Lab 2: Setup of a New Study

- Rum River, MN, as template
- Rum River Background
- Use of the Wizard
- Site Characteristics
- Importing Loadings

Photo: MN Pollution Control Agency

In Lab 1 we worked with an existing simulation to give you a preview of the types of analyses that can be performed with AQUATOX.

In Lab 2 we will start the process of setting up an AQUATOX simulation for a new site. In this case we will be applying the AQUATOX model to “your site” assuming “your site” is the Boise River in Idaho.

When you are applying AQUATOX to a new site it is usually most efficient to find a surrogate site that best matches the characteristics of the site you are modeling. You will then take that site and modify its characteristics so that it matches your site with respect to Nutrients, Organic Matter, Turbidity, Biota, and Organic Chemicals (if relevant).

In this laboratory we will start this process by taking the following steps

- Find a surrogate site (Rum River, MN)
- Modify the physical characteristics of the surrogate site to match “your site” (Boise River, ID).
- Modify the nutrients, organics loadings, and turbidity using data from “your site.”

Rum River Background

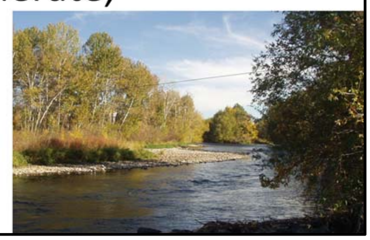
- Located in south central Minnesota
- Tributary to the Upper Miss. River
- Watershed Area is about 1,325 sq.miles
- Land use is 17% ag, 23% range (dairy farms), 31% forest
- Shallow with cobbles, gravel, & sand
- Nutrient concentrations moderate, turbidity low
- Abundant periphyton

The Rum River study file provides a useful template for this simulation. We will be modifying the site and biotic characteristics to match the Lower Boise River, Glenwood Bridge, Boise, Idaho, which is somewhat similar to the Rum River.

The file called **Study descriptions.pdf** included with these web materials includes a description of AQUATOX studies available. These can provide valuable hints to someone looking for a site to start with that is most similar to their site.

Boise River Background

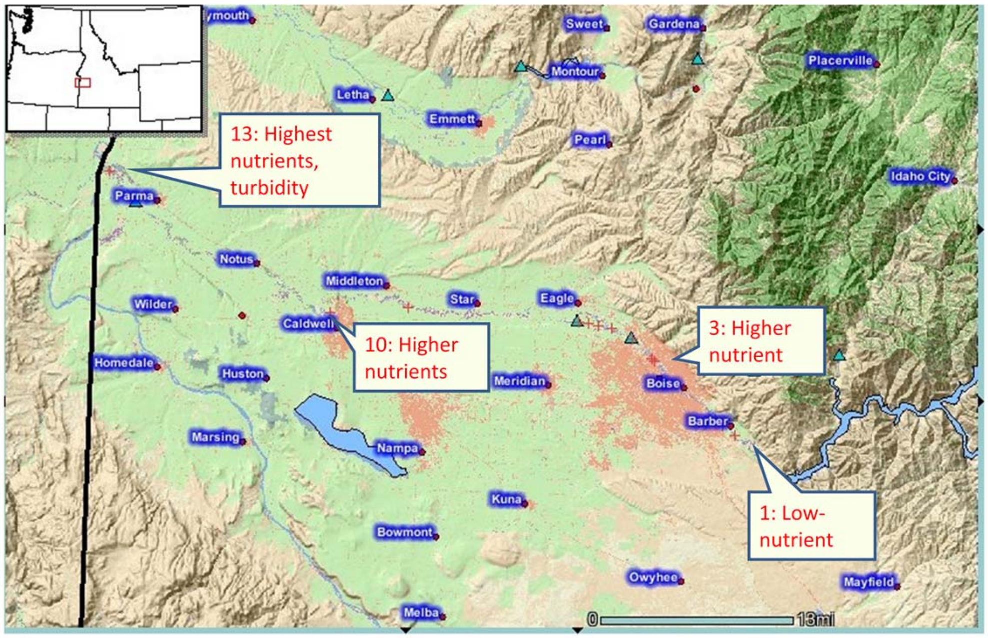
- Located in southern Idaho
- Typical of rivers in arid West
- Controlled releases upstream and diversions for irrigation
  - hydrology is opposite of normal seasonal
- Shallow with cobbles, gravel, & sand
- Nutrient concentrations moderate, turbidity low
- Abundant periphyton



The Lower Boise River, Glenwood Bridge, Boise, Idaho, is somewhat similar to the Rum River. However. it is heavily managed for irrigation purposes. As USGS states in their Web site:
REMARKS.--Flow regulated by Anderson Ranch Reservoir, Arrowrock Reservoir and Lucky Peak Lake (sta 13201500). The New York, Ridenbaugh and eight small canals (sta 13205995) divert between station "near Boise" (see sta 13202000) and this station.

High flow is in the summer and low flow is in the winter, starting about October 15.

Lower Boise River, Idaho
with WWTPs and agricultural drains

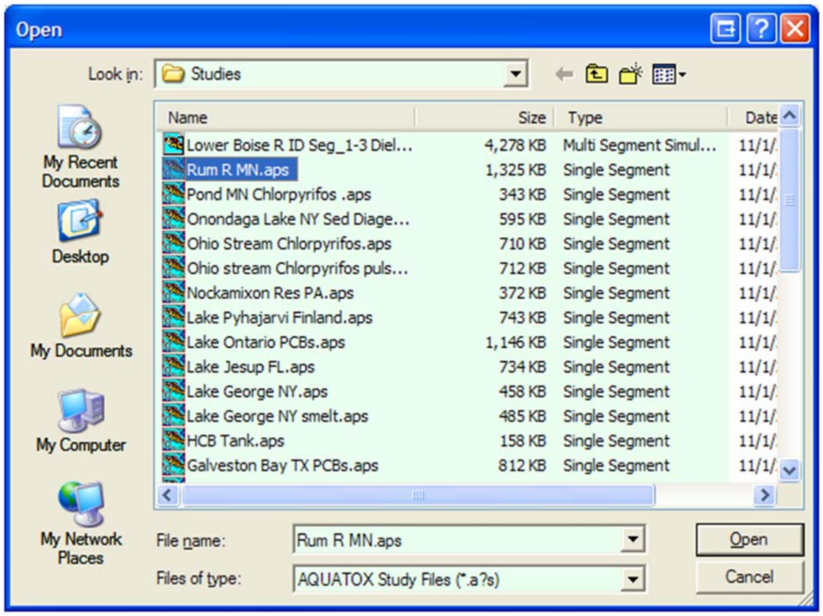


The Lower Boise River is a shallow river that is heavily managed for irrigation. In fact, the downstream segment 10 has the lowest flow because of diversions; below that reach, drains bring in nutrient- and sediment-laden return flow.

Lower Boise River in Boise, Idaho

Note how shallow the river is.

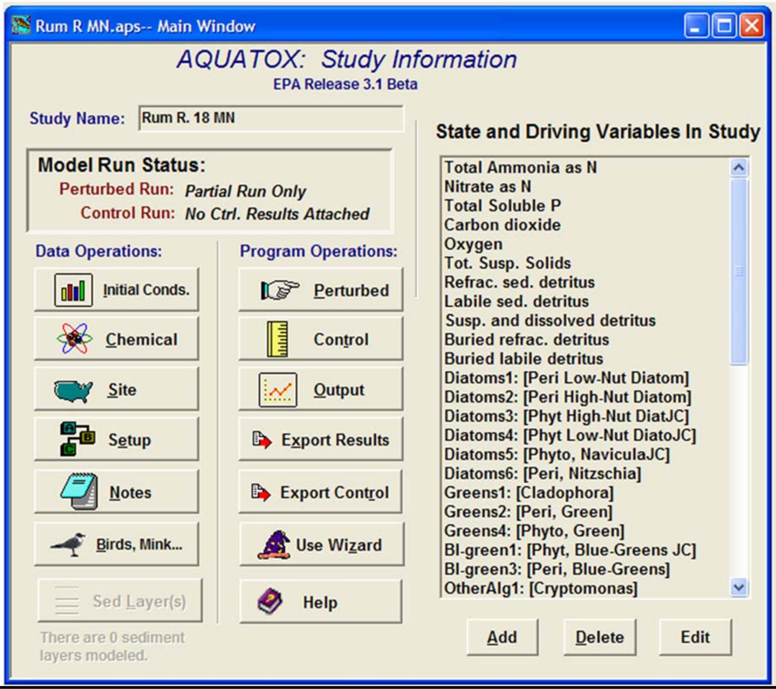
Load Rum R MN.aps



Rum R MN.aps forms the basis for this laboratory:

Rum River is a shallow river, with moderate nutrients and low suspended solids that drains forests and dairy farms in the North Central Hardwoods Forest ecoregion.

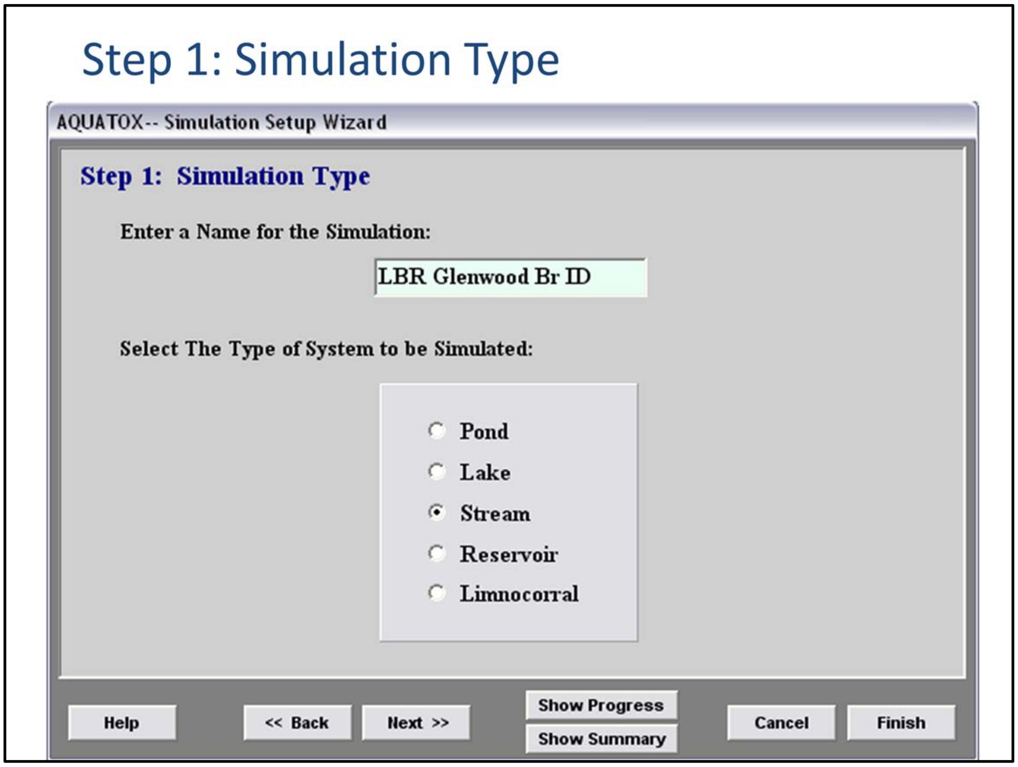
Main Study Window



The main study window is the first thing you see when you load an AQUATOX file. Each of these big buttons can be used to view or modify a different portion of the simulation's parameterization. The toolbar may also be used in this manner as the menu items at the top of the screen. Note that you may see the purpose of each tool-bar option by "hovering" your mouse cursor over each of the buttons. Additionally, the complete list of state variables within a simulation are listed to the right of the screen. By double-clicking on any of these variables you can look at the initial conditions, loadings, and underlying data that represent each state variable. However, to start, we are going to use the most user-friendly portion of the AQUATOX interface which is the Wizard. The Wizard is not comprehensive in that you cannot modify every portion of an AQUATOX simulation. However, it presents the most important characteristics of an AQUATOX simulation and is a great way to start as a beginner. Click on the Wizard button now.

AQUATOX Setup Wizard

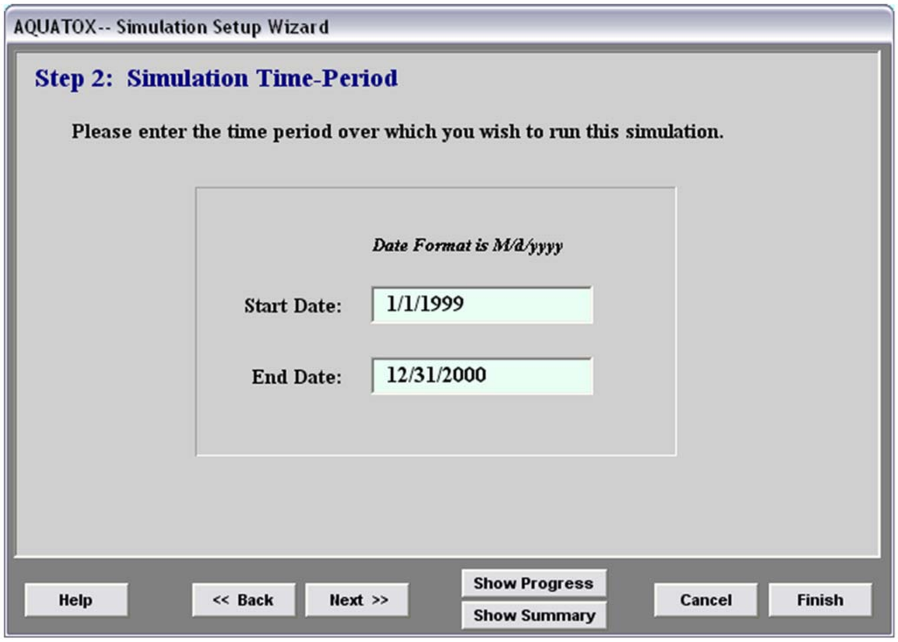
The simulation setup wizard is composed of three windows: “Progress” allows you to see each of the steps within the wizard and, by double clicking on any one of these steps you can jump to a specific step. The main window in the center is where you’ll be doing most of your work examining and modifying parameters. The “Wizard Summary” window shows you the current list of state variables contained within your simulation as you go through the modification process.



We'll start with the most basic change, and that is the name of the simulation. Change to **LBR Glenwood Br ID** for Lower Boise River, Glenwood Bridge, Idaho.

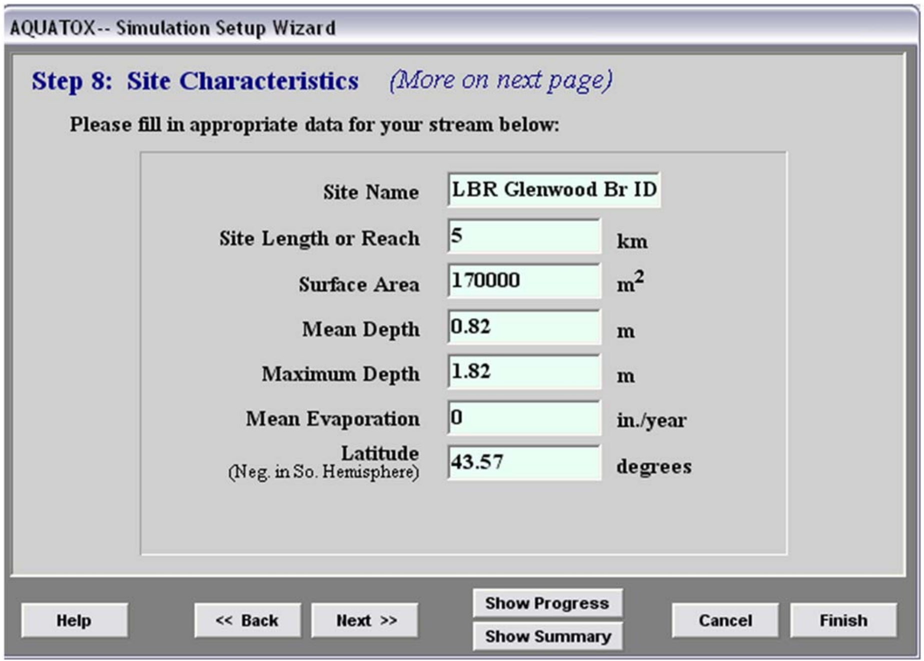
Check to make sure that the water body type selected is "Stream". The choice of water body type governs the physical processes that operate, and in some cases, availability of particular user options.

Simulation Time-Period



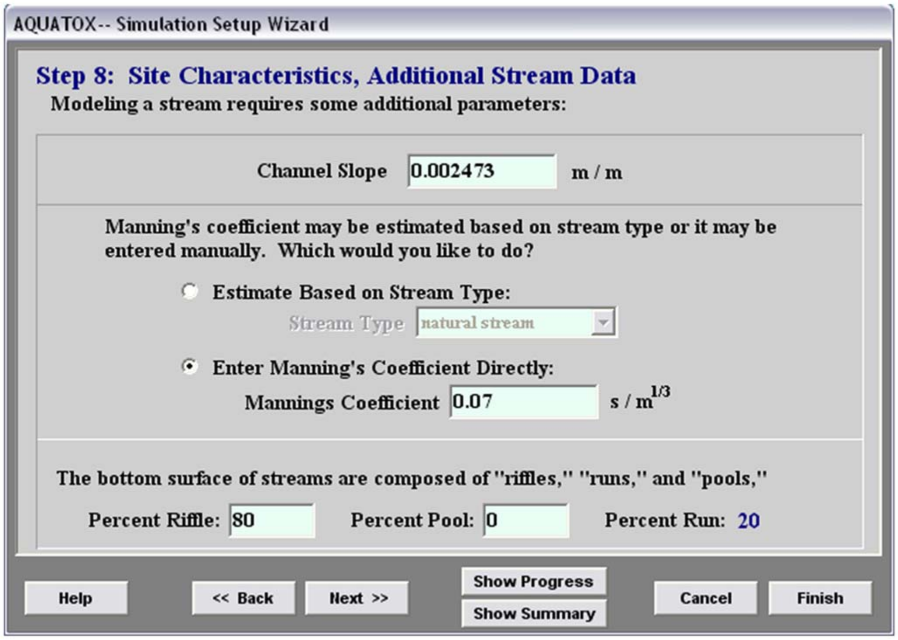
Next we'll move to the simulation time-period. We will simulate two years make sure the dates match the dates shown here. Next we're going to jump to the site characteristics so double click on **Step 8: Site characteristics** in the "Progress" window.

Site Characteristics



We are modeling LBR Glenwood Bridge so the site name should be changed to match the simulation name, We will model an arbitrary 5 km reach length (shorter reaches increase the simulation time because of the effects of the shorter residence time on the differential equation solver). The surface area is 170,000 m. Average Mean Depth is 0.82 meters. This can be replaced later by daily values if we have gage data or a watershed simulation to populate this as a time-series. (The mean depth affects several portions of the model including the light climate for bottom-dwelling plants.) The maximum depth is set at 1.82 meters for the site. We'll set the evaporation to zero for now as this is far-outweighed by inflow and outflow of water in calculating a water balance for this small segment of river. The Latitude should be set to 43.57 degrees, which affects the photoperiod when calculating photosynthesis.

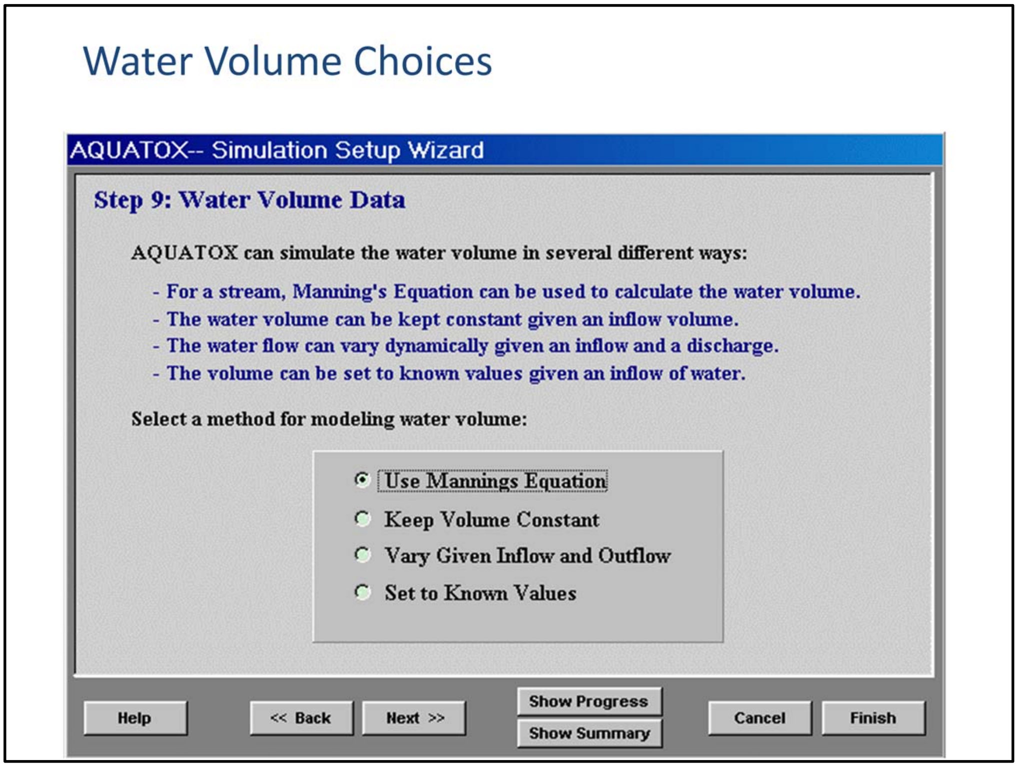
Site Characteristics *(cont.)*



We set the **channel slope** to 0.002473 based on measured hydraulic data from the site; this parameter affects the scour and deposition of detritus and plants from and to the stream's bottom.

Manning's coefficient can affect the water volume of the site if Manning's equation is used for this calculation. It could be estimated by the software based on the fact that this is a natural stream; however, based on a spreadsheet calibration tool that we will use shortly, we will see that the best fit is with a roughness value of **0.07**, which is reasonable for a cobblestone bed.

Based on pebble counts for the site we'll set the **Percent Riffle** of the site to 80% and the **Percent Pool** of the site to 0% (the percent run auto-calculates); these parameters affect the available habitat for different organisms that may be limited by water velocity.



The four options for modeling water volume are shown on this screen:

- **Manning's Equation Method** (for streams only) requires discharge data. Inflow data and site volume are calculated using Manning's Equation. Careful attention should be given to the "Channel Slope" and "Manning's Coefficient" parameters entered in the "Stream Data" screen (within the site underlying data screen), or in the previous Wizard screen.
- **Keep Water Volume Constant** method requires inflow data. Discharge is calculated based on inflow and evaporation.
- If you choose to **Vary Given Inflow and Outflow**, volume is calculated based on inflow, outflow and evaporation.
- The **Known Values** method requires a time-series of known volumes and inflow data. Outflow is calculated taking evaporation into account.

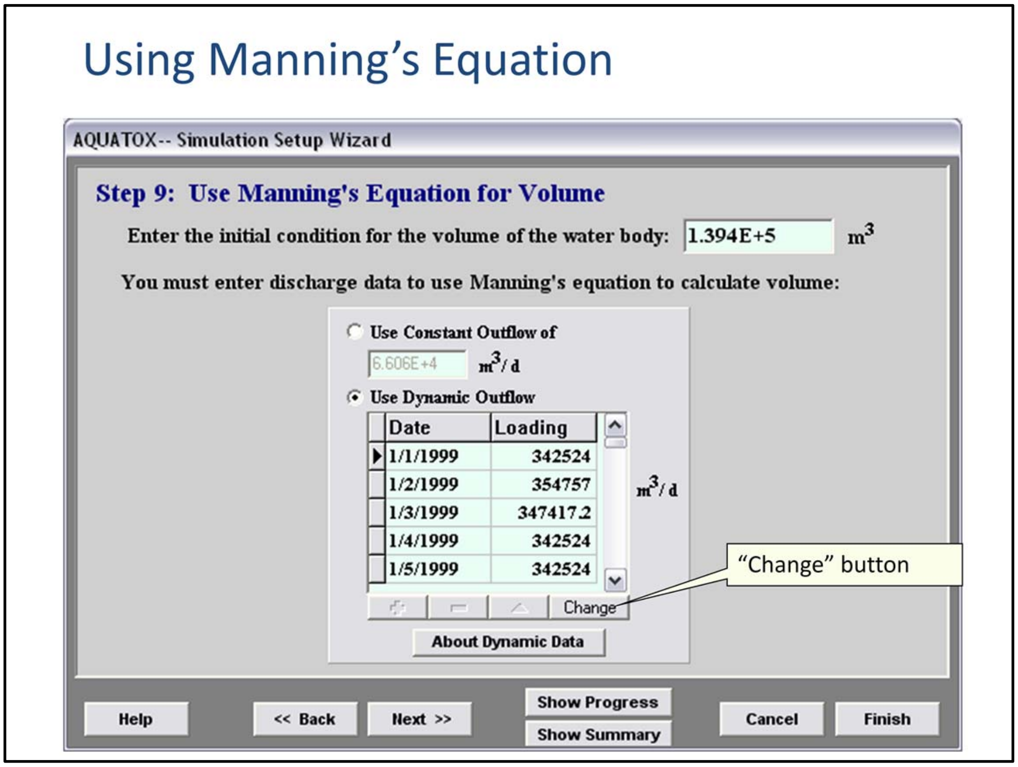
In this case, we have flow data only from the USGS gage so the Use Manning's Equation option will be most useful.

Manning's equation is given by:

$$v = k_n / n\ R^{2/3}\ S^{1/2}$$

where
v = cross-sectional average velocity (ft/s, m/s)
k_n = 1.486 for English units and k_n = 1.0 for SI units
A = cross sectional area of flow (ft^2, m^2)
n = Manning roughness coeffieicent
R = hydraulic radius (ft, m)
S = slope of pipe (ft/ft, m/m)

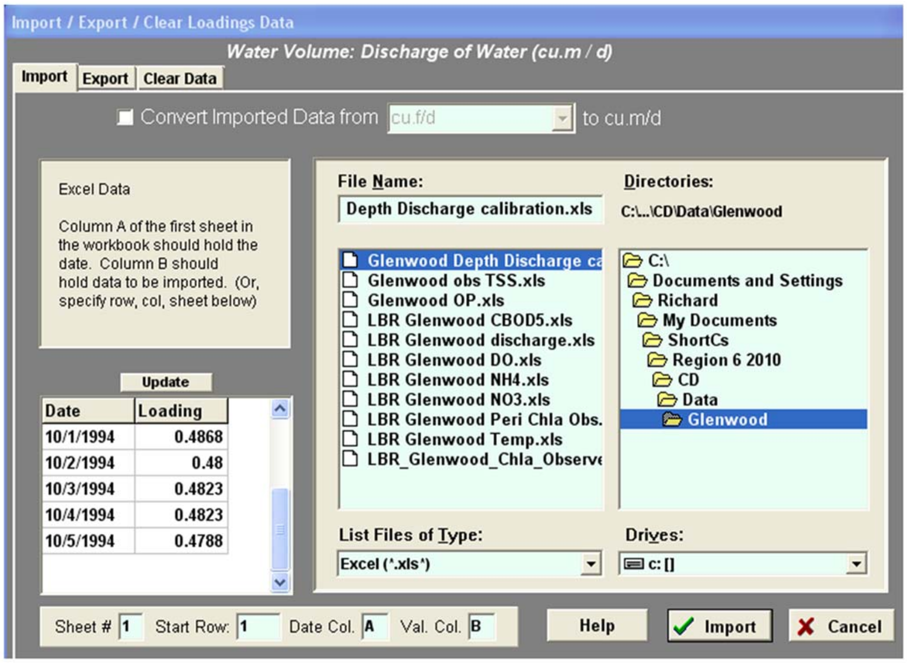
Hydraulic radius can be expressed as
$R = A / P$ (2)
where
A = cross sectional area of flow (ft^2)
P = wetted perimeter (ft)



The initial condition is not particularly important as the Manning's calculation will take place once the simulation starts. However, based on the mean depth and surface area, we'll set this value to 1.394e5.

Below you can see what will soon become a familiar sight: the AQUATOX loadings interface. You have two options when modeling loadings, using a constant loading each day of the simulation or entering a "dynamic" loading based on an entered or imported time-series. You can use the buttons at the bottom of the interface ("+" "-" "^") to manually edit or produce a time-series. Probably more efficient will be to create a time-series externally and to import this using the "change" button.

Import / Export / Clear Loadings



Using the interface shown here, you can import time-series loadings, or by clicking the two tabs at the top you can bring up interfaces to export or clear loadings. The formats available for import (click on downward facing arrow by **List Files of Type**) comma delimited, tab delimited, DBase, Paradox database, Excel, or in the case of water flows, USGS flow data as downloaded from the Internet. However, USGS has made their format more general, making it difficult to do an automatic conversion; therefore, we will import a file captured and converted earlier from the USGS Web site.

Import **LBR Glenwood discharge.xls**
All the files needed for this lab are located in the Glenwood directory

Once you have imported the file you must click on "Next" in the Wizard for it to actually be linked.

Exercise: Familiarize Yourself with the Technical Documentation

Q: How is Manning's Equation Utilized to Estimate Volume?

A:

Table 1. Computation of Volume, Inflow, and Discharge

Method	Inflow	Discharge
Constant	*InflowLoad*	*InflowLoad - Evap*
Dynamic	*InflowLoad*	*DischargeLoad*
Known values	*InflowLoad*	*InflowLoad - Evap + (State - KnownVals)/dt*
Manning	*ManningVol - State/dt + DischargeLoad + Evap*	*DischargeLoad*

The variables are defined as:

InflowLoad = user-supplied inflow loading (m^3/d);
DischargeLoad = user-supplied discharge loading (m^3/d);
State = computed state variable value for volume (m^3);
KnownVals = time series of known values of volume (m^3);
dt = incremental time in simulation (d); and
ManningVol = volume of stream reach (m^3), see (4).

Figure 14 illustrates time-varying volumes and inflow loadings specified by the user and discharge computed by the model for a run-of-the-river reservoir. Note that significant drops in volume occur with operational releases, usually in the spring, for flood control purposes.

The time-varying volume of water in a stream channel is computed as:

$$ManningVol = Y \cdot CLength \cdot Width \quad (4)$$

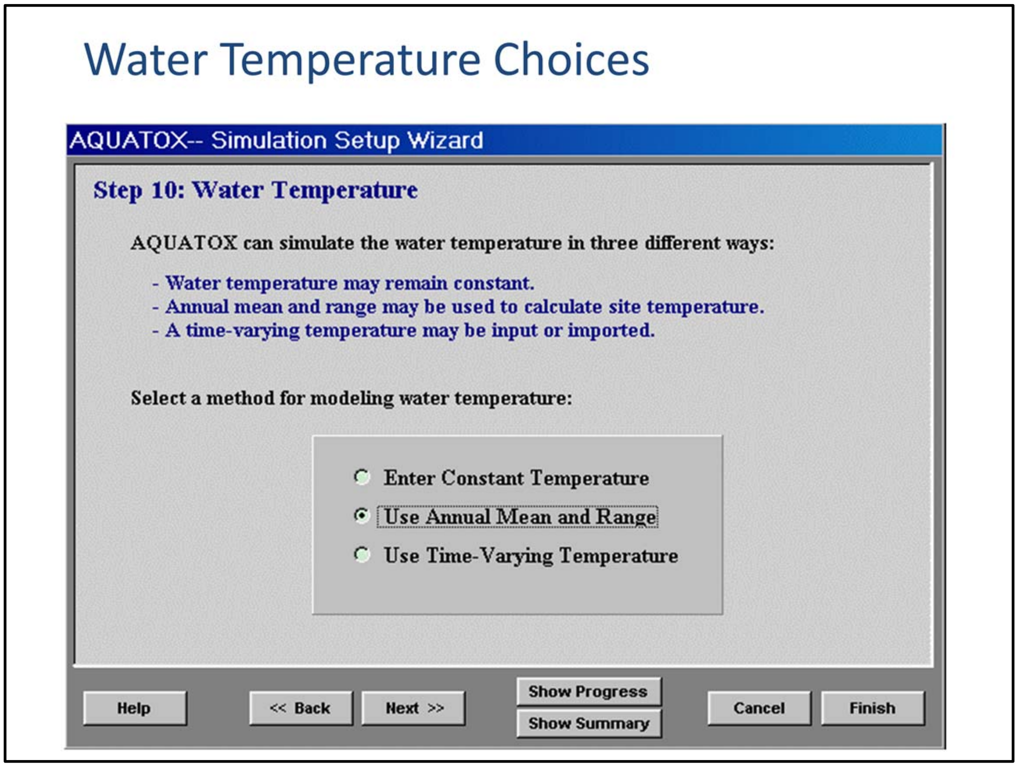
When you come across a question for which you need more information, your first resource should be the AQUATOX technical documentation. We will now take a break from using the wizard to navigate to the relevant file on your computer and spend a moment perusing it.

There is also an in-depth users manual and context-sensitive Help files that provide an introduction to the AQUATOX interface. We will open up this document as well.

USEFUL LINKS

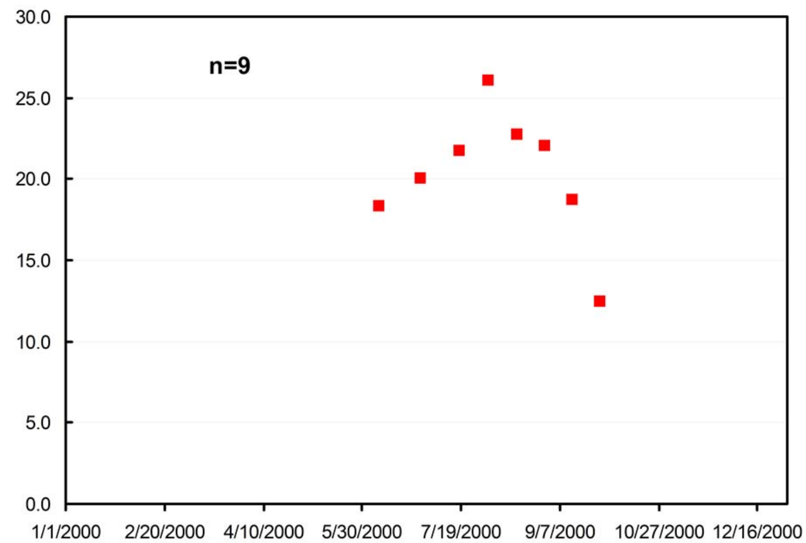
Technical Documentation:
http://water.epa.gov/scitech/datait/models/aquatox/upload/2009_08_28_models_aquatox_technical_aquatox_release_3_technical_doc.pdf

Users Manual:
http://water.epa.gov/scitech/datait/models/aquatox/upload/2009_08_26_models_aquatox_users_aquatox_release_3_users_manual.pdf



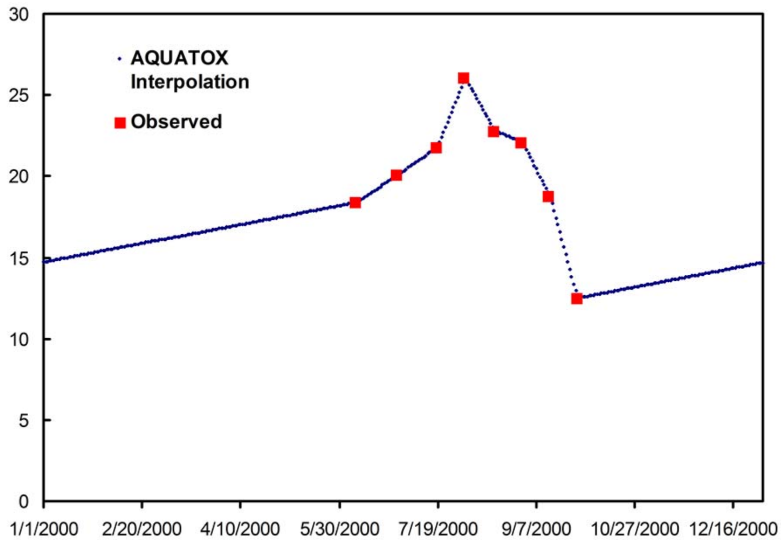
Temperature can be modeled as a constant, using dynamic data, or using annual means and ranges. In this case, our choice depends on the nature of the data that we have. **We will deviate from loading Glenwood Bridge data for the moment in order to illustrate issues to consider in using sparse data**. Our example is Blue Earth River, another MN river used in calibrating AQUATOX.

Available Blue Earth 54 Temperature Data



This graph shows the nine available temperature data points for mile 54 of the Blue Earth river. Now we could import these data into AQUATOX as dynamic temperature data, but this is a good time to illustrate one important aspect of AQUATOX dynamic data:

AQUATOX Interpolates Dynamic Loadings on an Annual Basis

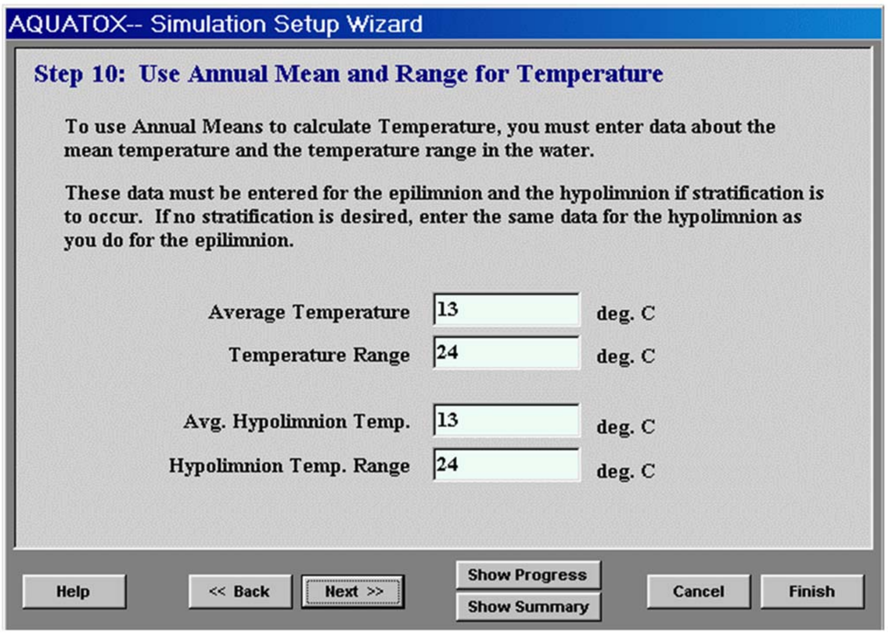


This graph shows actual simulation results for Temperature when the set of 9 observed data-points are simply loaded into the simulation. AQUATOX will linearly interpolate between available data-points when a limited set of dynamic data are available. As you can see, this interpolation takes place between years when there are no relevant data at the beginning or end of a simulation.

This interpolation can be important if you are trying to include a “spike” loading of toxicant or other perturbation. You must put dates with zero loadings on each side or there will be an unintended effect due to interpolation.

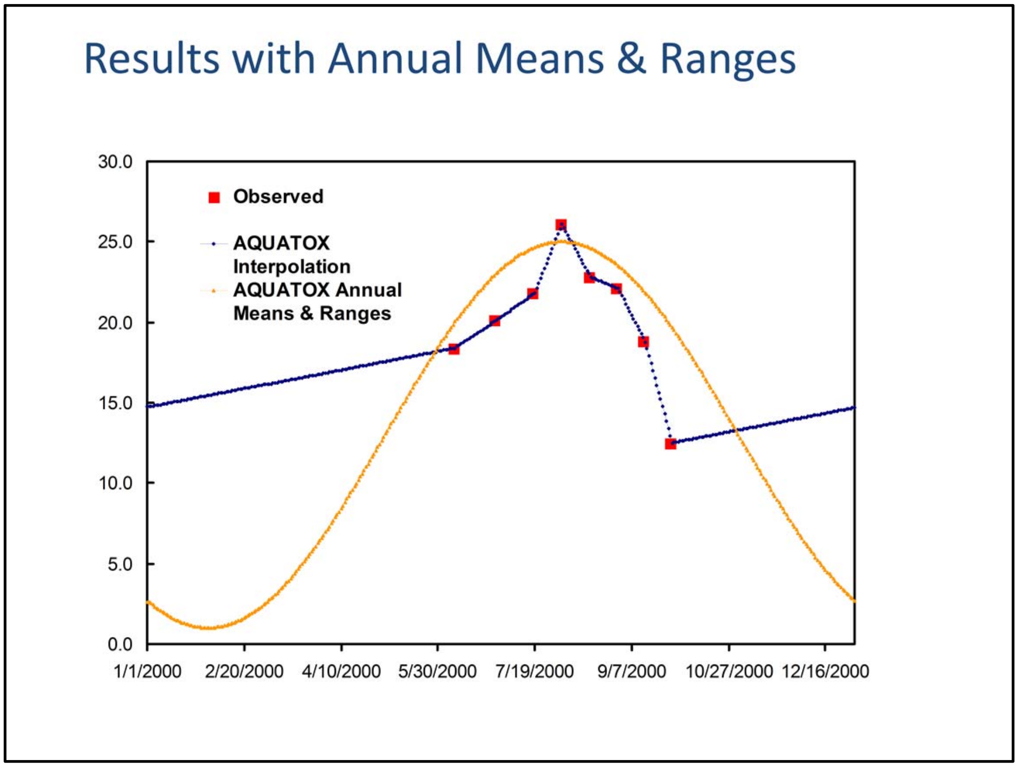
Getting back to temperature, we can look at the third option, using annual means and ranges.

Using Annual Means and Ranges



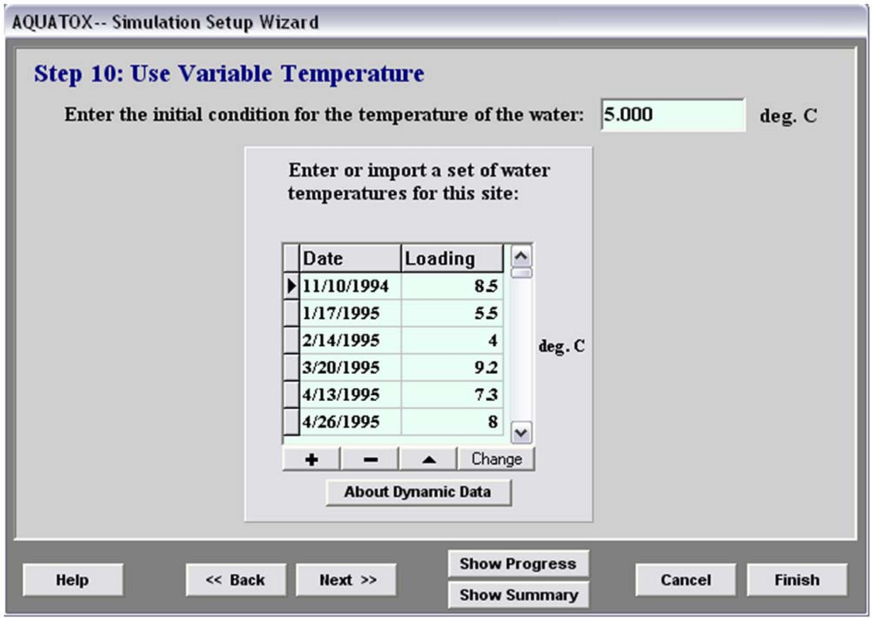
Looking at observed data for Blue Earth, we have a maximum value of 26.1 C but this is a bit of an outlier. So assuming that we would want a maximum temperature of around 25 degrees and a minimum of 1 degrees in the Minnesota winter, we have an average of 13 and a range of 24 degrees (max – min).

Note that because this is not a lake, the hypolimnion temperature is irrelevant so we would just enter the same values for epilimnion temperature.



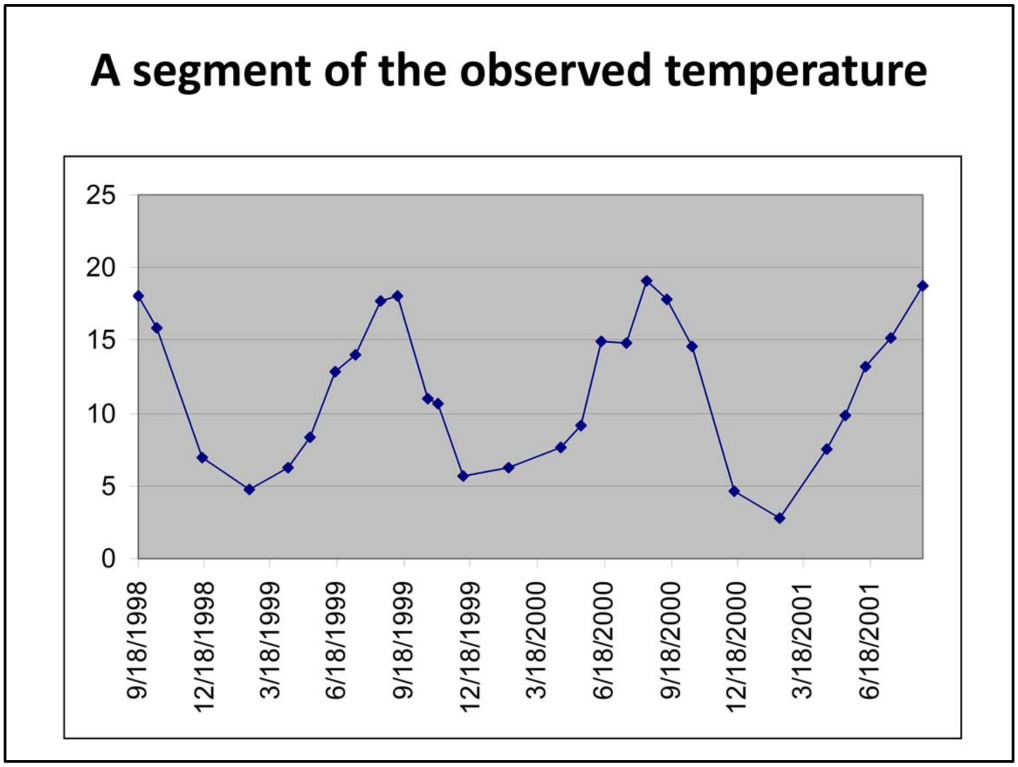
This graph shows how AQUATOX models temperature using the parameters we just provided. Though it does not hit the data points perfectly it is more important that the long winter dormancy period is properly modeled than the summer data gets represented perfectly.

Import observed temperature

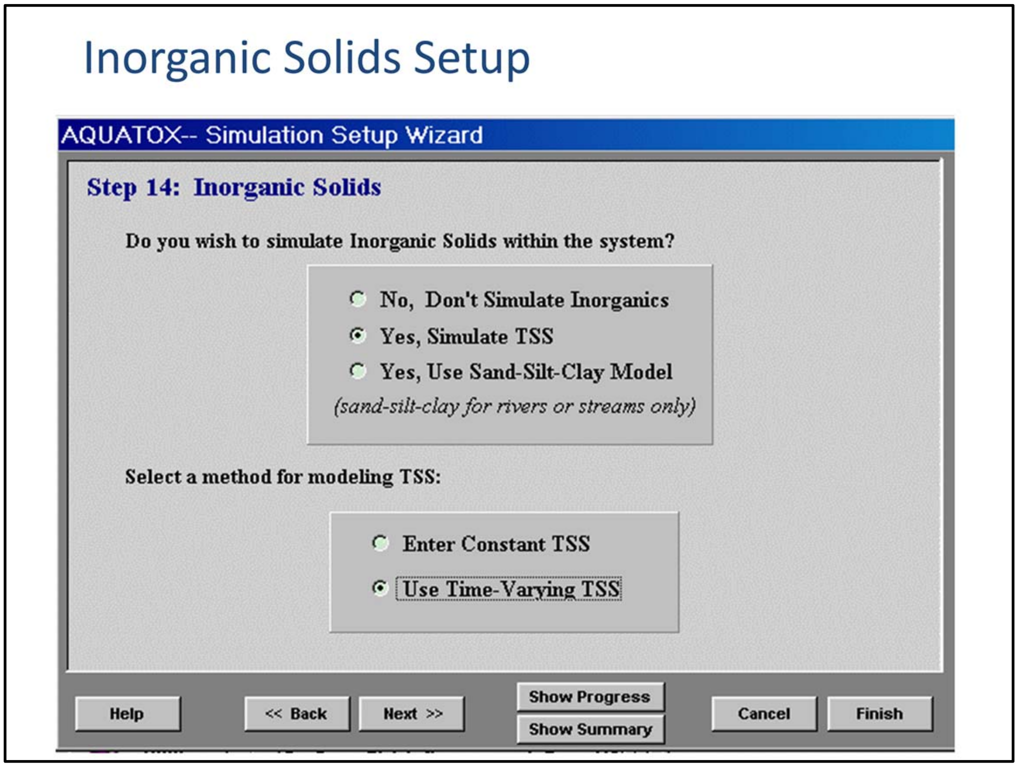


Getting back to our Glenwood Bridge example, we have a time series of observed temperature data that we will use. Those are imported into the study from **LBR Glenwood Temp.xls**.

Be sure to change the Initial Temperature condition at the top of this dialog box to from 25 to 5 deg C.



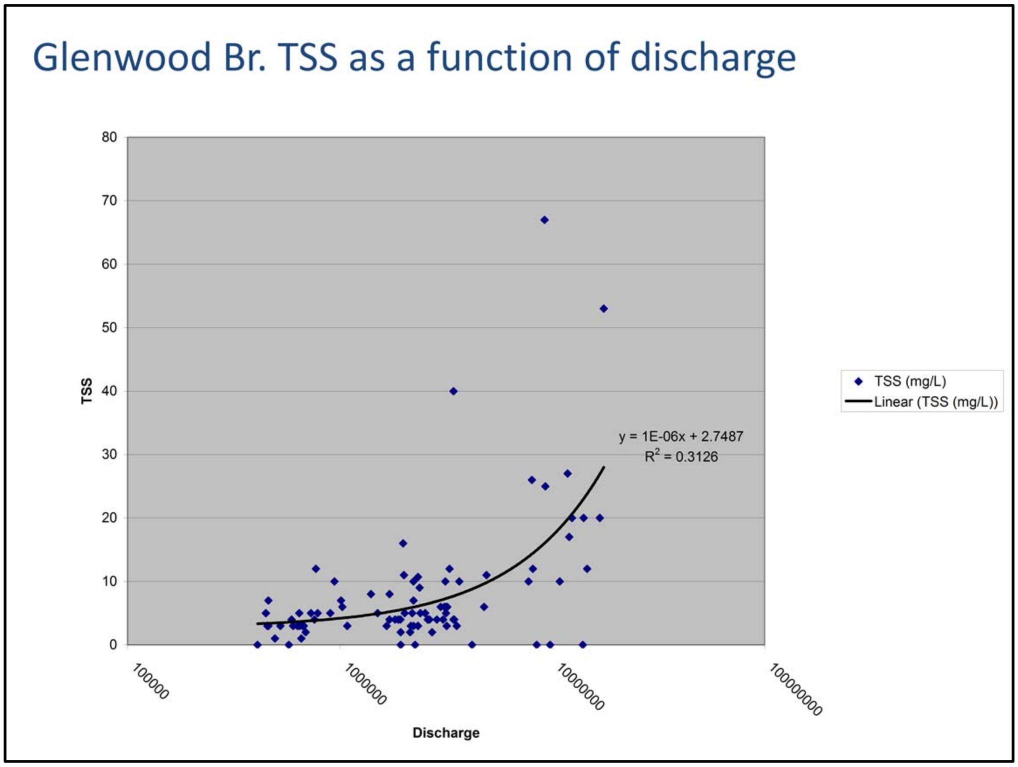
The observed USGS data are judged sufficient to define the time course for temperature.



Next we're going to jump to Inorganic Solids as the stream model is not sensitive to wind loadings. Double click on the **Step 14** text to jump within the Wizard. We will select to load time-varying TSS.

The three options for modeling inorganic sediments are to exclude organic sediments, model TSS as a non-reactive time-series, or to include the sand-silt-clay model which we will discuss on Day 3.

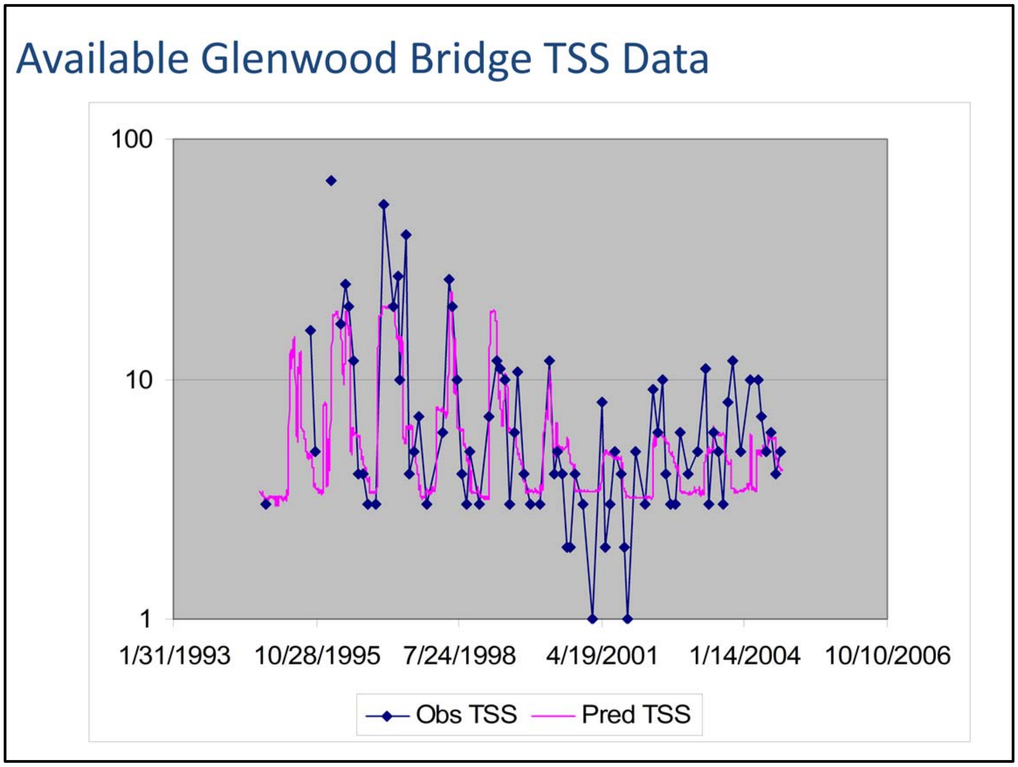
See Chapter 6 of the technical documentation for more information on these models.



Moving back to the slideshow for a moment, we see a weak relationship with much scatter between water discharge and observed total suspended sediment (not solids). This is a managed river with controlled releases and occasional flushing of sediment from upstream impoundments.

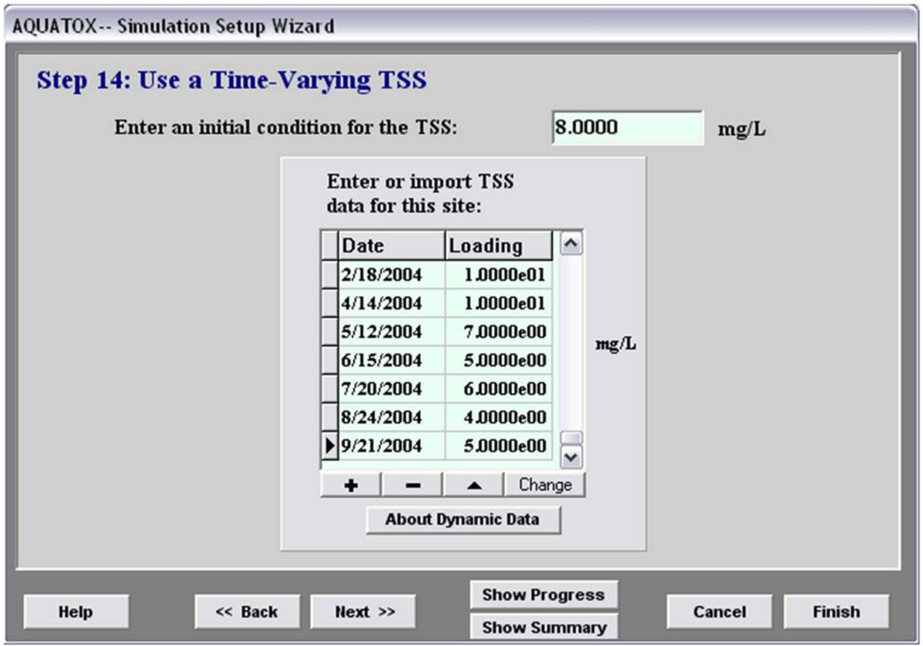
A TSS of 20 (mg/L), corresponds to a light extinction of 3.4 (1/m). This, in turn, corresponds to an estimated Secchi depth of 0.56m. It is clear how important TSS can be to algal growth given these facts. Because the model is so sensitive to low TSS modeling “average” conditions is not acceptable.

When modeling a relatively data-sparse river (and this is the case with the vast majority of rivers that you will encounter), linkage to a Hydrology/Watershed model is a powerful tool, and is likely to be more precise than the simple relationships that you will put together with data. However, we have no such model results to link for the Boise River.



Plotting the interpolated observed TSS with the results predicted by the empirical model, we see that the sparse observed data are preferable to estimates that miss both high and low values.

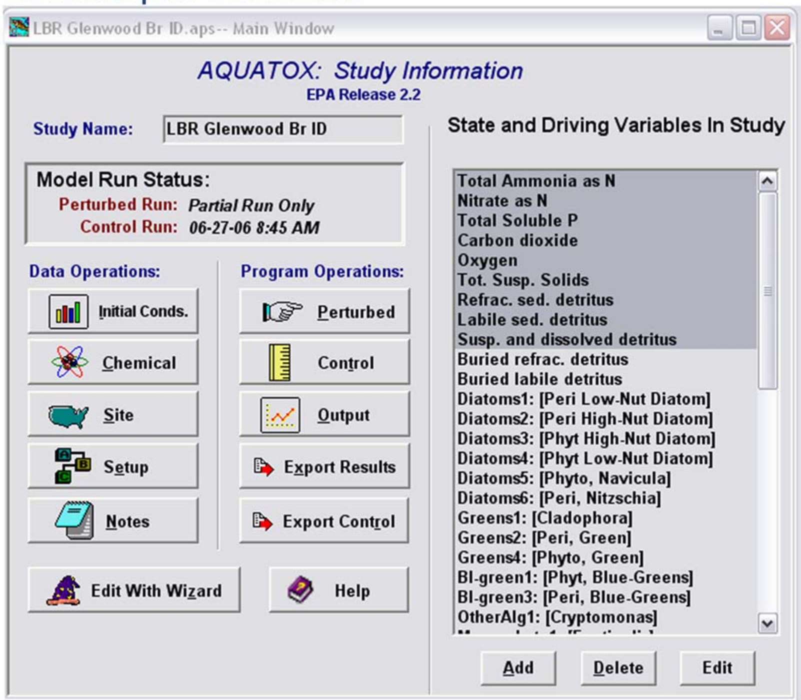
Import Time Varying TSS Input



Use the “change” button to import the file **Glenwood obs TSS.xls.**

Next, we’re going to modify inflow loadings. You may use the wizard screen to input inflow loadings, but as mentioned previously there are some subtleties in the interface that are not captured by the wizard. We’ll go into the state variable list to import these loadings. Select “Finish” after the import is complete and “yes” that you’d like to save changes.

Select Multiple Variables



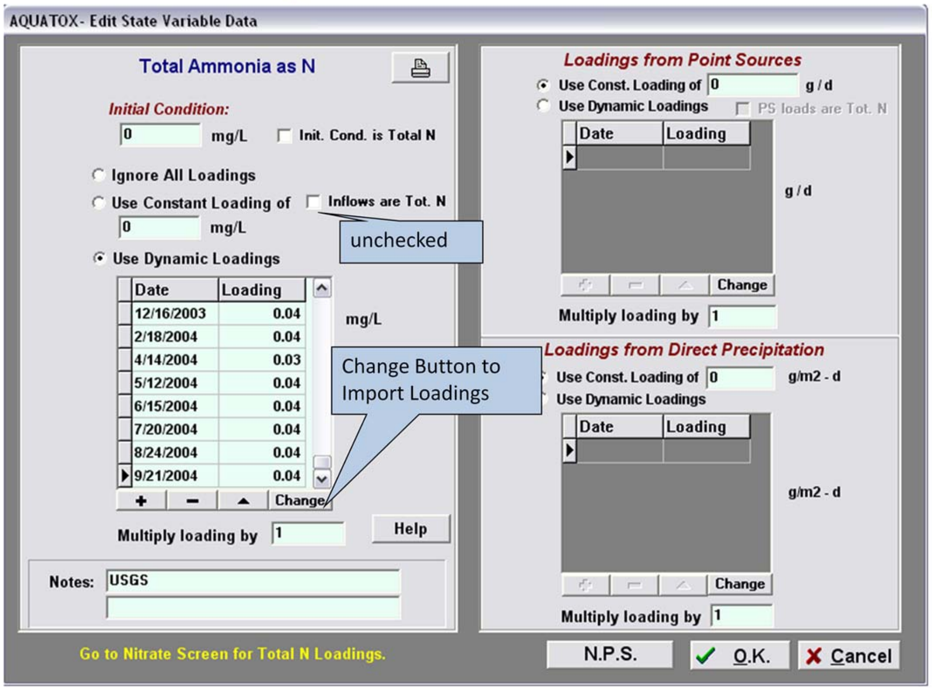
Click “Finish” to exit the Wizard and save your changes. Save the study as **LBR Glenwood Br ID.aps** before proceeding.

You may use the wizard screens to input inflow loadings, but as mentioned previously there are some subtleties in the interface that are not captured by the wizard. We’ll go into the state variable list to import these loadings.

It is very useful to select multiple items from a list using standard windows shift-click and control-click options. This can be useful when editing state variables and also producing output within AQUATOX.

In this case, we select the first nine variables within AQUATOX in which all nutrient and organics state variables are held (Total Ammonia as N through Susp. and dissolved detritus) and click Edit.

Ammonia Loadings

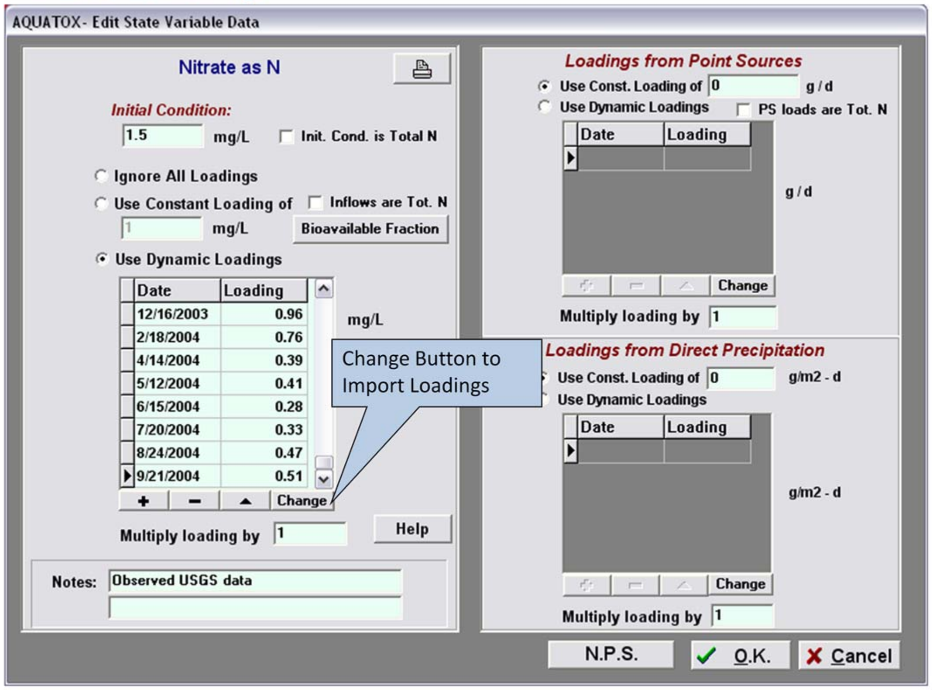


For ammonia select the **Dynamic Loadings** radio button and import observed values (**LBR Glenwood NH4.xls**) downloaded from the USGS Web site.

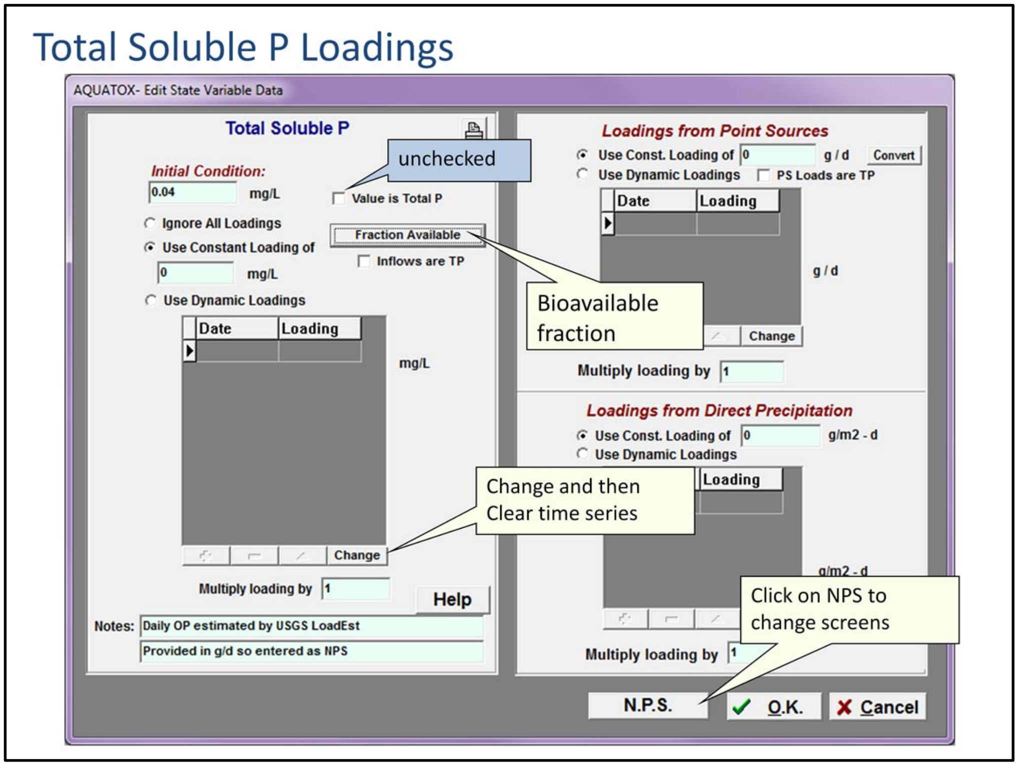
Note, de-select **Init Cond is Total N** and **Inflows are TotN**.

For bookkeeping purposes (so you know the source of the loadings in your simulation in the future) it is best to update the notes field at the bottom of each screen as you change a loading.

Nitrate Loadings



Nitrate as N: Select the **Dynamic Loadings** radio button and import **LBR Glenwood NO3.xls**. Initial conditions are much less important for stream simulations in which water flows through the system several times each day so we do not have to worry about being precise for that parameter. Alternatively, we could import total N loadings.

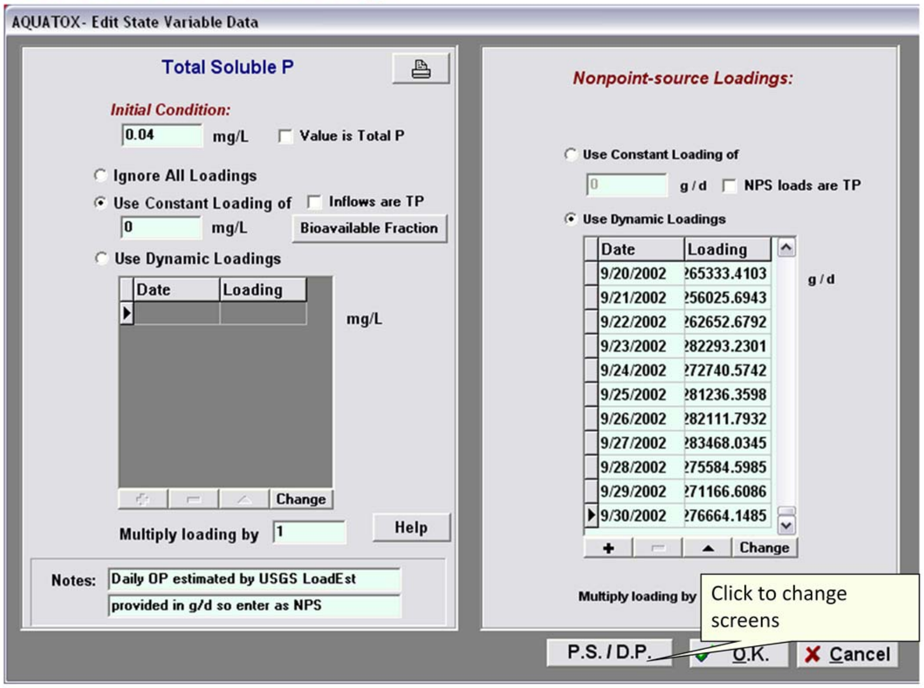


This will require several steps to modify the previous loading options. (The input data are orthophosphate, so do not check the box for **Inflows are TP)** set **Constant Loading** to 0. By setting the "constant loading" to zero specifies that zero loading of P is associated with loadings from upstream water. Click on **Change** button to then **Clear** dynamic loadings (option at the top of the loadings window). Click on **NPS** to change screens. The estimated OP values were obtained by regression using the USGS LoadEst program; they are in g/d and could be input as either point-source loadings or nonpoint-source loadings; we will choose the latter so that point-source loadings can be added at a later date if desired.

Import **Glenwood OP.xls** as Nonpoint-source Loadings (see next slide).

The Fraction Available (or **Bioavailable Fraction**) button allows the user to input the fraction of Phosphorus loading that is available versus that which is tied up in minerals. The user can specify the fraction of phosphate loading received from the Inflow, Point Source, Non-Point Source, and Direct Precipitation. This is more applicable to TP; we will assume that all OP is available

Total Soluble P Loadings



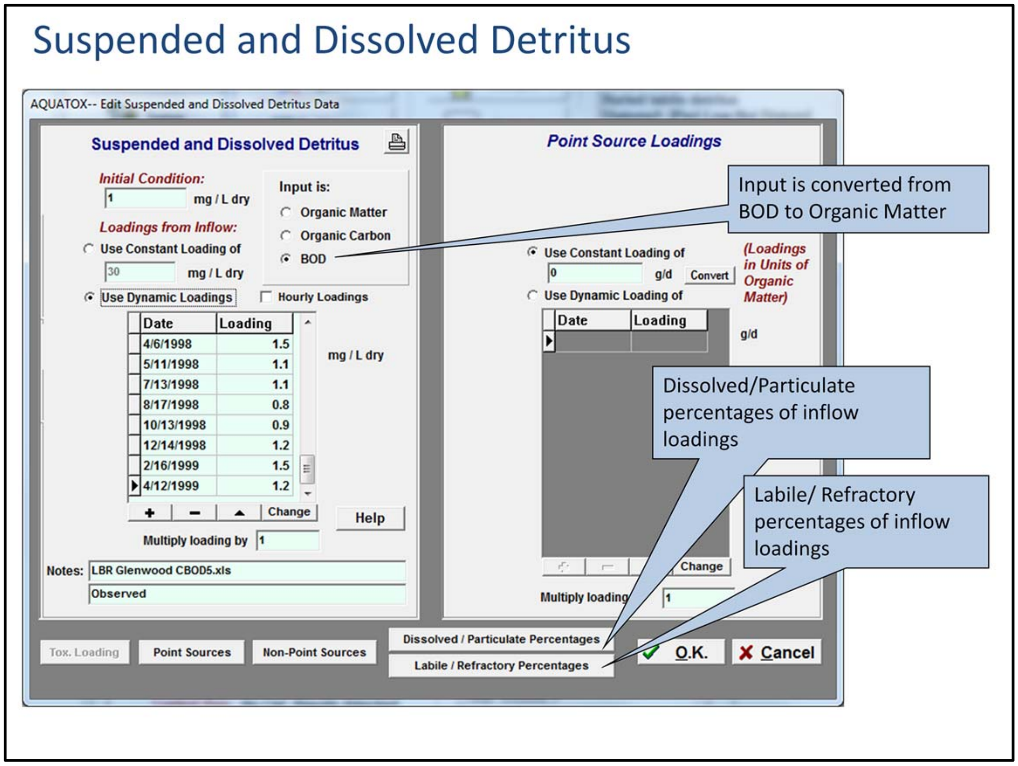
This is how the Nonpoint-source Loadings screen will look after the time series is imported.

Next, for **Carbon Dioxide**, in the absence of other data, keep the default assumption of an inflow load of 0.7 mg/L.

For **Oxygen**, import available DO values (**LBR Glenwood DO.xls**). Oxygen concentrations in the stream will be dominated by these loadings due to the frequency which water flows into and out of the reach.

TSS: This shows us the values we've imported from the wizard. You probably should clean up the notes fields.

Sedimented Detritus (two screens): Keep constant at initial condition levels

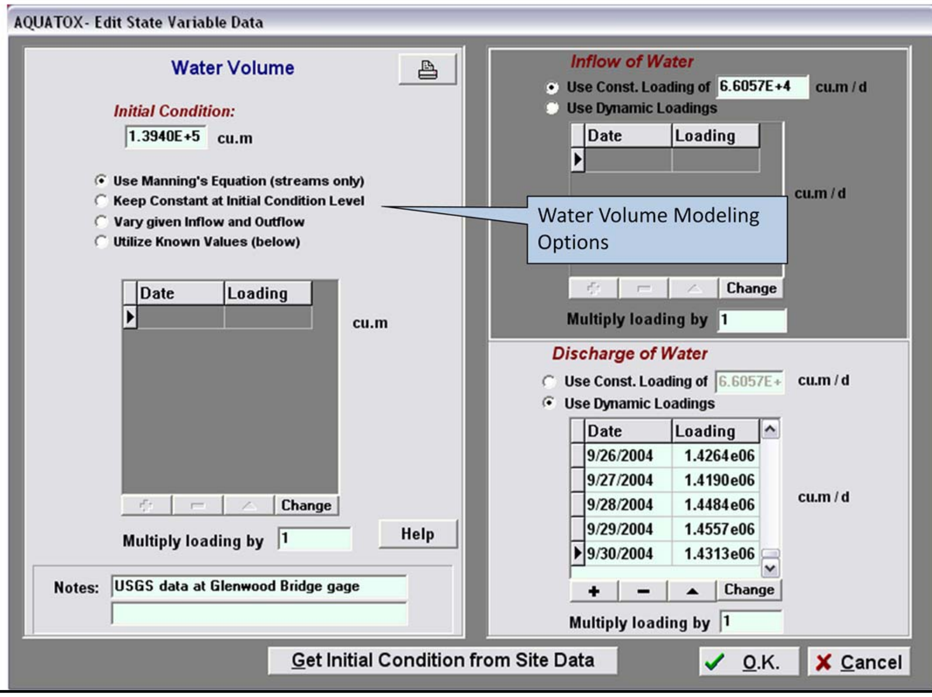


Suspended and Dissolved Detritus: Select input as BOD. Import **LBR Glenwood CBOD5.xls.**

Input may be entered as Organic Matter, or may be converted from inputs of Organic Carbon or BOD. If BOD is entered, inflow loadings of phytoplankton, which contribute to BOD, are subtracted before converting to the model's internal organic matter units. The conversions used are:
Organic matter = BOD * 0.74
Organic matter = organic carbon * 1.9

Using the percentage entry boxes, organic matter loadings must also be split into four compartments: Particulate Refractory Detritus, Particulate Labile Detritus, Dissolved Refractory Detritus, and Dissolved Labile Detritus. (Labile detritus is organic matter that decomposes at a much faster rate than refractory detritus.) A general default value for percent particulate is 10%. Because the basis is BOD5, a value of 20% for refractory is reasonable.

Water Volume Screen



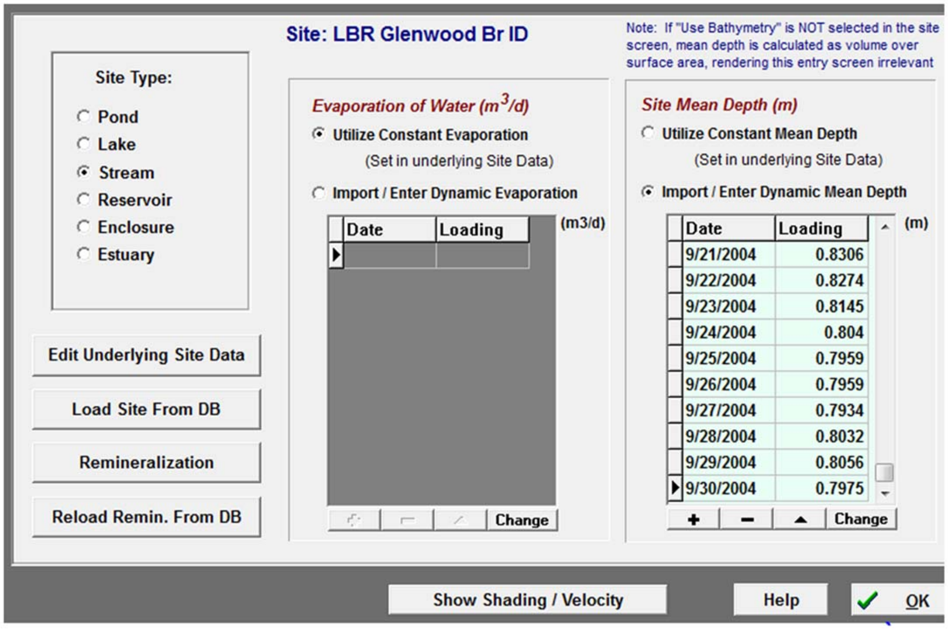
In the interest of completeness, we should go to the water volume screen and update the notes field.

Summary

- Steps taken to produce a new project from an existing site:
  - We identified a surrogate site to use as a template
  - We modified the physical characteristics of the surrogate site to match "our site"
  - We modified the nutrients, organics loadings, and turbidity using data from "our site."
- We have not yet modified the biota.
  - However, if the biota are not dramatically different from site to site we may still get a decent simulation, just by using the physical characteristics, nutrient, and organics loadings from "our site."

Remember the called **Study descriptions.pdf** can provide valuable hints to someone looking for a site to start with that is most similar to their site.

Water Depth



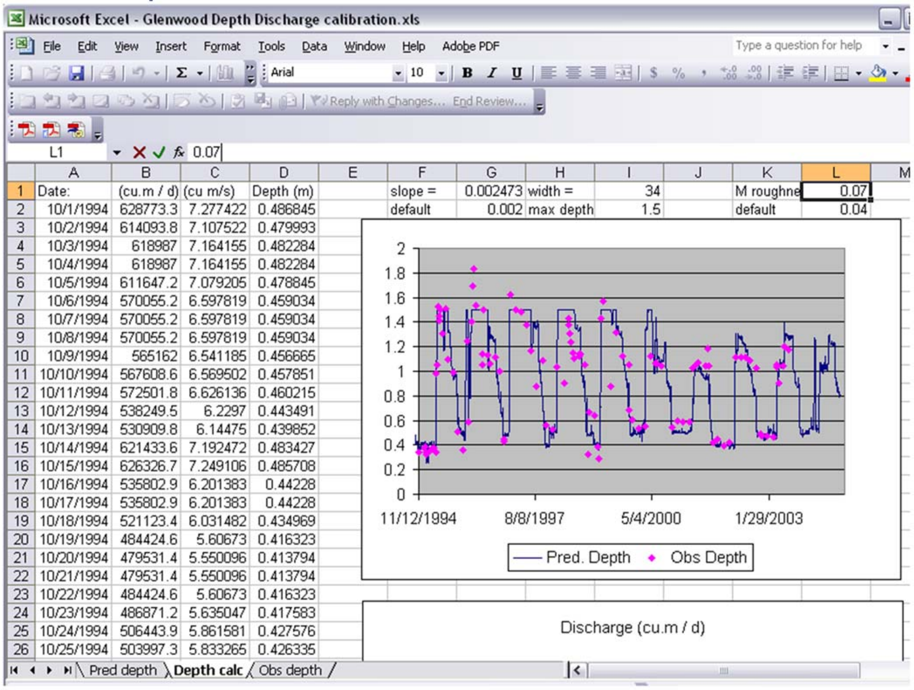
Finally, we want to calculate and enter dynamic water depth as a function of discharge. On the Main Screen, click on Site. The time series can be imported into the first screen. Import: **Glenwood Depth Discharge calibration.xls**.

The model imports the first two columns from the first worksheet, which is **Pred Depth**. Save the study as before, **LBR Glenwood Br ID.aps**. This file should correspond to **LBR Glenwood 1.aps**, which is in the files directory.

Clear all results first.

The model will take about 10 minutes to run, so click on **Control** in the Main Screen to start. We'll look at the results in Lab 3.

Water Depth



Microsoft Excel - Glenwood Depth Discharge calibration.xls

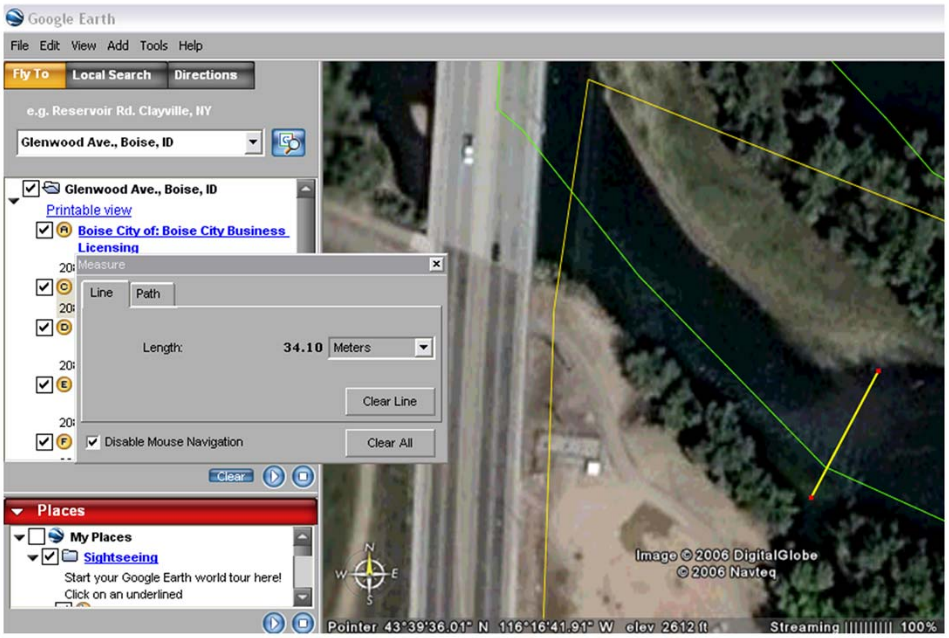
L1 0.07

	A	B	C	D	E	F	G	H	I	J	K	L
1	Date:	(cu.m / d)	(cu m/s)	Depth (m)		slope =	0.002473	width =	34		M roughne	0.07
2	10/1/1994	628773.3	7.277422	0.486845		default	0.002	max depth	1.5		default	0.04
3	10/2/1994	614093.8	7.107522	0.479993								
4	10/3/1994	618987	7.164155	0.482284								
5	10/4/1994	618987	7.164155	0.482284								
6	10/5/1994	611647.2	7.079205	0.478845								
7	10/6/1994	570055.2	6.597819	0.459034								
8	10/7/1994	570055.2	6.597819	0.459034								
9	10/8/1994	570055.2	6.597819	0.459034								
10	10/9/1994	565162	6.541185	0.456665								
11	10/10/1994	567608.6	6.569502	0.457851								
12	10/11/1994	572501.8	6.626136	0.460215								
13	10/12/1994	538249.5	6.2297	0.443491								
14	10/13/1994	530909.8	6.14475	0.439852								
15	10/14/1994	621433.6	7.192472	0.483427								
16	10/15/1994	626326.7	7.249106	0.485708								
17	10/16/1994	535802.9	6.201383	0.44228								
18	10/17/1994	535802.9	6.201383	0.44228								
19	10/18/1994	521123.4	6.031482	0.434969								
20	10/19/1994	484424.6	5.60673	0.416323								
21	10/20/1994	479531.4	5.550096	0.413794								
22	10/21/1994	479531.4	5.550096	0.413794								
23	10/22/1994	484424.6	5.60673	0.416323								
24	10/23/1994	486871.2	5.635047	0.417583								
25	10/24/1994	506443.9	5.861581	0.427576								
26	10/25/1994	503997.3	5.833265	0.426335								

Now, let's see how the dynamic depth was estimated. Open **Glenwood Depth Discharge calibration.xls**.

The model imports the first two columns from the first worksheet, which is **Pred Depth**. The calculations are done in sheet 2, **Depth calc**. To calibrate depth, the objective is to vary one or more parameters so that the estimated depth corresponds to the observed values (purples dots). We have measured values for slope (G1) and width (I1). However, we should vary the Manning's roughness coefficient (L1) from the default value of 0.04—try it! A value of 0.07, which is near the upper end of the normal range of values, seems to give the best fit. The computations are performed in Column D and flow to Column B in the **Pred depth** worksheet.

Tip: use Google Earth to get width



Tip: if you do not have the channel width, you can obtain it by locating the site with Google Earth and using the Measure tool to obtain the width. In this example the measurement is made at the riffle upstream from Glenwood Bridge.