



PONDS 3.2 Technical Memo

SUBJECT: MODELING MULTIBASIN / INTERCONNECTED PONDS

Date: January 21, 2008

The following memo discusses the Multibasin SCS hydrograph in the PONDS 3.2 Refined Method software, and the use of this hydrograph type in modeling ponds with multiple runoff basins and/or for modeling a chain of cascading ponds.

Part 1 of the following memo outlines the general procedure for modeling a series of interconnected (chained) ponds using the PONDS 3.2 Refined Method software.

Part 2 of the memo presents a numerical example problem with screen captures of the required data entry.

PART 1

A GENERAL DISCUSSION OF INTERCONNECTED PONDS USING MULTIBASIN SCS HYDROGRAPHS IN PONDS 3.2 REFINED METHOD.

Modeling interconnected ponds using the PONDS software is largely a manual (labor intensive) procedure, as compared to something like AdICPR. The ability to model a series of chained ponds was added due to a specific need that arose after the program was written, and this feature was implemented in a way which would not require a major re-write of the program, but which leaves a certain amount of work to be done by the user.

In PONDS, each pond in the chain is modeled separately, starting at the top of the chain of ponds. The discharge from one pond is exported to a data file which is then read in to the hydrograph data of the next downgradient pond to be analyzed. And so on, until you get to the bottom of the chain of ponds. Exhibit 1 below shows an example of this for three interconnected ponds. The most downgradient pond may or may not have discharge.

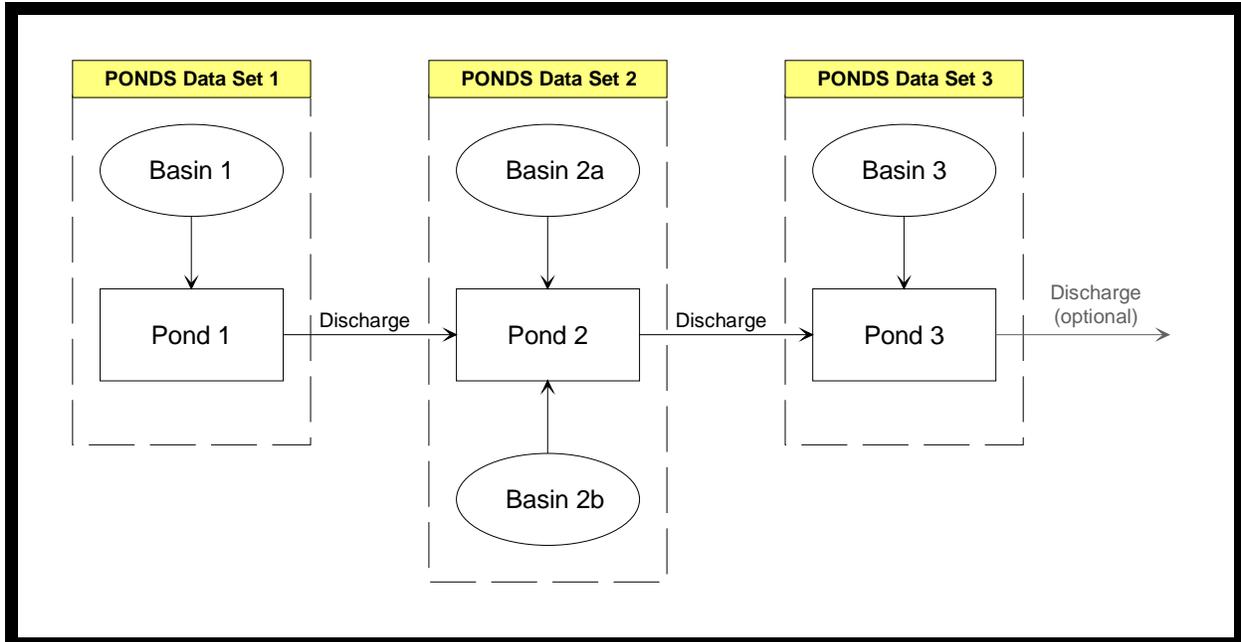


Exhibit 1. Example nodal diagram for interconnected ponds using PONDS 3.2 software

Multi-basin SCS Hydrograph

In order to model a series of interconnected ponds using the PONDS 3.2 Refined Method, you need to use the multi-basin SCS hydrograph type in PONDS. The multi-basin SCS hydrograph includes the following features:

- ① Allows for more than one contributing runoff basin per pond. (Also works for a single basin.)
- ② Allows importing discharges from one or more upgradient ponds, which are treated as inflows and are combined into the resulting hydrograph.
- ③ Allows the user to specify the time increment used in the simulation
- ④ Allows user to directly specify the duration of simulation

Note that the Multi-basin SCS hydrograph can also be used for single basin analysis, as an alternative to the Single-basin SCS hydrograph type.

In order to model a series of upgradient ponds, the solution time increment and duration of simulation must be the same for each pond in the chain, i.e., the hydrographs need to be synchronized in order for the discharges from an upgradient pond to be used with a downgradient pond.

For example, Table 1 below shows some assumed times of concentration for the nodal diagram in Exhibit 1 above.

Table 1. Times of Concentration for Example Nodal Diagram	
Basin	Time of Concentration (min)
Basin 1	60
Basin 2a	10
Basin 2b	30
Basin 3	45
Minimum Time of Concentration	10

In this example, the minimum concentration for all of the contributing runoff basins in the chain of ponds is 10 minutes. In general, it is recommended that the solution time increment should be less than or equal to the time of concentration divided by 7.5. In the above example, the solution time increment would therefore be

$$T \leq t_{cmin} / 7.5 \rightarrow T \leq 10 \text{ min} / 7.5 = 1.33 \text{ min} \rightarrow T = 1 \text{ min}$$

The time increment determined by the minimum time of concentration should be used for all ponds in the chain of ponds, regardless of the times of concentration for the individual basins directly contributing to a pond. The solution time increment (1 minute in this example) becomes a global variable which should be used for each of the ponds, and insures that the time increment for each of the ponds is synchronized in order to allow importing of upgradient discharges.

Entering the Hydrograph Data

The following steps describe how to enter the hydrograph data for a multi-basin hydrograph.

Defining the hydrograph type

In the main window of the Refined Method module, select the data input page for Hydrographs (Tab 6). Then...

- ① Select the hydrograph scenario number for which you want to create hydrograph data, (Scenario 1 in this example, see Exhibit 2 below).
- ② Define the hydrograph type for the currently selected scenario by clicking one of the indicated toolbar icons (in Exhibit 2), or alternately by selecting **Hydrographs \ Edit Hydrograph Data** from the menu

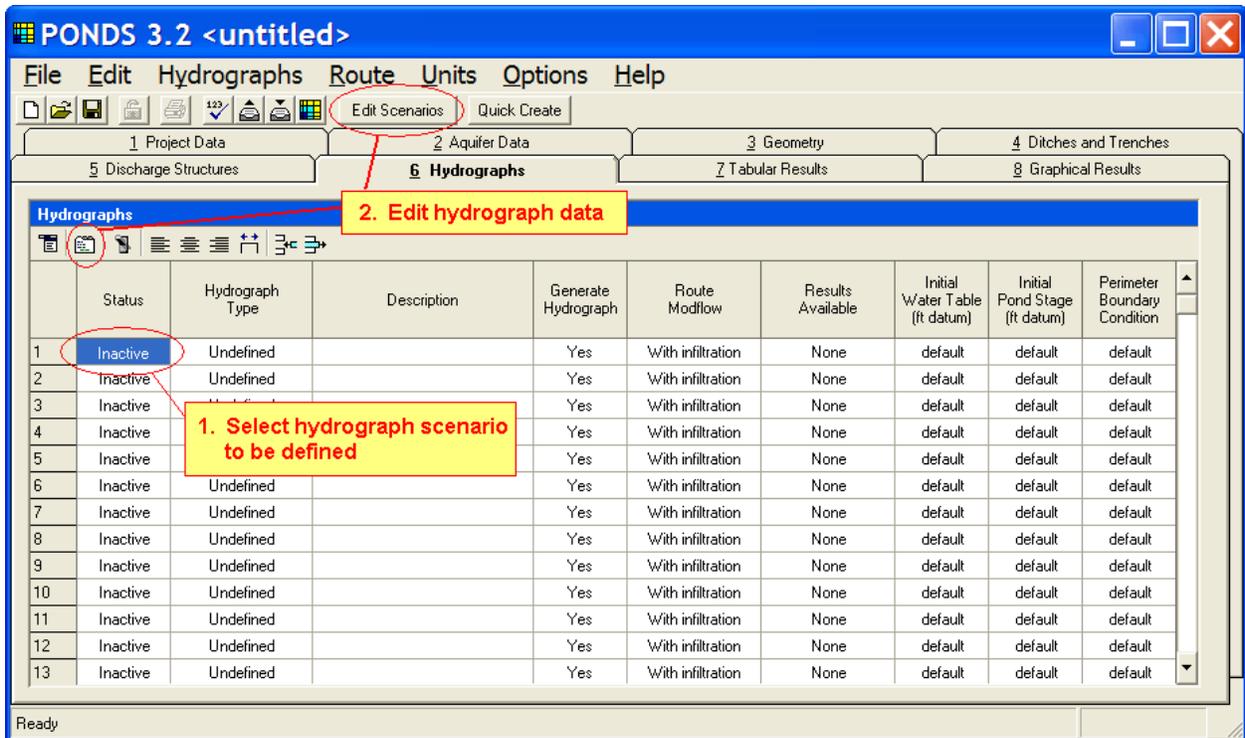


Exhibit 2. Screen shot of Hydrographs data page in main program window

Initially, the hydrograph type will be undefined, and you will see the following dialog box. In the drop down listbox for Hydrograph Type, choose Multi-basin SCS Hydrograph, which is the last item in the listbox.

