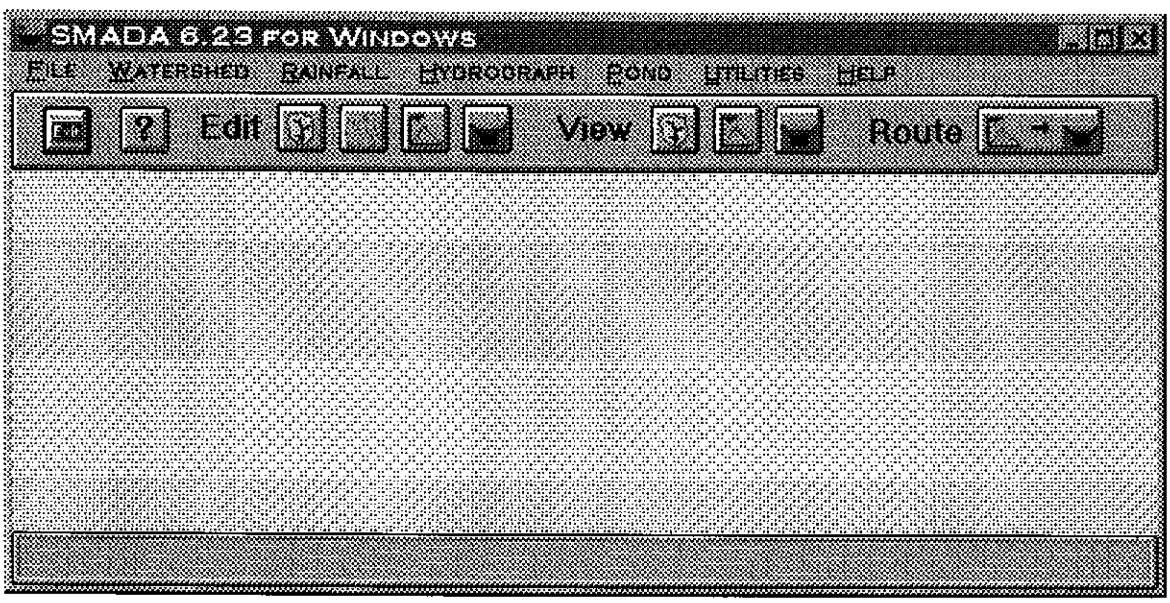
SMADA
Stormwater Management and Design Aid

Introduction

The SMADA computer program is designed to assist in the generation of watershed hydrographs and the routing of the hydrographs through a retention or detention basin. The program is designed for single watershed - single rainfall - single pond types of analyses (however there are provisions for multple storm/rainfall analysis). The creation and routing or a watershed hydrograph involves 5 basic steps (If you only need a watershed hydrograph the analysis would stop at step 3);

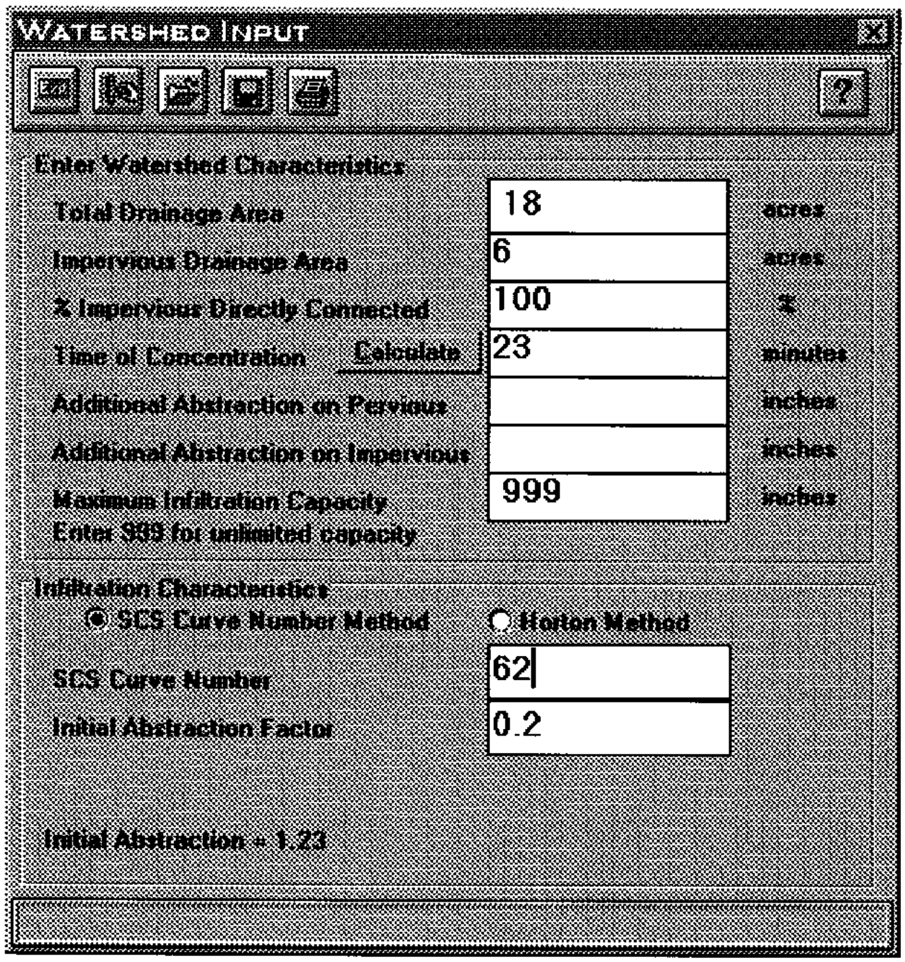
1. Create a watershed
2. Create a rainfall
3. Generate a watershed hydrograph using the watershed and rainfall
4. Define basic pond characteristics
5. Route the watershed hydrograph through the pond.



Watersheds

I. Watersheds in SMADA

SMADA can keep only one watershed in active memory at a time. To enter or edit the characteristics of this watershed use the **Watershed**, **Create/Edit Watershed** menu options. The watershed entry dialog window will appear allowing for input of defining characteristics for your watershed.



The Watershed Characteristics field definitions are:

Total Area - The total area of the watershed in acres.

Impervious Area - The area of the watershed which will not allow for infiltration, typically pavement, houses, concrete, etc...

Percent Impervious Directly Connected - The percentage of the impervious area which is directly connected to the watershed point of discharge. Precipitation which falls on directly connected impervious area will have no opportunity for infiltration. Precipitation which falls on impervious areas which are not directly connected, will have the opportunity to flow to pervious areas and thus infiltrate.

Time of Concentration - The length of time it takes water to flow from the furthest point in the watershed to the watershed outlet. This time of concentration can be calculated from watershed parameters using the TC Calculator (TCCALC) included in the SMADA suite. Simply click on the "Calculate" button and TCCALC will automatically be activated. The time of concentration can then be calculated after entering the necessary parameters. The calculated TC will NOT be automatically entered into your Watershed Characteristics dialog window.

Additional Abstraction over Pervious - This is storage which is available on the pervious area. It is measured in inches over the pervious area, and any volumes must be converted to these units by dividing by the pervious area and converting units to inches.

Additional Abstraction over Impervious - This is storage which is available on the impervious area. It is measured in inches over the impervious area, and any volumes must be converted to these units by dividing by impervious area and converting units to inches.

Maximum Infiltration Capacity - This is the total amount of storage which is available in the column of pervious soil. Any precipitation which occurs above this amount will become excess. This can usually be estimated as the product of soil porosity and average depth to groundwater table.

II. Infiltration Methods

SMADA allows for the use of two methods of infiltration; the Horton infiltration method and the Soil Conservation Service (SCS, now called NRCS) Curve Number (CN) method.

A. SCS Curve Number Method

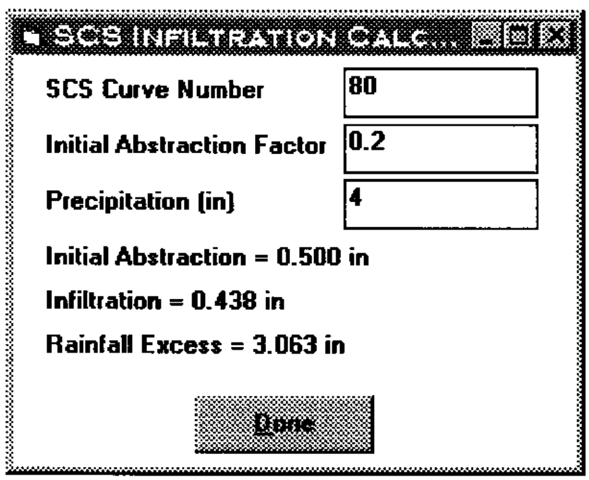
The SCS Curve Number Method for the determination of infiltration is well documented in the Hydrology text, Hydrology: Water Quantity and Quality Control. Select the "SCS Curve Number Method" option button and enter the following information:

Curve Number on Pervious (CN) - The SCS Curve Number as defined by the Soil Conservation Service for the pervious soil regions. A more detailed discussion of this curve number is included in the theory section. If the "Composite Curve Number" method is used, the composite curve number would be entered here and the Impervious Area should be entered as zero.

Initial Abstraction Factor (IAF) - This is the multiplication factor used in the SCS Curve Number method calculation of rainfall excess. This is typically 0.2 and is the program default value. S' (storage factor) is defined as 1000/CN - 10, and can be used to calculate the initial abstraction; IA = (IAF)S'.

SCS Infiltration Calculator

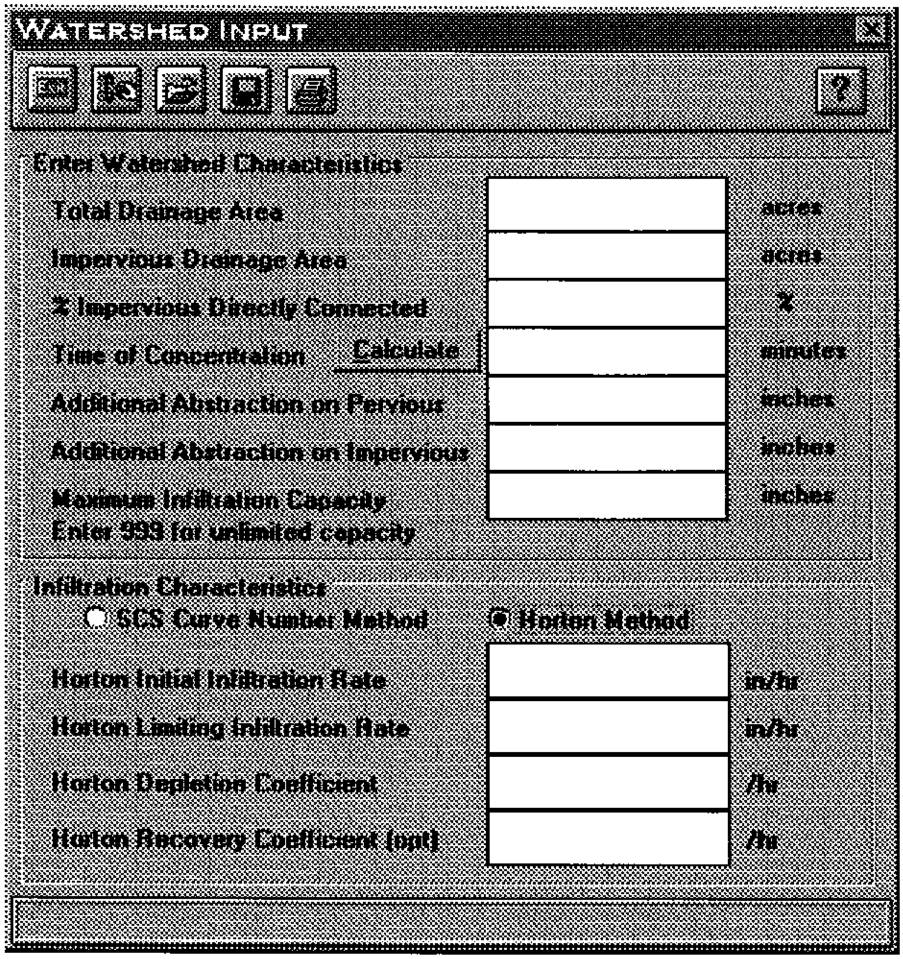
If specific calculations are necessary, then the **SCS Infiltration Calculator** option of the **Watershed** menu might prove useful. This calculator allows for the calculation of infiltration, rainfall excess, and initial abstraction using the SCS curve number method.



When using the **SCS Infiltration Calculator** the Initial Abstraction, Infiltration, and Rainfall Excess will be automatically calculated when the data are entered.

B. Horton Method

The Horton method uses an exponential function to estimate infiltration. SMADA uses a modification of this general equation to solve for infiltration rate as a function of cumulative infiltration. The derivation of this equation is included in the basic theory section of this chapter. The standard Horton equation is well-outlined in the Hydrology text, <u>Hydrology: Water Quantity and Quality Control</u>.



Select the **Horton Method** option button and enter the following information:

Horton Initial Infiltration Rate - This is typically the initial infiltration rate or the infiltration rate at time zero (inches/hour) using the Horton method.

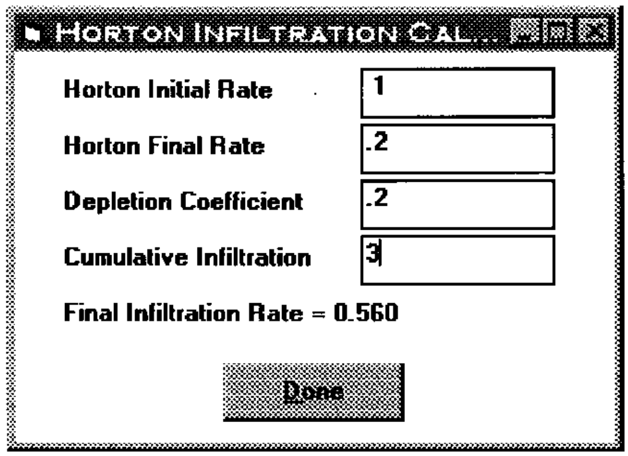
Horton Limiting Infiltration Rate - In the Horton method, the infiltration rate usually decreases over time to a constant value. This value is the Horton limiting infiltration rate in inches/hour.

Horton Depletion Coefficient - This is the exponential coeffcient of the Horton equation. This coefficient is expressed as 1/time. SMADA requires the units of time to be in hours.

Horton Recovery Coefficient - Exponential infiltration capacity coefficient used in the continuous simulation portion of the SMADA program. This coefficient is expressed as 1/time. SMADA requires the units of time to be in hours.

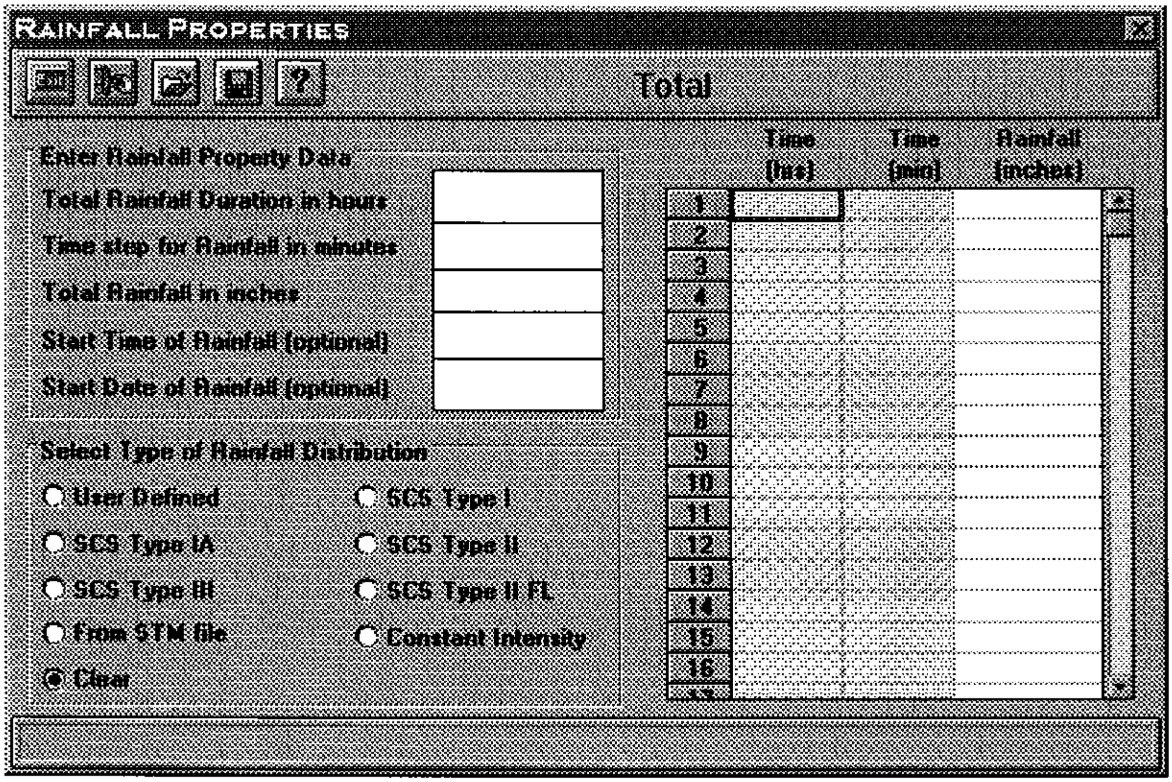
Horton Infiltration Calculator

The **Horton Infiltration Calculator** uses the Horton equation (in the form of infiltration rate as a function of cumulative infiltration as outlined in the theory section) to calculate infiltration rate. The infiltration rate is automatically calculated as the data are entered.



Rainfall

To enter rainfall data select the **Create/Edit Rainfall** option in the **Rainfall** menu. The "Rainfall Properties" dialog window will appear.



SMADA allows for two different methods of entering rainfall; by hand and using dimensionless curves (STM curves). The program comes with a number of dimensionless curves (or STM files) which must be accessible to the program to be used.

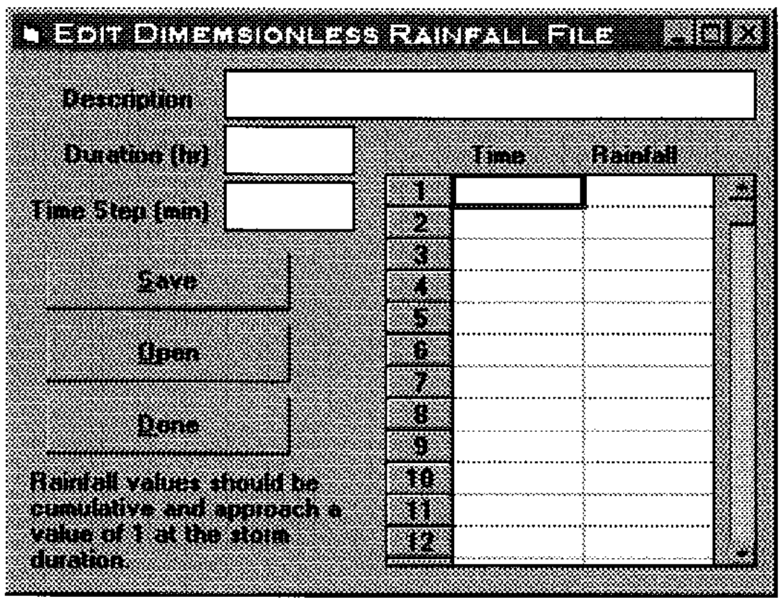
If SMADA cannot find the requested STM file for the generation of a rainfall, you will be prompted with a dialog where you can specify the location of this file. These curves allow the easy creation of storms which follow the dimensionless mass curves of the types;

SCS Type I	scsi.stm
SCS Type IA	scsia.stm
SCS Type II	scsii.stm
SCS Type III	scsiii.stm
SCS Type II Florida Modified	scsiifl.stm

Since dimensionless curve data are kept in external files (STM files), the user can specify any available dimensionless curves or create their own dimensionless curves.

SMADA has a routine to assist in the creation of these curves (or any text editor can be used).

To use SMADA's routine, select **Rainfall** from the main menu, then select **Create/Edit Dimensionless Rainfall**. Enter the required information in the dialog window shown below.



Description - identification of the type of rainfall file created/edited. For example, SCS Type II would be a description of the scsii.stm file.

Duration - storm duration for this rainfall file in hours.

Time Step - time step for this rainfall file in minutes.

Click on the first **Time** entry and SMADA will automatically enter your desired **Time Steps**. Enter in the **Rainfall** column the cumulative values which should equal one at the end of the storm's duration.

Save your dimensionless rainfall file before selecting the **Done** button.

If you desire to edit an existing dimensionless rainfall, select the **Open** button, then select the desired rainfall file to be edited.

If you wish to use a text editor, the file format for a dimensionless curve is:

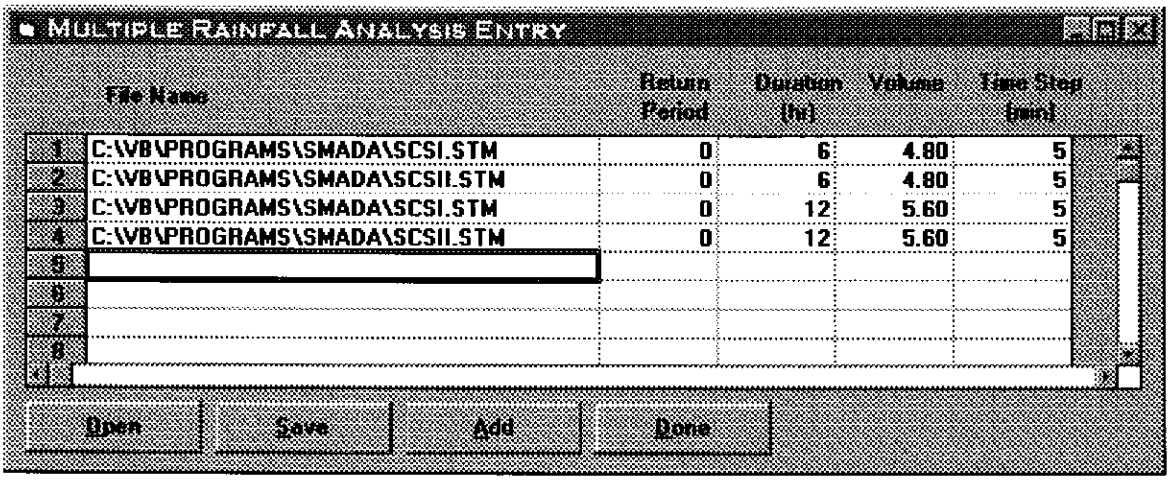
```
** Beginning of File **
SCS Type II Rainfall
24.0
0       0.000
0.25    0.002
0.5     0.005
0.75    0.008
1       0.011
1.25    0.014
1.5     0.017
1.75    0.02
2       0.023
2.25    0.026
2.5     0.029
2.75    0.032
3       0.035
3.25    0.038
3.5     0.041
3.75    0.044
4       0.048
4.25    0.052
4.5     0.056
4.75    0.06
5       0.064
5.25    0.068
5.5     0.072
5.75    0.076
6       0.08
6.25    0.085
6.5     0.09
6.75    0.095
7       0.1
7.25    0.105
7.5     0.11
7.75    0.115
8       0.12
8.25    0.126
8.5     0.133
8.75    0.14
9       0.147
9.25    0.155
9.5     0.163
9.75    0.172
10      0.181
10.25   0.191
10.5    0.203
10.75   0.218
11      0.236
11.25   0.257
11.5    0.283
11.75   0.387
12      0.663
12.25   0.707
12.5    0.735
12.75   0.758
13      0.776
13.25   0.791
13.5    0.804
13.75   0.815
14      0.825
14.25   0.834
14.5    0.842
14.75   0.849
15      0.856
15.25   0.863
15.5    0.869
15.75   0.875
16      0.881
16.25   0.887
16.5    0.893
16.75   0.898
17      0.903
17.25   0.908
17.5    0.913
17.75   0.918
18      0.922
18.25   0.926
18.5    0.93
18.75   0.934
19      0.938
19.25   0.942
19.5    0.946
19.75   0.95
20      0.953
20.25   0.956
20.5    0.959
20.75   0.962
21      0.965
21.25   0.968
21.5    0.971
21.75   0.974
22      0.977
22.25   0.98
22.5    0.983
22.75   0.986
23      0.989
23.25   0.992
23.5    0.995
23.75   0.998
24      1
** End of File **
```

The first line contains text which describes the type of dimensionless curve. The second line of the file contains the length of time for the dimensionless curve. If the curve is dimensionless in both time and volume, this number would be 1.0.

The remaining lines of the file contain two numbers which can be separated by a space, a tab, or a comma - the first of these numbers is time and the second is cumulative precipitation.

The cumulative precipitation values should be dimensionless (range from one to 0). SMADA includes an editor which can be used to create dimensionless rainfall which is in the Rainfall menu.

SMADA also allows for the creation of what is called a **Multiple Rainfall File** (MRF File). This file will is used by the multiple hydrograph analysis and contains information about each of the rainfalls used in this analysis. SMADA includes a dialog window to assist in the creation of this MRF file.



An MRF file consists of a list of rainfall characteristics based on a dimensionless rainfall (STM) file. Each line of an MRF file contains the **File Name** (including path) of an STM, a **Return Period** (value optional), a **Rainfall Duration** (in hours), a **Rainfall Volume**, and a **Time Step** for rainfall (in minutes).

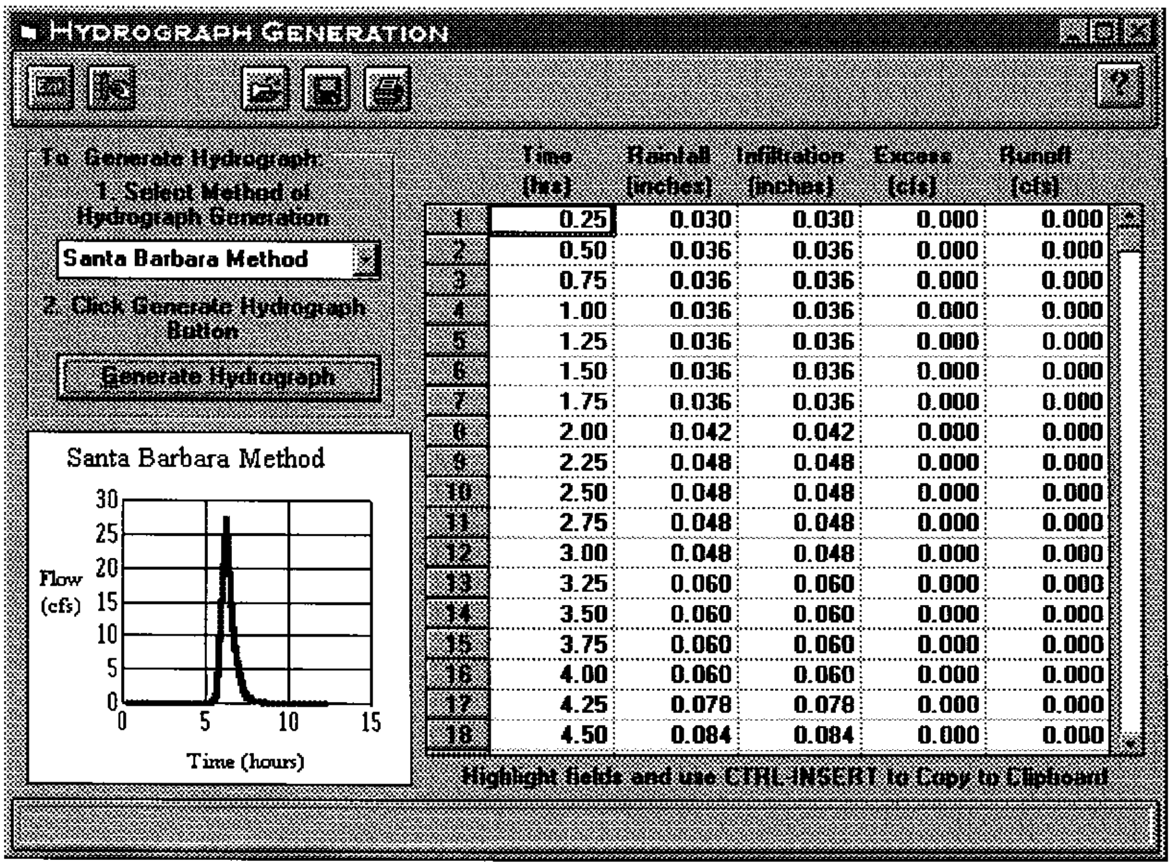
Each line of this file can be used to create a full rainfall for hydrograph generation. If you create an MRF file, it must be saved before exiting the dialog window. SMADA will not keep the contents of this file in active memory. The MRF file can be used in the **Multiple Hydrograph Analysis** dialog window.

The MRF file shown above has 0 for the entries of return period. This field is not used in the analysis and is only included for the purposes of bookkeeping.

Hydrographs

There are many options in the **Hydrograph** menu, but the most common will be the **Generate Watershed Hydrograph** option. This option allows for the generation of a hydrograph when both an active watershed and rainfall have been created or opened (from file). At this point the generation of a hydrograph is fairly simple.

1. Select **Generate Watershed Hydrograph** from the pull-down box.



2. Select the appropriate **Method of Hydrograph Generation**.
3. Click on the **Generate Hydrograph** button.

The hydrograph will be generated from the watershed and rainfall information and the results placed in the spreadsheet on the dialog window. A plot of the hydrograph will also appear in the lower left hand corner of the dialog window.

The spreadsheet contains 5 columns:

1. **Time** - the time in hours of the time step.

2. **Rainfall** - the incremental rainfall in inches for that time step.

3. **Infiltration** - the incremental infiltration for that time step as caluclated by the infiltration method selected in the **Watershed** dialog window

4. **Excess** - the rainfall excess for that time step converted to cfs, this is the difference in rainfall (P) and infiltration (F) divided by time step and multiplied by watershed area - with units converted to cfs.

5. **Runoff** - this is the runoff as determined by routing the excess using the selected hydrograph generation method (i.e. SCS 484 Method, Santa Barbara Method, ...).

If more analysis is required with these spreadsheet values, they can be easily copied and pasted into any Windows spreadsheet (or word processor).

To copy the values,

1. Use the mouse to highlight the section of the spreadsheet you wish to copy

2. Hit the Ctrl-Insert keys (you can also use Ctrl-C).

3. You can then paste it into the other application by using that application's paste sequence. The selection will paste as tab-delimited text.

* Hydrograph Generation Example Problem *

A hydrograph is required for the following watershed:

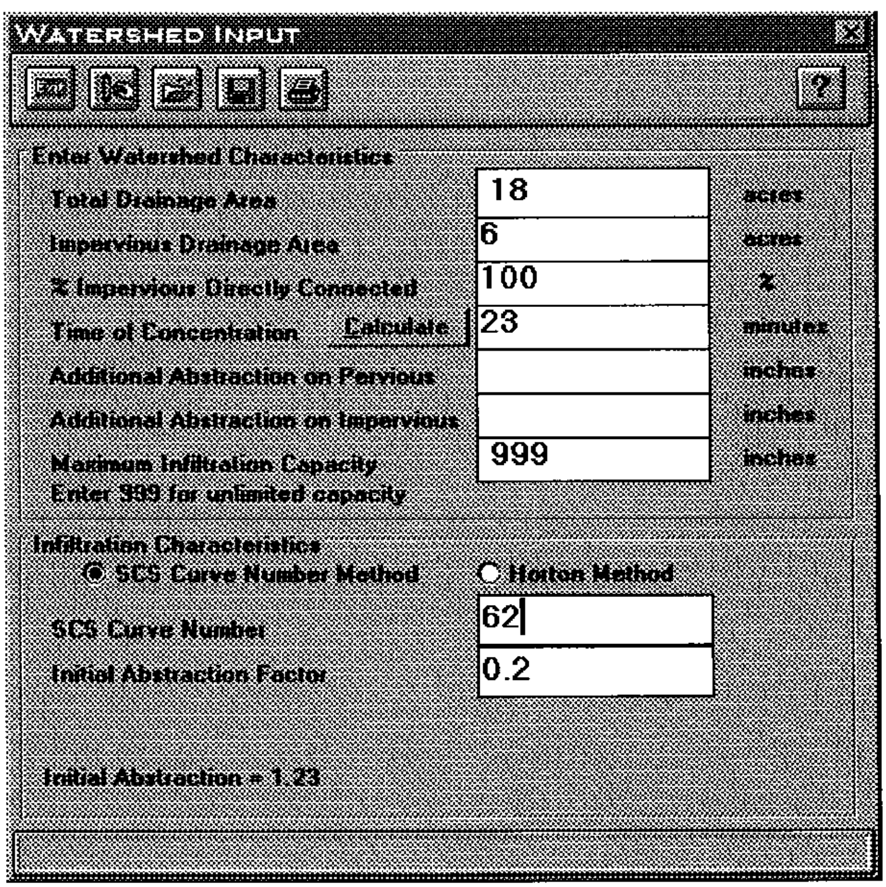
Total Area = 18.0 acres
Impervious Area = 6 acres (all directly connected)
Time of concentration = 23 minutes
Unlimited Infiltration Capacity
Based on soil types the pervious SCS curve number = 62

What is the peak runoff rate in response to an SCS Type II storm with a total volume of 6.4 inches and a duration of 24 hours?

Solution: The watershed can be modeled in one of two ways:

1. A composite curve number can be determined for the pervious and impervious areas
2. The watershed can be modeled by routing the pervious and impervious separately.
   (default for routing in SMADA)

Using the **Watershed, Create/Edit Watershed** option in the main menu, enter the information as shown below. Click the red Exit button in the upper left corner of the dialog window when you are finished entering the information.

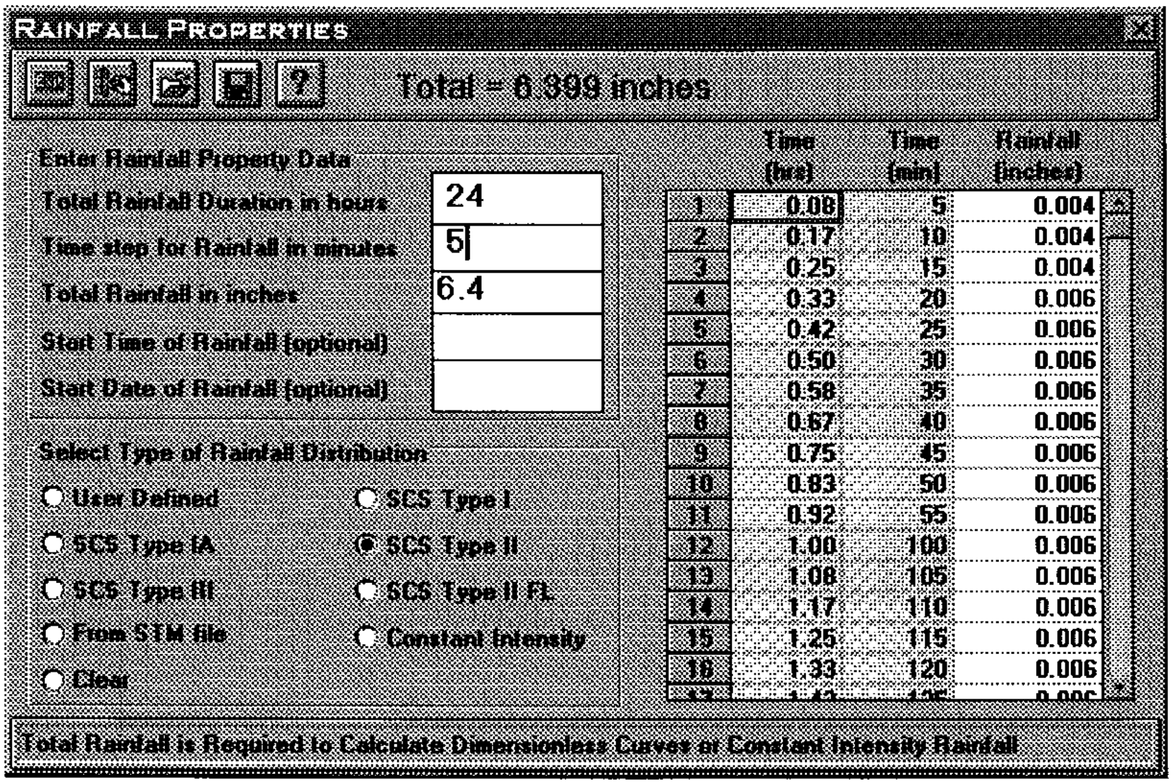


You must next create a rainfall for use in generating the hydrograph.

Use the **Rainfall, Create/Edit Rainfall** option in SMADA to create the rainfall file.

First you must select a **Time Step** for the rainfall. Since the time of concentration of the watershed is 23 minutes, a good choice of time step would be 5 minutes. The generated rainfall will have 12*24 (or 288) steps.

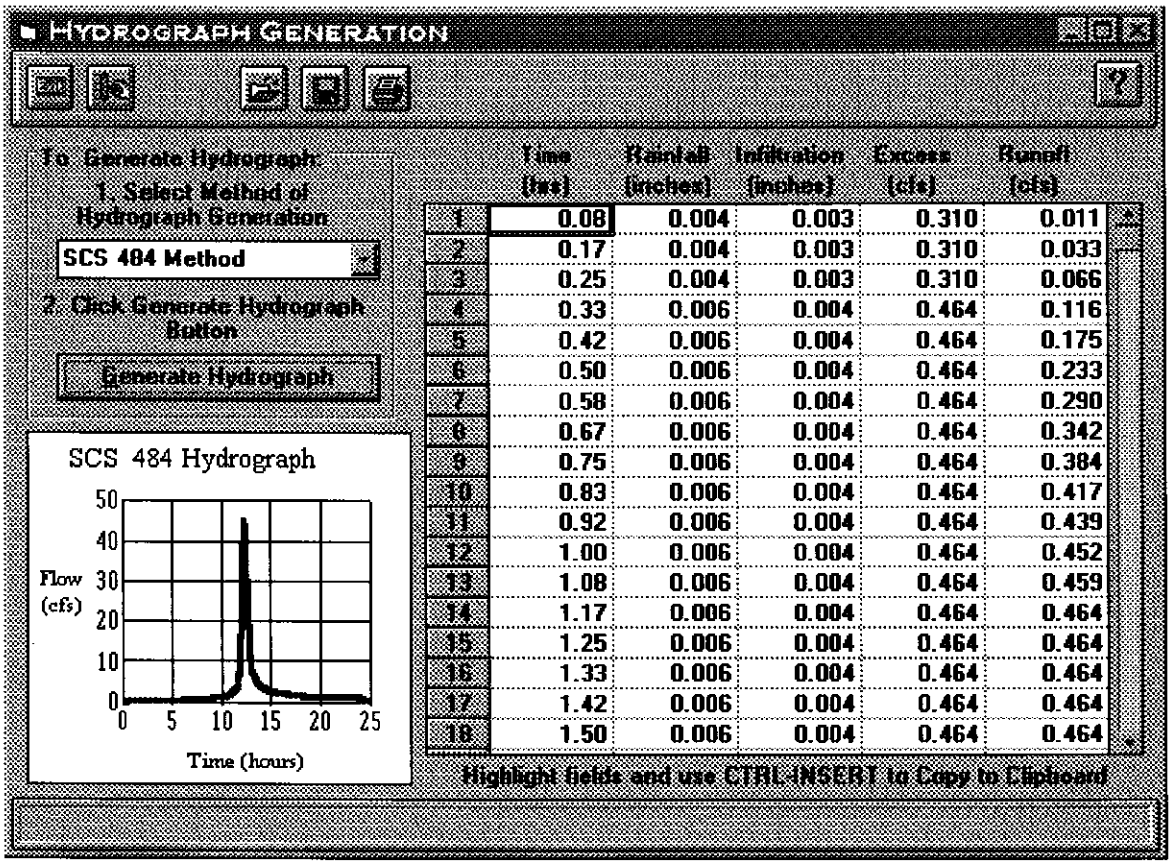
Click on the red Exit button when the information has been entered.



At this point you are ready to generate your hydrograph.

Use the **Generate Watershed Hydrograph** option from the **Hydrograph** pull-down menu. Without further information to aid in the selection of a hydrograph generation technique - select SCS 484 hydrograph.

After clicking on the **Generate Hydrograph** button, the dialog window shown below will appear.



	Time [hrs]	Rainfall [inches]	Infiltration [inches]	Excess [cfs]	Runoff [cfs]
1	0.08	0.004	0.003	0.310	0.011
2	0.17	0.004	0.003	0.310	0.033
3	0.25	0.004	0.003	0.310	0.066
4	0.33	0.006	0.004	0.464	0.116
5	0.42	0.006	0.004	0.464	0.175
6	0.50	0.006	0.004	0.464	0.233
7	0.58	0.006	0.004	0.464	0.290
8	0.67	0.006	0.004	0.464	0.342
9	0.75	0.006	0.004	0.464	0.384
10	0.83	0.006	0.004	0.464	0.417
11	0.92	0.006	0.004	0.464	0.439
12	1.00	0.006	0.004	0.464	0.452
13	1.08	0.006	0.004	0.464	0.459
14	1.17	0.006	0.004	0.464	0.464
15	1.25	0.006	0.004	0.464	0.464
16	1.33	0.006	0.004	0.464	0.464
17	1.42	0.006	0.004	0.464	0.464
18	1.50	0.006	0.004	0.464	0.464

You may wish to print the results of the hydrograph generation. You can access the print option from this dialog window by clicking on the printer button on the top toolbar. An abbreviated version of the printout is shown below:

Hydrograph Type :SCS 484 Hydrograph

Time (hr)	Time	Rain (in)	C Rain (in)	Infiltration (in)	Instant (cfs)	Outflow (cfs)
0.083	00005	0.004	0.004	0.003	0.310	0.011
0.167	00010	0.004	0.009	0.003	0.310	0.033
				:		
11.83	01150	0.589	3.066	0.251	73.607	13.194
11.91	01155	0.589	3.654	0.216	81.120	20.073
12.00	01200	0.589	4.243	0.188	87.180	28.816
12.08	01205	0.094	4.337	0.028	14.381	36.754
12.16	01210	0.094	4.431	0.027	14.503	42.746
12.25	01215	0.094	4.525	0.027	14.622	44.980
12.33	01220	0.060	4.585	0.017	9.364	42.892
12.41	01225	0.060	4.644	0.017	9.410	37.942
				:		
24.50	00030	0.000	6.400	0.000	0.000	0.295
24.58	00035	0.000	6.400	0.000	0.000	0.193
			6.400	2.688	3.711	3.710

Totals for Watershed in inches over 18.00 acres
Rational Coefficient = 0.580 Peak Flow (cfs) = 44.98

From this printout is possible to see that the peak runoff rate is 44.98 cfs and that it occured at 12.25 hours. You can also see the balance of precipitation (P), infiltration (F), and excess (R) in inches.

Note that the sum of infiltration and excess is 6.399 inches which matches very closely to the volume of precipitation which was 6.4 inches. Also note that 0.001 inches of volume were lost (due to roundoff) in the routing of the excess to runoff (3.711 inches vs. 3.710 inches).

*** End of Example Problem ***

The hydrograph portion of SMADA contains a number of useful menu options, in addition to Generate, Open, