Creek improved. Does it change from red to green when switching between BASE and TMDL1?
7. If the color has changed from red to green, it is an indication that the TMDL calculation is successful. The program will indicate **Yes** to the question of “is the TMDL acceptable?” Click the **Save TMDL** button. The point and nonpoint load allocations will appear in the spreadsheet.
8. If it is not successful, the program will indicate **No** to the question of “is the TMDL acceptable?”. That means the water quality criterion cannot be met even with zero point source loading. The program will suggest the user to try another solution at a higher level of nonpoint source control. By this process, it is possible to generate multiple solutions of TMDL with different point and nonpoint load allocations.
9. To continue the TMDL calculation for the next downstream water quality limited segment, make a new scenario (TMDL2), and go back to step 1 of TMDL module. For the control point, select McAlpine Creek as the second water quality limited segment. Calculate the TMDL for all loads upstream of McAlpine Creek, including those discharged to Upper Sugar Creek.
10. To view results, click on **Loading** to see the loading change and click on **Water Quality** to see if the water quality of at the control point has improved. Does it change from red to green when switching between BASE and TMDL runs?
11. Repeat the same procedure to calculate TMDL for Lower Sugar Creek as the control point. You will end up with a table of loading allocations for each control point in the watershed.

Since TMDL is calculated for each control point, do not be surprised by a result that the TMDL for the lower control point is higher than the TMDL for an upper control point. This can happen when the stream segment receives another tributary inflow of higher water quality. In that case, the TMDL for the upper stream segment is more restrictive and is the one to adopt. This will result in a smaller total load to the lower stream segment. Thus, after all TMDLs are calculated for all control points in the entire watershed, the user must go through the results and adopt the most restrictive TMDLs for the final TMDL plan.

Alternatively, one may wish to calculate and preserved the TMDL for the upstream WQLS. To do that, it is necessary to set a breakpoint for the upstream WQLS. After the calculation of TMDL for the river section, turn off the subwatershed in the **Run** dialog of the TMDL calculations for the downstream WQLS. The procedure has been described in Chapter 3. TMDLs can be calculated for rivers or reservoirs. They can also be calculated for a variety of intended uses, criteria, and control parameters. By varying the level on nonpoint source control, a user will end up with a matrix of potential point and nonpoint allocations. The total loads are not constant, meaning that point and nonpoint load do not have the same water quality effect. Point source loading is generally steady throughout the year. Nonpoint loading usually enters the system during storm periods and can be attenuated by various natural processes. Because of these differences, it is necessary to calculate TMDL with a tool such as WARMF. One cannot

calculate a TMDL and divide the total into point and nonpoint allocations on an equal weight basis.

Because WARMF produces multiple solutions for TMDL, it is possible to engage stakeholders in the public allocation of the assimilative capacity as stipulated in the Water Quality Act. In this process, stakeholders can consider other factors such as cost, equity, pollution trading, and social considerations in their deliberation for a final TMDL plan as long as they stay within the acceptable TMDL solutions.

Growth Factor

The Water Quality Act requires that TMDL must take into account the growth factor. This exercise is designed to evaluate the water quality effects of urban growth in the watershed.

1. Under the **Scenario** menu select the **Scenario Manager**, select **BASE**, click on **Copy** and give it a new name (e.g. GROWTH). Make the GROWTH scenario active.
2. Ask the responsible planning agencies to supply an ArcView shape file of projected land use and import it into WARMF via the **File/Import** function.
3. If the projected land use shapefile is not available, the land use data can be modified by hand. Under the **Module** menu, select **Engineering**. Under the **Mode** menu, select **Input**. Click on catchments that are subjected to urban growth. Change their land use coefficients to reflect an increase in residential, commercial, industrial, high or low density developments. Reduce the land use for forest and cropland/pasture that have been converted to urban area. Click **OK**.
4. To make the appropriate changes in the point source loading to accommodate the growth. Prepare new point source files for dischargers with anticipated increase in loads. Click on the stream or reservoir segments where the increased point source load will be discharged to. In the dialog, select **Point Source**. Use **Add** and **Remove** buttons to replace the a new point source files.
5. To make the appropriate adjustment for increase in air pollution due to new growth in industries and automobiles, select **Consensus** under the **Module** menu. Push down arrow of data Edit box of step 5 and select **Atmospheric deposition** from the list. Push **Edit** button and make global increases of deposition factors for various constituents.
6. Under the **Scenario** menu, select **Save** to retain the changes in land use, point source loading, and atmospheric deposition under the new scenario name.
7. Under the **Module** menu, select **Engineering**. Under the **Mode** menu, select **Run**, turn **Generate Loading Data** switch on, and make sure the simulation parameters are as intended and push **OK** to start the simulation.

8. When the simulation finishes, click on **Loading** to see how urban growth changes the point and nonpoint source loading. Click on **Water Quality** to assess the water quality impact of urban growth. Has the water quality changed enough to affect the suitability for any intended uses?

Cost / Benefit and Cost Sharing

This exercise is designed to show how WARMF evaluates cost-benefit of alternatives. It is also designed to show how to calculate equitable contributions of funds from various point source dischargers. These contributions will be used to pay for a part of the nonpoint source control cost in exchange for a less stringent treatment requirement for point source dischargers.

The exercise will be performed through the consensus module. The exercise will use some of the scenarios created previously.

It must be pointed out that WARMF is not an economics model. It does not calculate the cost of various management alternatives. Rather, WARMF brings the cost data, which must be generated outside of WARMF, into the matrix of decision variables for the stakeholders.

1. Under the **Module** menu, select **Consensus**. Under the **Scenario** menu, select scenario manager. Use the scenario manager to open BASE, BUFFER, CROPFAC, and AIRDEP.
2. Click on the **Cost / Benefit** button. Enter costs of various management alternatives into the spreadsheet.
3. Examine the **Benefit** section in the spreadsheet. In WARMF, the benefit is not expressed in monetary terms. Rather it is expressed in percent compliance. Better alternatives will have higher percentage of compliance. Click OK, instead of Cancel, to save the costs data in the program.
4. Click on **Cost Sharing**. Enter the **Annual Overhead** (i.e. 10 to 15%) for administering the cost-sharing program.
5. Enter the proposed **Target Point Source Share** that is the desired amount of contribution from point source dischargers. The remainder will be paid for by the nonpoint dischargers. Remember that this is a term for negotiation during the consensus building process.
6. Enter the proposed Loading Fees of BOD, nitrogen, and phosphorus for point source dischargers. Remember that the loading fees are also for negotiation during the consensus building process. Their purpose is to assess sufficient funds to pay for the share of nonpoint control cost. Knowing what the assessment will be, some point source dischargers may opt to upgrade their treatment plants.
7. The loading fees can be adjusted until the **Actual Point Source Share** is close to the target value. WARMF allocates a share of the project cost to each discharger based on the current loadings of BOD, nitrogen, and phosphorus.

Consensus

This exercise looks at the path to consensus. It is designed for stakeholders to register their preference for the proposed management alternatives or TMDL plans. The preference is converted into a nominal score, which gives each stakeholder an equal voice.

- While actual stakeholders are to be used in the consensus process, the exercise can be performed by an individual or by a focus group. They just have to pretend that they act on behalf of real stakeholders.

It is assumed that a large number of possible TMDL solutions are generated ahead of time. These technically acceptable alternatives are to be evaluated by stakeholders with different interests and concerns.

1. Under the **Module** menu, select **Consensus**. Click on the **List** button of step 1 and collect stakeholder information and their concerns on various issues deemed important in the watershed.
2. Under the **Scenario** menu, select the **Scenario Manager**. Open all TMDL scenarios to be compared.
3. Click **Pros and Cons** of step 7. Push the down arrow button of stakeholder box. Select a stakeholder and ask him/her to rank the TMDL alternatives from 1 to 5 (5 is the most favored) in each area of his/her registered concern. For example, if one of the concerns is good water quality, ask the stakeholder to find an alternative (or TMDL plan) that would give the best water quality and give it a score of 5. The next alternative that would give the second best a score of 4, and so on so forth. If a concern is cost and equity, ask the stakeholder to register a score of 5 for the TMDL plan that is most cost effective and equitable.
4. Follow the same procedure to register the preferences for all stakeholders.
5. After all votes are taken and entered into WARMF, push the **Nominal Scores** button. The program will display a nominal score summary and show the percentage of stakeholders who choose a given TMDL plan as the top 1, 2, and 3 choice. It will also display the preference of each stakeholder group (i.e. local agency, water company, environmental organization, etc.).
6. The nominal score summary gives a clear picture of what stakeholders like. Try to find out why a certain group of stakeholders prefer one TMDL plan over the other. Try to find out why a group of stakeholders does not like a certain plan. Also, try to see if a given plan can be modified to receive a higher acceptance among stakeholders.

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