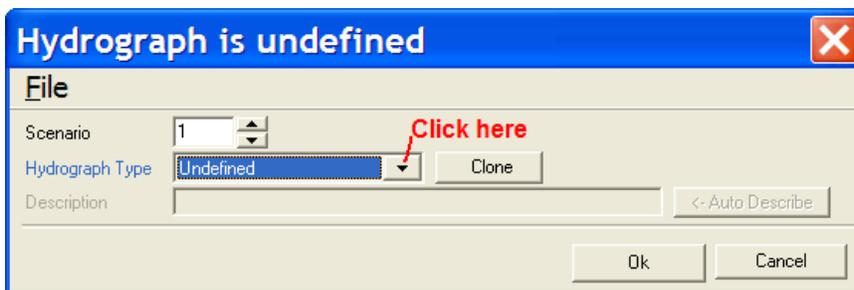


Exhibit 3. Undefined hydrograph dialog box

The dialog box will change to the data input dialog box for the Multi-basin SCS Hydrograph, as seen below.

The dialog box is titled "Multibasin / Interconnected SCS Hydrograph". It features a "File" section with a "Scenario" dropdown menu, a "Hydrograph Type" dropdown menu set to "Multi-basin SCS Hydrograph", and a "Clone" button. Below this is a "Description" text field. A vertical sidebar on the left contains four buttons: "Modflow Options", "Simulation Parameters" (which is highlighted), "Basin Data", and "Upgradient Inflows". The main area of the dialog is titled "Simulation Parameters" and contains a "Data input units" dropdown menu set to "English", and three input fields: "Minimum time of concentration for all contributing basins in chain of ponds (minutes)", "Computational Time Step (minutes)", and "Duration of simulation (hours)". At the bottom right are "Ok" and "Cancel" buttons.

Exhibit 4. Multi-basin hydrograph, simulation parameters

On the left hand side of this dialog box are buttons to navigate between different categories of data to be input:

- Modflow Options
- Simulation Parameters
- Basin Data
- Upgradient Inflows

Modflow Options

You probably won't have to modify the modflow options at this point in time.

Simulation Parameters

By default, the Simulation Parameters will be selected when you first enter the multi-basin hydrograph dialog box. You will need to define the following simulation parameters

- **Minimum time of concentration for all contributing basins in chain of ponds.**

This data parameter is not actually used in the analysis. It's purpose is to remind you that the minimum time of concentration is important in defining the time step. If you enter a time increment which is larger than this value divided by 7.5, you will get a warning message that you have exceeded the recommended maximum time increment. You may choose to ignore this warning message if you like.

- **Computational Time Step.** This is the solution time increment which will be used in constructing the hydrograph. For a series of chained ponds, this time increment should be the same for each pond.
- **Duration of simulation.** This specifies the total duration of the simulation from the beginning of the storm event. If you are interested in the recovery of the pond, the duration of simulation should be long enough to extend beyond whatever recovery criteria you are using. For example, if you have a 24-hr storm, and are interested in recovering the storm within 14 days, then the duration of simulation should be

$$24 \text{ hrs} + (14 \text{ days}) \times (24 \text{ hrs/day}) = 360 \text{ hrs, or greater}$$

Basin Data

The data input page for the basin data in a multi-basin SCS hydrograph is shown below

The dialog box is titled "Multibasin / Interconnected SCS Hydrograph". It has a "File" menu and several input fields: "Scenario" (set to 1), "Hydrograph Type" (set to "Multi-basin SCS Hydrograph"), and "Description". On the left, there are buttons for "Modflow Options", "Simulation Parameters", "Basin Data" (selected), and "Upgradient Inflows". The "Number of Basins" is set to 2. The main area contains a table titled "Hydrographs" with columns for "1" and "2". The table has the following rows: "Basin Name", "Basin Area (acres)", "Time of Concentration (minutes)", "DCIA (%)", "Curve Number", "Rainfall Depth (inches)", "Rainfall Duration (hours)", "Shape Factor", and "Rainfall Distribution". The "Basin Name" cell for the first basin is highlighted in black. At the bottom right, there are "Ok" and "Cancel" buttons.

	Hydrograph	
	1	2
Basin Name		
Basin Area (acres)		
Time of Concentration (minutes)		
DCIA (%)		
Curve Number		
Rainfall Depth (inches)		
Rainfall Duration (hours)		
Shape Factor		
Rainfall Distribution		

Exhibit 5. Multi-basin hydrograph, basin data

Begin by defining how many runoff basins directly contribute to the pond. There must be at least one basin defined, but there can be up to 20 contributing basins, or somewhere in between. Then for each of the basins, define the following.

- Basin Name (optional)
- Basin Area
- Time of Concentration
- DCIA (directly connected impervious area)
- Rainfall Depth
- Rainfall Duration
- Shape Factor
- Rainfall Distribution

Upgradient Inflows

The upgradient inflows data page looks like this.

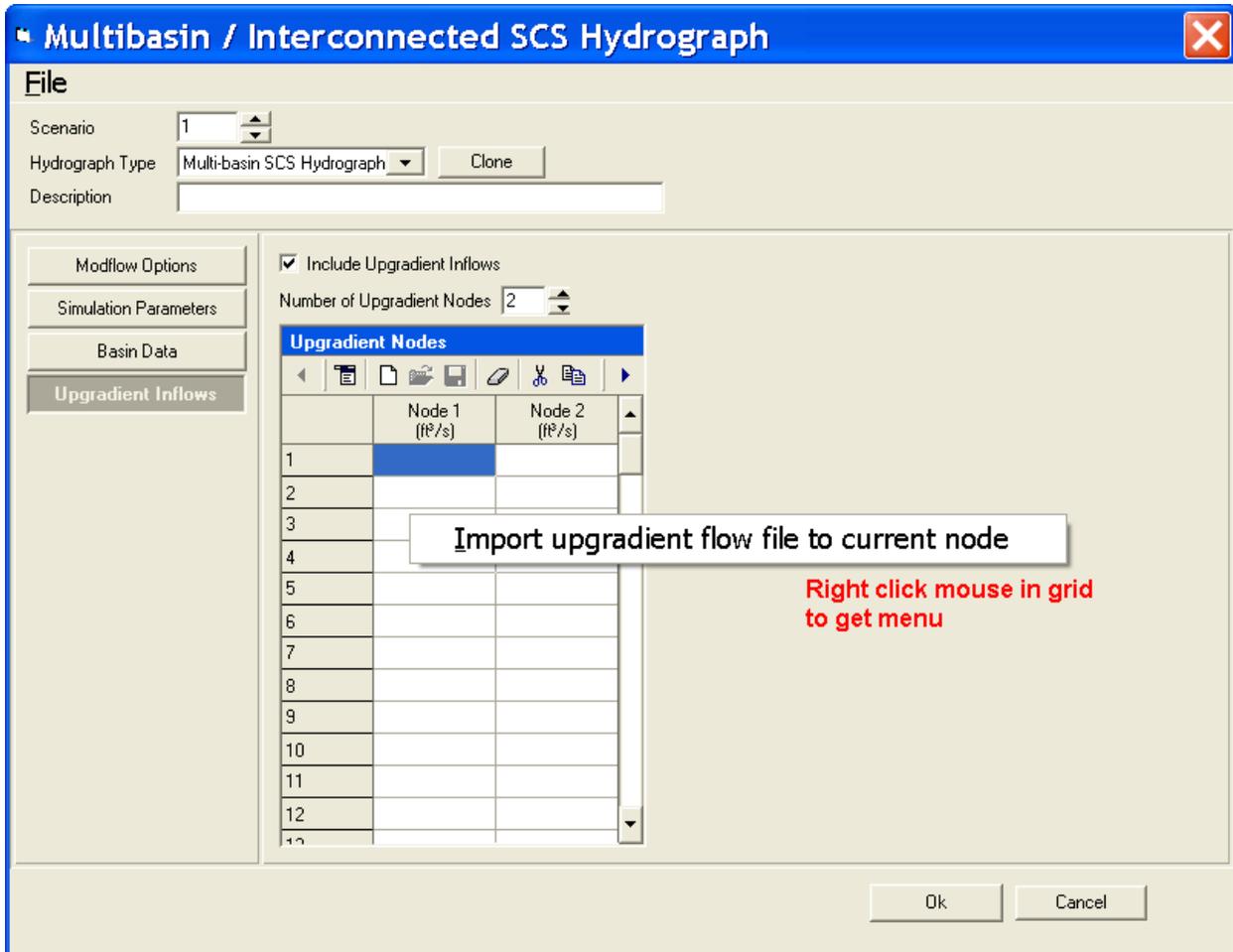


Exhibit 6. Multi-basin hydrograph, upgradient inflows

For the most upgradient pond there won't be any upgradient inflows, so the **Include Upgradient Inflows** checkbox should be unchecked. (It is unchecked by default).

If the current pond is receiving upgradient inflows, then check the **Include Upgradient Inflows** checkbox, and define the **Number of Upgradient Nodes** being routed to the current pond.

You will then need to import the upgradient flows, which were saved to a data file. [*Saving the discharges for use in a downgradient pond will be discussed below. You will obviously need to save the discharges from the upgradient pond before you can read them in.*] Start by clicking somewhere within the grid so that the currently selected grid cell is in the column of the grid where you want the upgradient flows read into, and then right click with the mouse to bring up a menu option to read in the upgradient flows.

Once you entered the data, hit the Ok button to return to the main program window, or select Cancel to return without saving.

Saving Upgradient Discharges Rates for use in a downgradient pond

Once you have successfully input the data for the first pond, and have completed the analysis of the first pond (i.e., results are available), you can export the discharges from the pond to a data file which can be imported as upgradient flow to the next pond in the chain.

In the main program window, select the Hydrographs data page (Tab 6). Then select the hydrograph scenario which contains the discharges you want to export (in this example, Scenario 1) by clicking the mouse on the appropriate grid line. Then from the menu, select **Hydrographs \ Export discharge for upgradient flow \ To file**, as shown below.

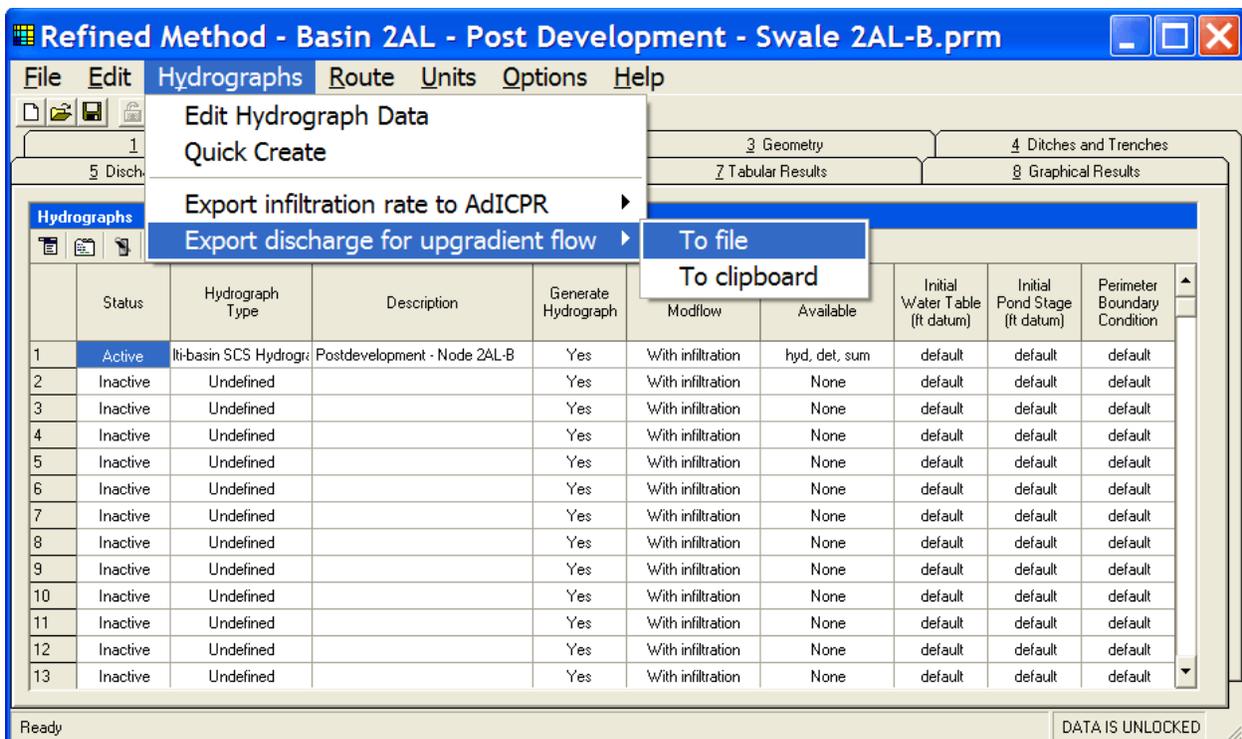


Exhibit 7. Exporting discharges for upgradient flow

The following dialog box will appear. Double check that the scenario number indicated in the dialog box corresponds to the scenario for which you want to export the discharges, and press Ok. You will then get a standard Windows file dialog box, which allows you to specify the name and location of the file in which to save the discharges. (Give the file a name that describes its contents in enough detail to be identifiable later when you need to import it.)

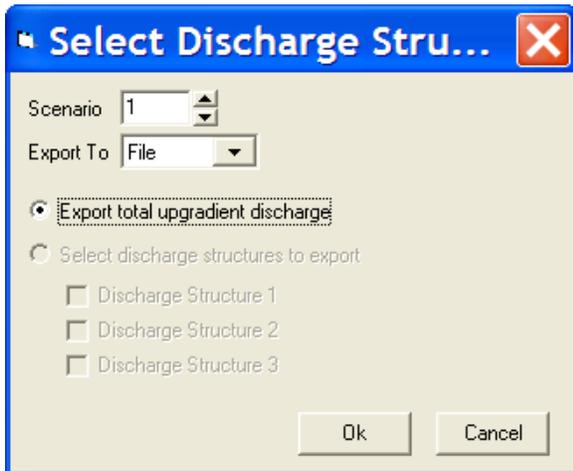


Exhibit 8. Confirm scenario to export

PART 2

MULTIBASIN / CHAINED PONDS EXAMPLE PROBLEM

The following example illustrates the features of the Multibasin SCS Hydrograph in PONDS 3.2. Data files for these examples are included in the PONDS 3.2 Software Distribution: files **Example 4a, Multibasin, Pond 1.prm** and **Example 4b, Multibasin, Pond 2.prm**. If you don't find these files then please make sure you are using the most recent update for PONDS by visiting the Devo Engineering Website at www.devoeng.com. Normally, these files will be located in the following folder:

C:\Program Files\Ponds32\Refined Method\Data\Example 4 - Multibasin Hydrograph\

The Multibasin SCS hydrograph uses the same fundamental input parameters (basin parameters and storm event parameters) as the Single Basin SCS hydrograph, but with the following distinctions:

- ① Multiple runoff basins can be defined for each pond.
- ② Ponds can be chained together (manually), by exporting the discharge from an upgradient ponds and importing that discharge as an upgradient inflow in the downgradient pond.
- ③ The time increment and duration of the simulation are explicitly specified by the user.

Note that the Multibasin SCS hydrograph can also be used instead of the Single Basin SCS hydrograph for single basin systems, and offers more flexibility in setting the time step increment and duration of simulation, etc.

In this example, we will consider the following pond and basin configuration:

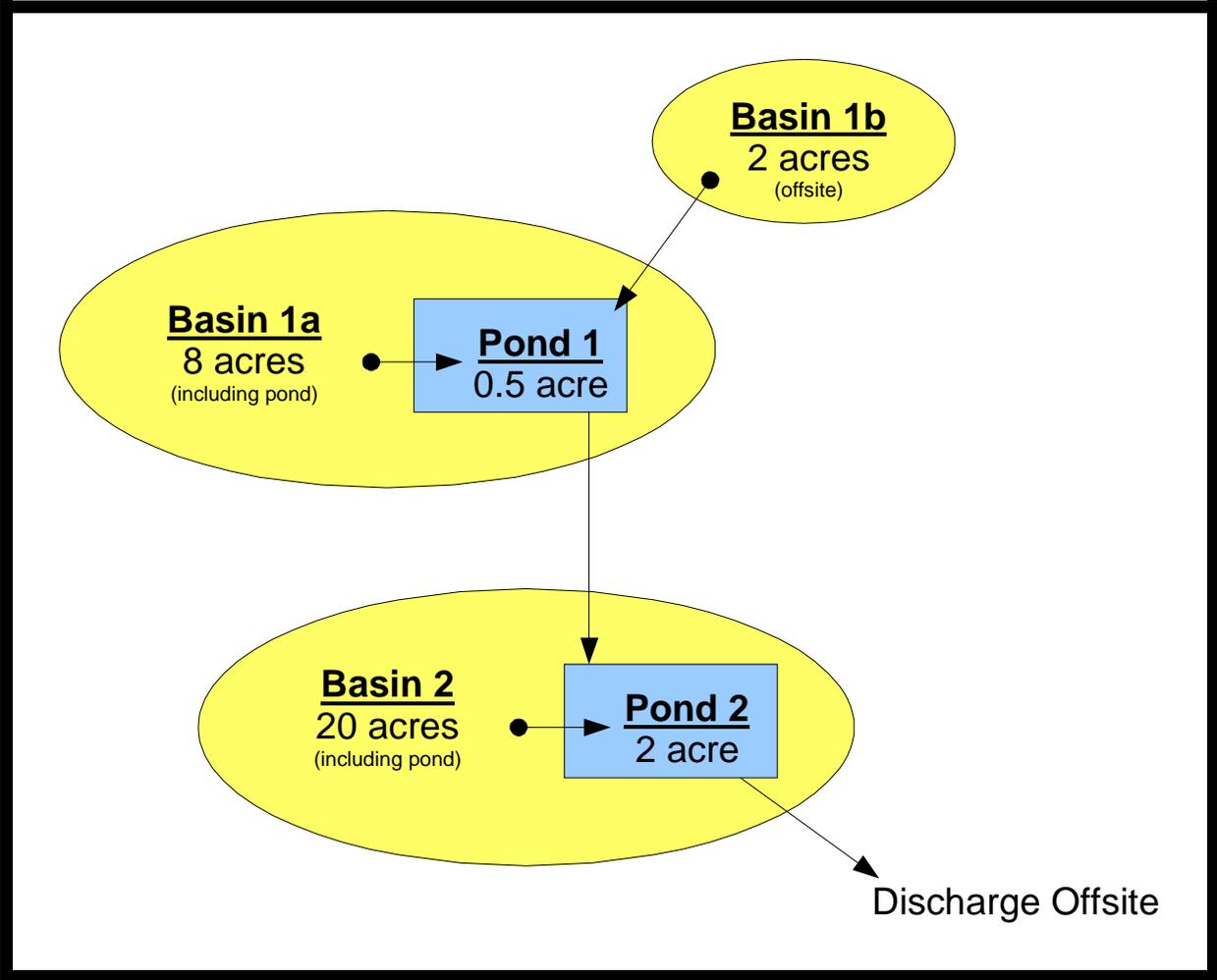


Exhibit 9. Nodal Diagram

As shown above, Pond 1 is located within the boundary of Basin 1a, and Pond 1 receives the direct runoff from Basin 1a. In addition, Pond 1 receives the offsite discharge from Basin 1b. Pond 1 then discharges downgradient to Pond 2. Pond 1 is a dry bottom pond.

Pond 2 is located within the boundary of Basin 2 and receives the direct runoff from Basin 2. Pond 2 also receives the upgradient discharge from Pond 1. Pond 2 discharges offsite. Pond 2 is a wet pond.

The following data are given:

Design Storm Event

- 100 Year / 24 Hour Storm
- Design Rainfall Depth = 9.6 inches
- Shape Factor = UHG 323
- Rainfall Distribution = FDOT 24 Hour

Pond 1

- Pond area = 0.5 acre
- Stage vs Area:

Stage (ft)	Area (ft ³)
47	15,126
50	21,780
52	26,856

- Equivalent Length = 181 ft
- Equivalent Width = 120 ft
- Discharge Structure: 3 ft. wide rect. broad crested weir @ elevation +50 ft
- Soil Properties:

Base of Aquifer = +38 ft
Groundwater Table Elevation = +42 ft
Horizontal Saturated Conductivity = 10 ft/day
Fillable Porosity = 20%
Unsaturated Vertical Infiltration Rate = 5 ft/day

Basin 1a

- Total Area = 8 acres (including pond)
 - Pond area = 0.5 acres
 - Time of Concentration = 15 minutes
 - Curve Number = 65
-
-

Basin 1b

- Area = 2 acres
 - Time of Concentration = 20 minutes
 - Curve Number = 85
-
-

Pond 2

- Effective Pond Area = 2 acres
- Stage vs Area:

Stage (ft)	Area (ft ³)
36	69254
40	87120
41	91907

- Equivalent Length = 295 ft
- Equivalent Width = 295 ft
- Discharge Structures:

10 ft wide rect. sharp crested weir @ elevation +40 ft
3-inch bleed-down orifice at elevation +36 ft

- Soil Properties:

Base of Aquifer = +30 ft
Groundwater Table Elevation = +36 ft (wet pond)
Horizontal Saturated Conductivity = 10 ft/day

Fillable Porosity = 20%

Basin 2

- Total area = 20 acres (including pond)
 - Pond area = 2 acres
 - Time of Concentration = 30 minutes
 - Curve Number = 56
-
-

POND 1 DATA SCREENS

Aquifer parameters for Pond 1 are entered as shown in Exhibit 10 below. Note that the Maximum Area for Unsaturated Infiltration corresponds to the area at the control elevation for this example.

Parameter	Value
Base Of Aquifer Elevation, [B] (ft datum)	38
Water Table Elevation, [WT] (ft datum)	42
Horizontal Saturated Hydraulic Conductivity, [Kh] (ft/day)	10
Fillable Porosity, [n] (%)	20
<input checked="" type="checkbox"/> Include Unsaturated Vertical Infiltration	
Unsaturated Vertical Infiltration Rate, [Iv] (ft/day)	5
Maximum Area For Unsaturated Infiltration, [Av] (ft ²)	21780

Exhibit 10. Pond 1 Aquifer Parameters

Geometry data for Pond 1 are entered as shown in Exhibit 11.

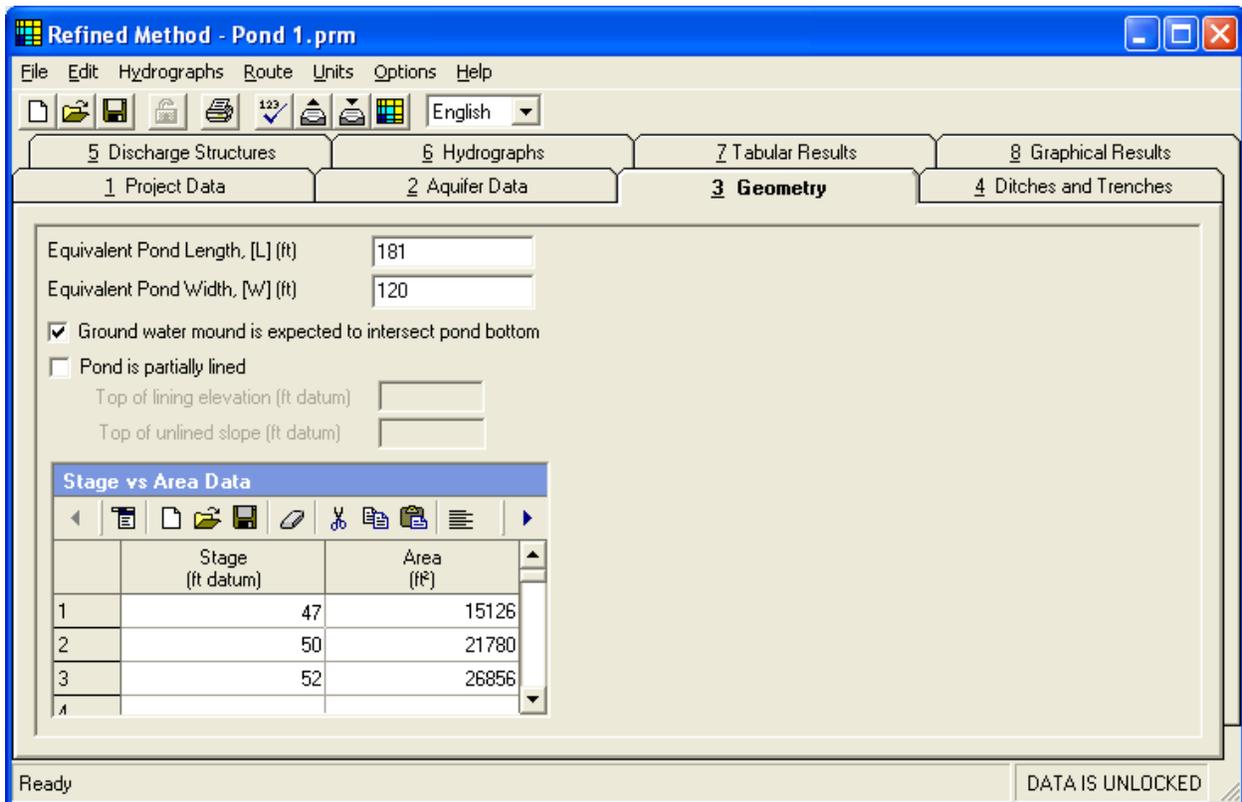


Exhibit 11. Pond 1 Geometry Data

Pond 1 contains a single discharge structure, a 3 ft weir (broad crested). Data are entered as shown in Exhibit 12 below.

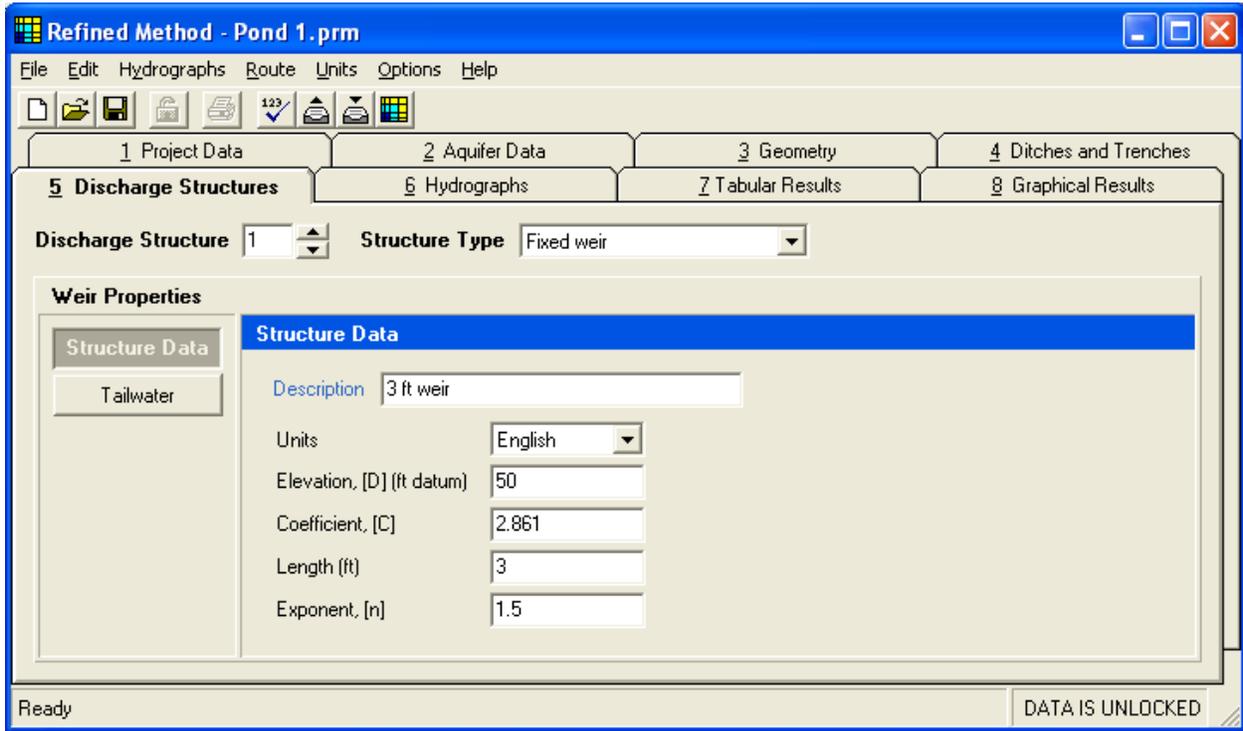


Exhibit 12. Pond 1 Discharge Structure Data

The simulation parameters for the 100-yr/24-hr storm event are entered as shown in Exhibit 13 below.

The screenshot shows a software window titled "Multibasin / Interconnected SCS Hydrograph". The window contains the following fields and controls:

- Scenario: 1
- Hydrograph Type: Multi-basin SCS Hydrograph (with a "Clone" button)
- Description: 100 Year / 24 Hour Storm
- Data input units: English
- Minimum time of concentration for all contributing basins in chain of ponds (minutes): 15
- Computational Time Step (minutes): 2
- Duration of simulation (hours): 360

On the left side, there are four tabs: "Modflow Options", "Simulation Parameters" (which is selected), "Basin Data", and "Upgradient Inflows". At the bottom right, there are "Ok" and "Cancel" buttons.

Exhibit 13. Simulation Parameters for Pond 1, 100-yr/24-hr Storm

In general, it is recommended that the Computational Time Step should be less than or equal to the time of concentration divided by 7.5, so as not to miss the peak runoff.

When analyzing a multibasin pond, the time step should be less than or equal to the **minimum** time of concentration of all contributing basins divided by 7.5. Therefore, in this example, the computational time step should be less than or equal to $T_c = 15 \text{ minutes} / 7.5 = 2 \text{ minutes}$.

Furthermore, when analyzing a series of chained ponds, the Computational Time Step must be the same for each pond analyzed, so that discharge data can readily be exported from one pond and imported to the next. Therefore, the Computational Time Step should be less than or equal to the minimum time of concentration of any basin contributing to any pond in the chain. In this example, we have times of concentration of 15 min, 20 min and 30 min for Basins 1a, 1b and 2 respectively. Therefore the minimum time of concentration of 15 minutes controls, and a Computational Time Step of 2 minutes is used for all ponds analyzed.

The duration of simulation (360 hrs) allows for the duration of the storm event (24 hrs) plus 14 days after the storm event (15 days total).

The runoff basin parameters and design storm event parameters for Pond 1 are entered as shown in Exhibit 14 below.

The screenshot shows a software window titled "Multibasin / Interconnected SCS Hydrograph". At the top, there is a menu bar with "File". Below the menu bar, there are input fields for "Scenario" (set to 1), "Hydrograph Type" (set to Multi-basin SCS Hydrograph), and "Description" (set to 100 Year / 24 Hour Storm). A "Clone" button is next to the Hydrograph Type dropdown. On the left side, there are several buttons: "Modflow Options", "Simulation Parameters", "Basin Data" (which is highlighted), and "Upgradient Inflows". In the center, there is a "Number of Basins" dropdown set to 2. Below this is a "Hydrographs" table with a toolbar above it. The table has two columns for basins, labeled 1 and 2. The parameters listed in the table are: Basin Name, Basin Area (acres), Time of Concentration (minutes), DCIA (%), Curve Number, Rainfall Depth (inches), Rainfall Duration (hours), Shape Factor, and Rainfall Distribution.

	Hydrograph	
	1	2
Basin Name	Pond + Basin 1a	Basin 1b
Basin Area (acres)	8	2
Time of Concentration (minutes)	15	20
DCIA (%)	6.25	0
Curve Number	65	85
Rainfall Depth (inches)	9.6	9.6
Rainfall Duration (hours)	24	24
Shape Factor	UHG 323	UHG 323
Rainfall Distribution	FDOT 24 Hour	FDOT 24 Hour

At the bottom right of the window, there are "Ok" and "Cancel" buttons.

Exhibit 14. Pond 1 Basin Parameters

Note that the pond area itself should be entered as Directly Connected Impervious Area (DCIA). Although the pond is not impervious, it behaves as DCIA in the sense that all of the rainfall that falls directly within the footprint of the pond is assumed to reach the pond instantaneously without any appreciable loss of volume.

The percentage of DCIA in this example is calculated as follows

$$\text{DCIA} = \text{Pond Area} / \text{Total Basin Area} = 0.5 \text{ acres} / 8 \text{ acres} = 6.25\%$$

Note that the DCIA from development (paving, rooftops, etc.) is commonly included in one of two ways.

- ① The DCIA from development is sometimes included in the calculation of the weighted average curve number, but is not included in the DCIA percentage, or
- ② A weighted average curve number is calculated for just the non-DCIA areas, and the DCIA from development is included in the percentage of DCIA.

In either case, it is recommended that the pond be included in the DCIA percentage directly.

The results for Pond 1 are shown in Exhibit 15 below. As seen in Exhibit 15, the pond stage has recovered to the pond bottom (+47 ft) after 14 days after the storm (total elapsed time of 15 days). The peak discharge rate from Pond 1 is just over 4 cfs.

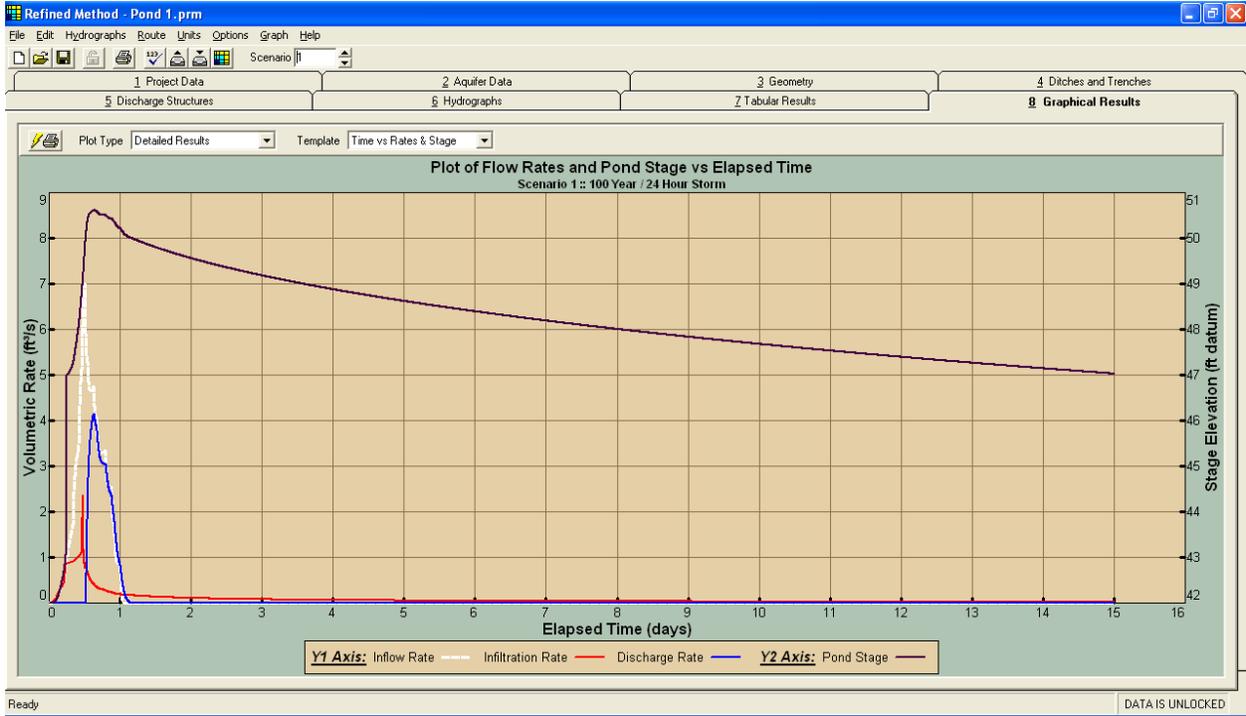


Exhibit 15. Results for Pond 1

The discharge rates for Pond 1 need to be exported and then imported to Pond 2. To export the discharges, perform the following steps:

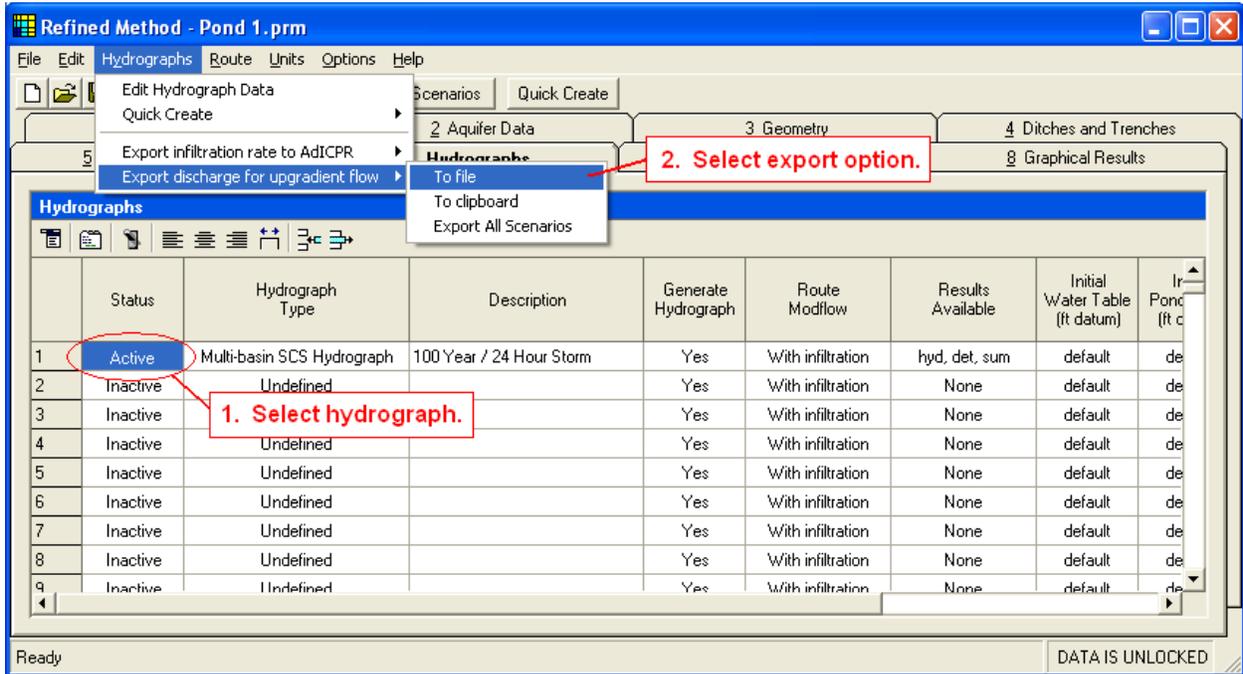


Exhibit 16. Exporting Discharges for Upgradient Flow

First, go to the Hydrographs data page in the main program window.

Next, click on the location in the hydrographs grid that contains the storm event whose discharges you wish to export (Step 1 in Exhibit 16 above).

Next, from the menu, chose **Hydrographs / Export discharge for upgradient flow / To file** (Step 2 in Exhibit 16 above).

You will be asked to confirm which storm event to export discharges for, and then asked to specify a location and filename.

POND 2 DATA SCREENS

Aquifer parameters for Pond 2 are entered as shown in Exhibit 17 below. Note that Pond 2 is a wet pond, so there is no unsaturated vertical infiltration.

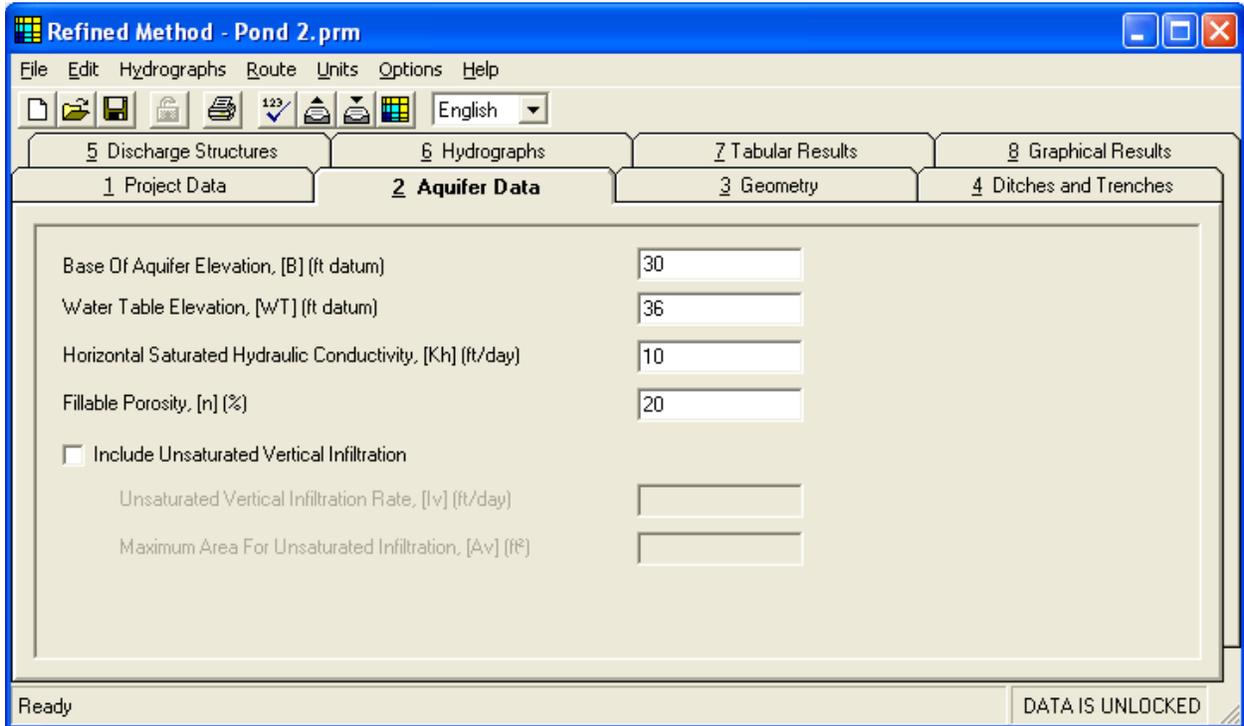


Exhibit 17. Pond 2 Aquifer Parameters

Geometry data for Pond 2 are entered as shown in Exhibit 18 below.

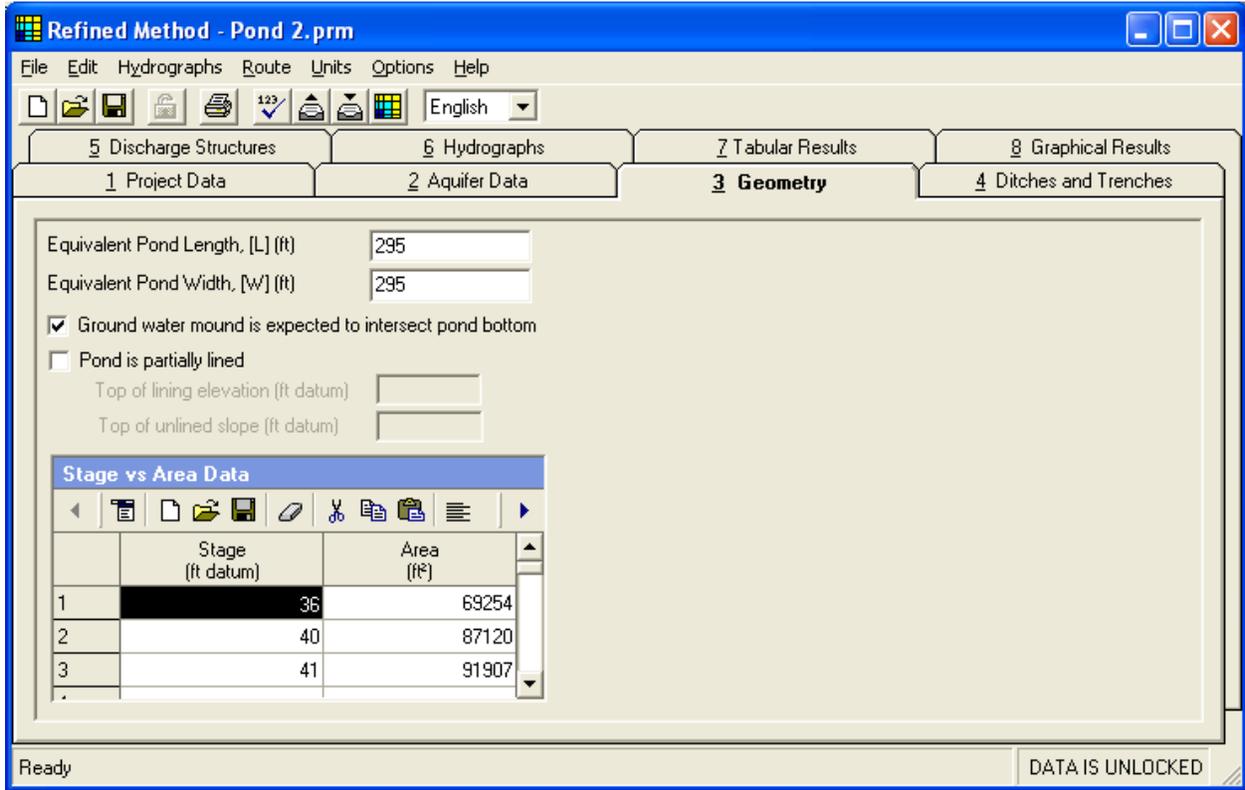


Exhibit 18. Pond 2 Geometry Data

There are 2 discharge structures for Pond 2, an 10-ft long (sharp crested) overflow weir and a 3-inch diameter bleed-down orifice. Data are entered as shown in Exhibits 19 and 20 below.

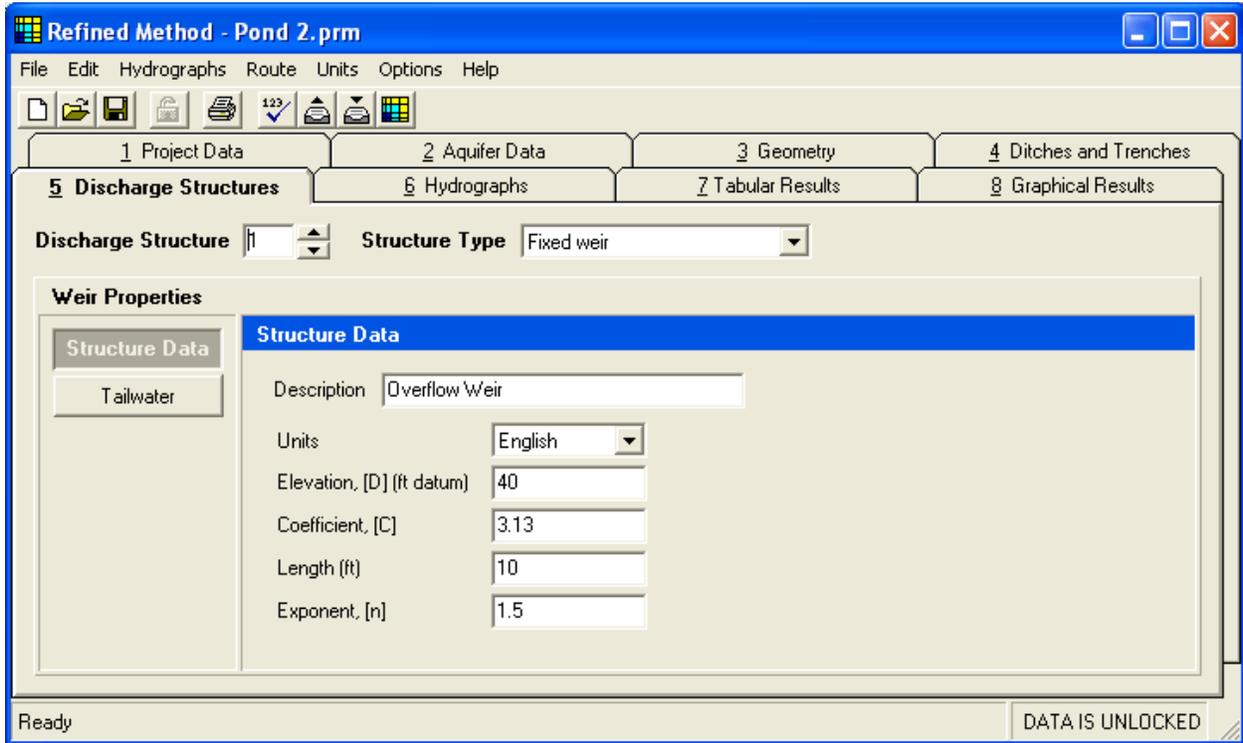


Exhibit 19. Pond 2 Discharge Structure Data, Overflow Weir

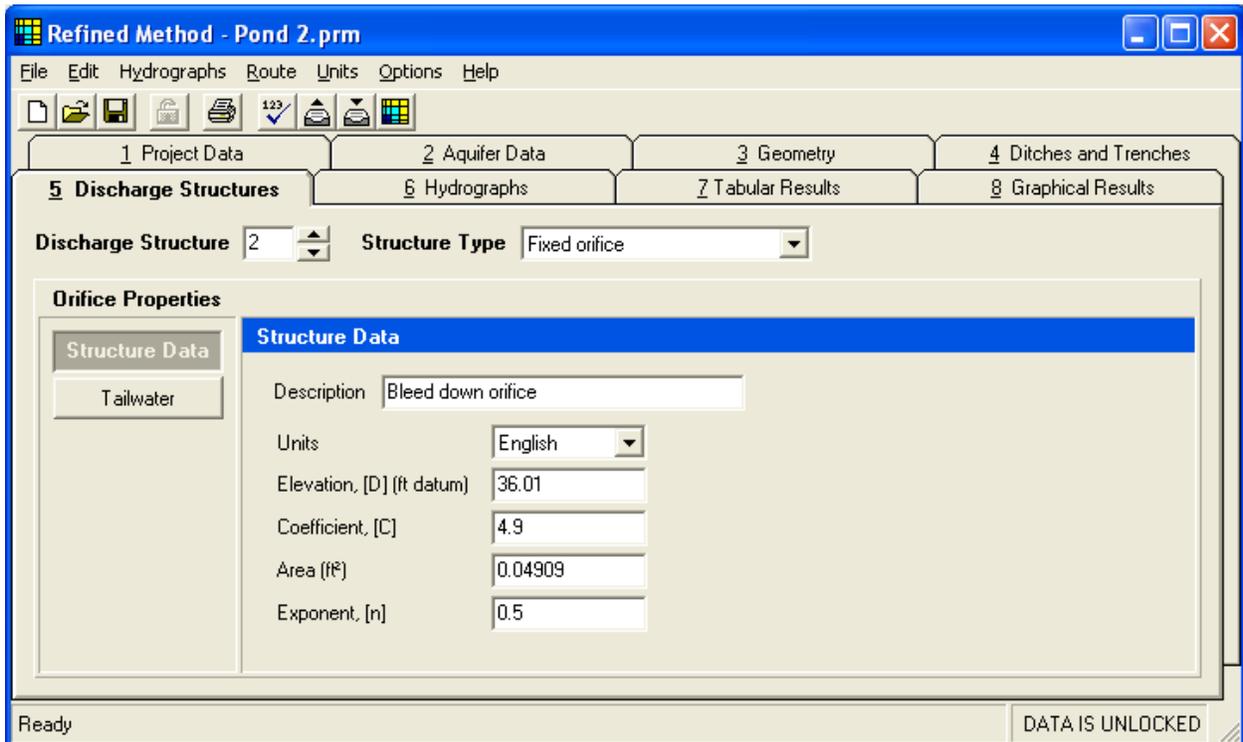


Exhibit 20. Pond 2 Discharge Structure Data, Bleed-down Orifice

The simulation parameters for the 100-yr/24-hr storm event for Pond 2 are entered as shown in Exhibit 21 below.

The screenshot shows a software dialog box titled "Multibasin / Interconnected SCS Hydrograph". The "File" menu is open, showing "Scenario" (1), "Hydrograph Type" (Multi-basin SCS Hydrograph), and "Description" (100 Year / 24 Hour Storm). The "Simulation Parameters" section is active, showing "Data input units" (English), "Minimum time of concentration for all contributing basins in chain of ponds (minutes)" (15), "Computational Time Step (minutes)" (2), and "Duration of simulation (hours)" (360). Buttons for "Modflow Options", "Basin Data", and "Upgradient Inflows" are visible on the left. "Ok" and "Cancel" buttons are at the bottom right.

Parameter	Value
Scenario	1
Hydrograph Type	Multi-basin SCS Hydrograph
Description	100 Year / 24 Hour Storm
Data input units	English
Minimum time of concentration for all contributing basins in chain of ponds (minutes)	15
Computational Time Step (minutes)	2
Duration of simulation (hours)	360

Exhibit 21. Simulation Parameters for Pond 2, 100-yr/24-hr Storm

Note that the minimum time of concentration occurs for Basin 1a (15 minutes), and this minimum time of concentration controls the Computation Time Step for each pond in the chain of ponds. The time of concentration is recommended to be less than or equal to the minimum time of concentration divided by 7.5, therefore $T_c = 15 \text{ minutes} / 7.5 = 2 \text{ minutes}$.

The runoff basin parameters and design storm event parameters for Pond 2 are entered as shown in Exhibit 22 below.

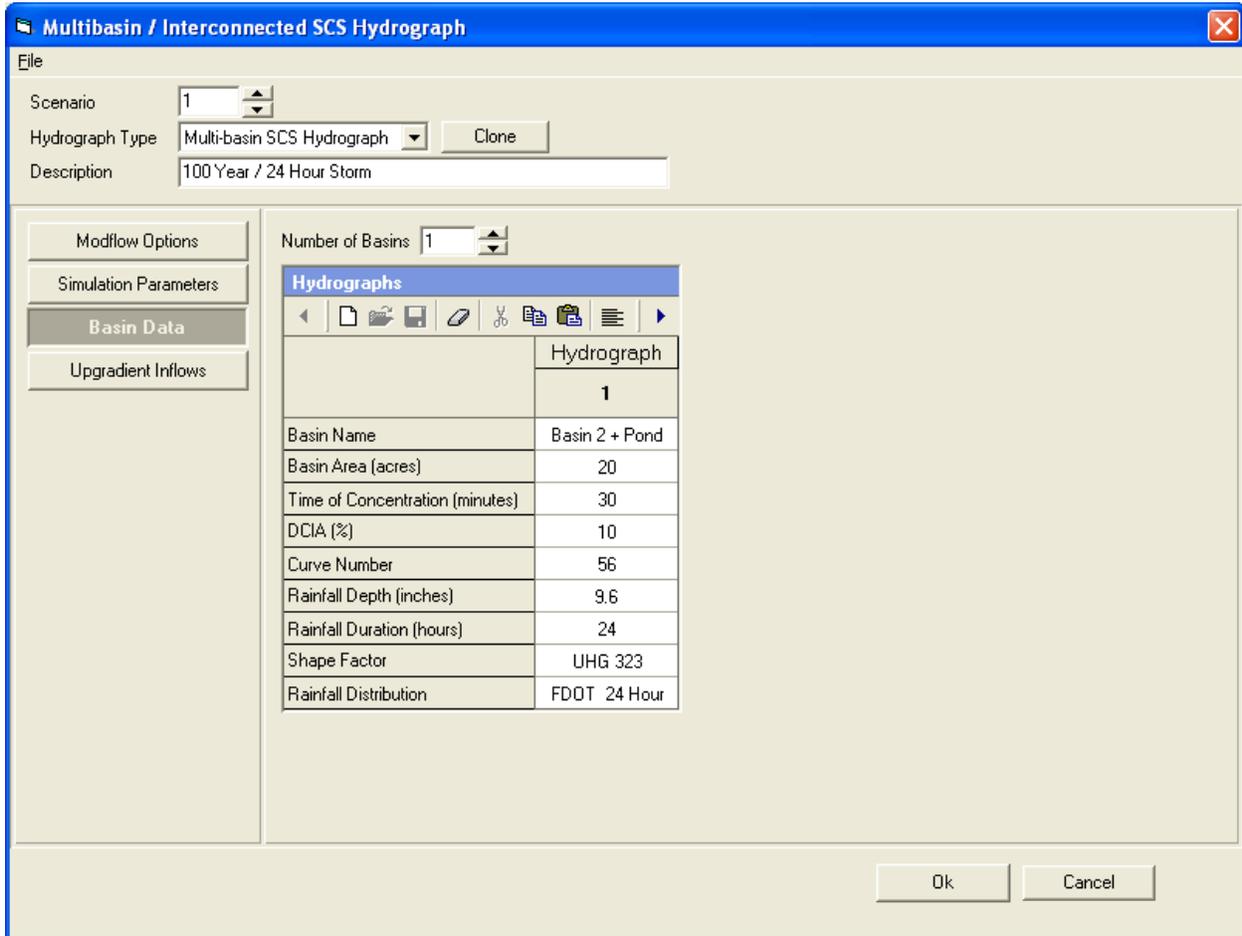


Exhibit 22. Pond 2 Basin Parameters

Note that the pond itself is included in the DCIA:

$$\% \text{ DCIA} = \text{Pond Area} / \text{Total Basin Area} = 2 \text{ acres} / 20 \text{ acres} = 10 \%$$

(This assumes that any DCIA from development - pavement, roofs, etc. - is included in the weighted average Curve Number.)

Since Pond 2 receives the discharges from Pond 1, it is necessary to manually import the discharges from Pond 1 as Upgradient Inflows to the inflow hydrograph of Pond 2 as follows:

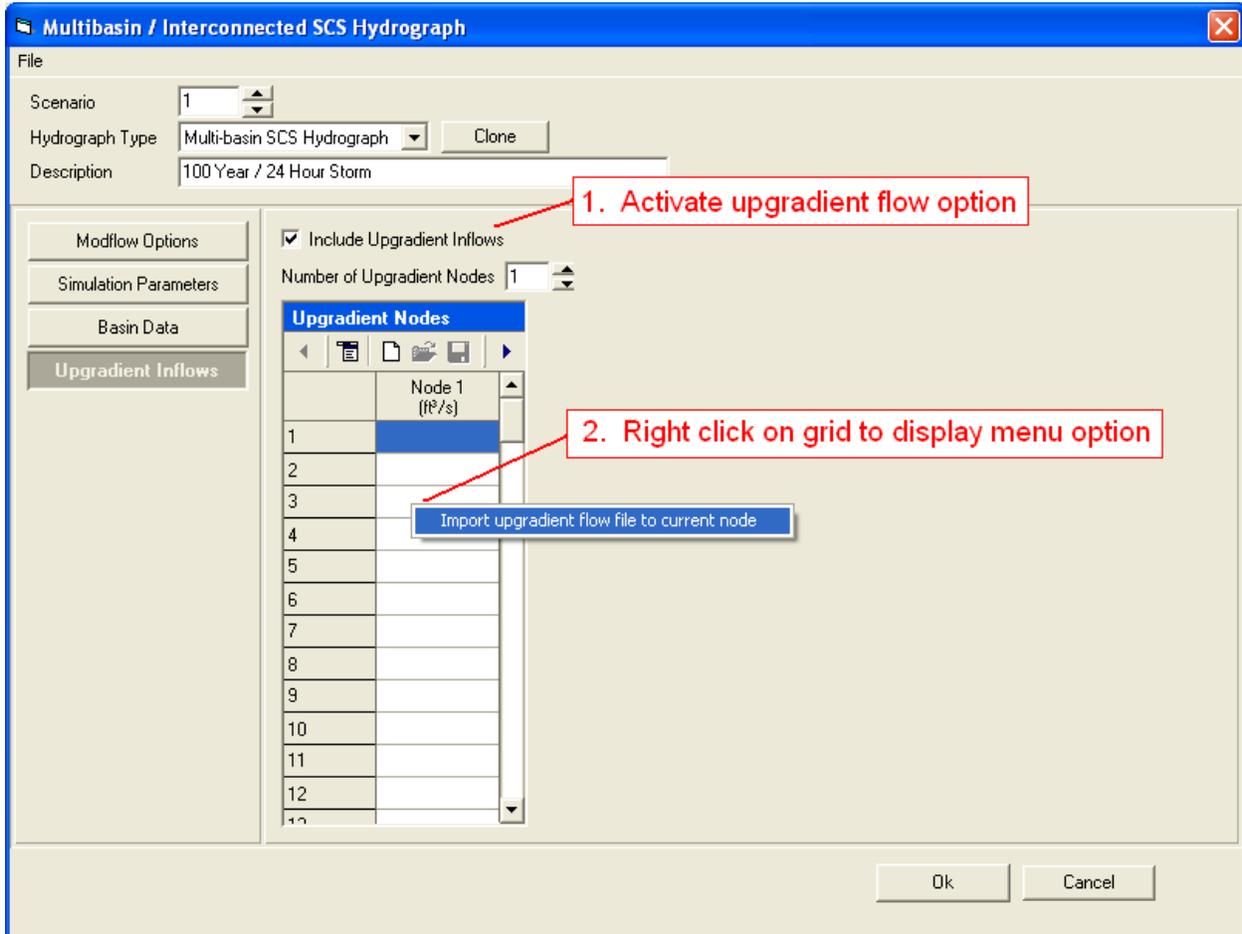


Exhibit 23. Importing Upgradient Inflows to Pond 2, 100-yr/24-hr Hydrograph

From the Upgradient Inflows data entry screen, perform the following steps:

- ① First, activate the upgradient inflows option by checking its checkbox, and specify the number of contributing upgradient nodes.
- ② Next, right click on the upgradient flows grid, on the node for which you want to import upgradient discharges. Right clicking will display a menu with only one choice: **Import upgradient flow file to current node**.

Clicking on the menu option will then display a file open dialog box. Select the file which was previously saved containing the Pond 1 discharges.

Having successfully imported the discharges from Pond 1, the Upgradient Inflows will appear as shown in Exhibit 24.

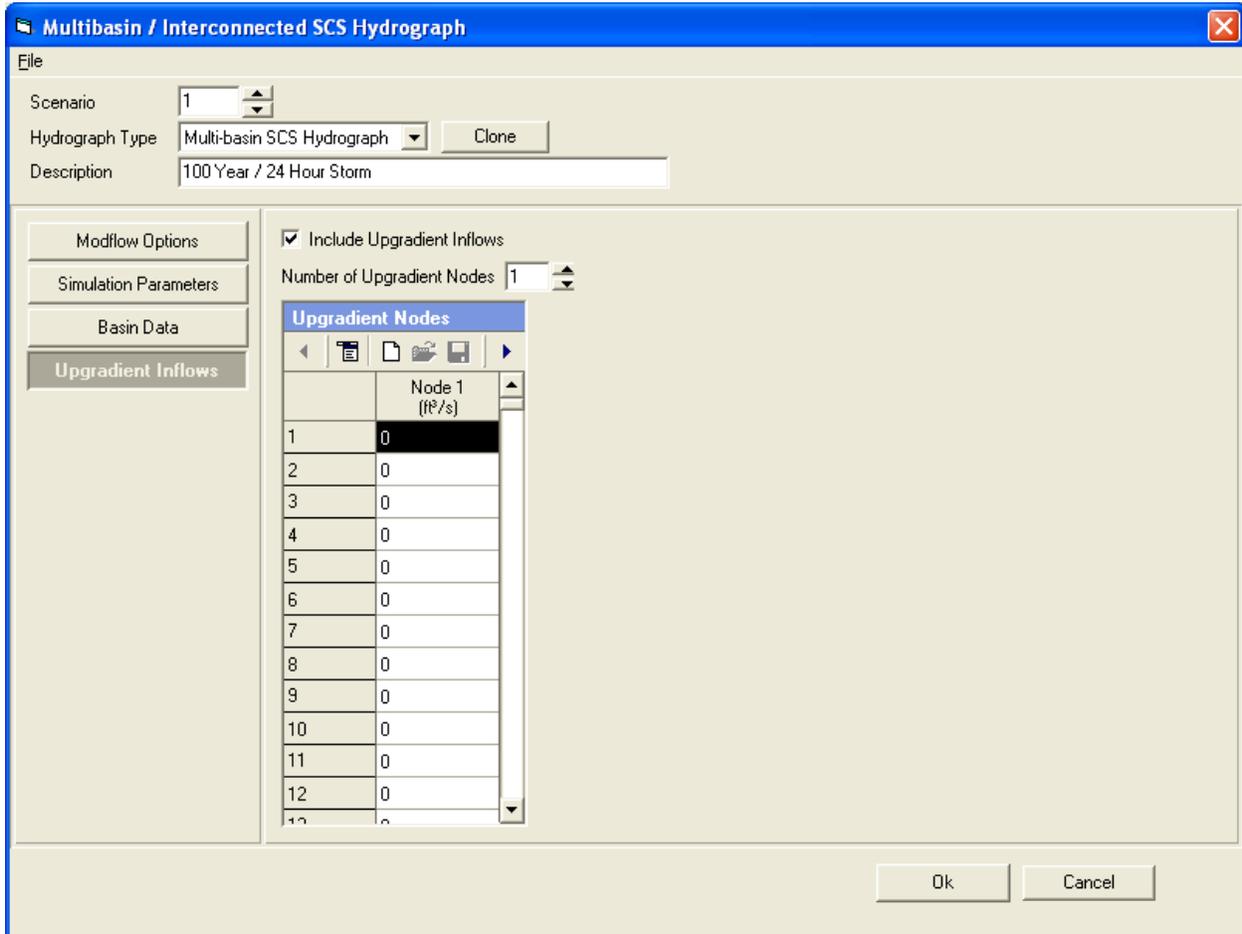


Exhibit 24. Upgradient Inflows for Pond 2, 100-yr/24-hr Storm

Note that if any changes occur to an upgradient pond, then the entire chain of ponds must be re-analyzed from that pond to the most downgradient pond in the chain. Changes to an upgradient pond will not be automatically reflected in the downgradient ponds, and the discharges for the upgradient pond must be re-exported, and re-imported to the downgradient pond, throughout the entire chain of ponds until the most downgradient pond is reached.

Assuming that all data has been entered and processed correctly, the results for Pond 2 will appear as shown in Exhibit 25. Note that the pond has (nearly) recovered at 14 days after the storm event (total elapsed time of 15 days) and that the peak discharge rates is approximately 6 cfs.

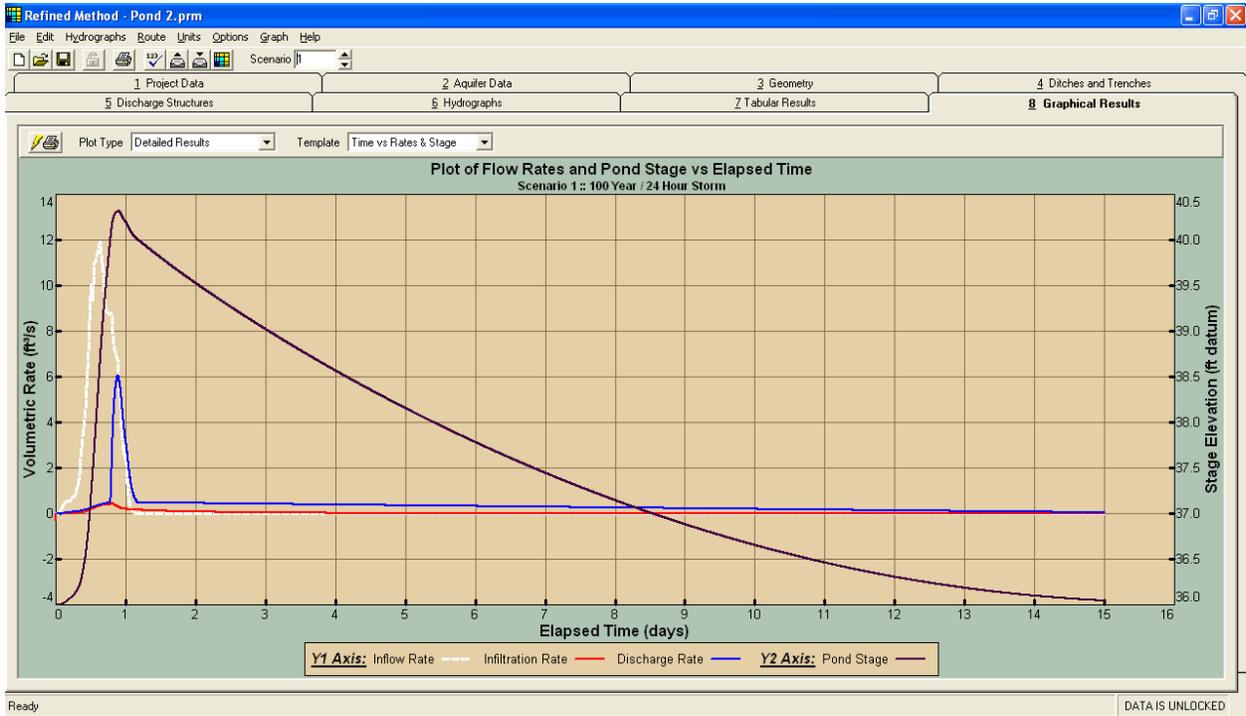


Exhibit 25. Results for Pond 2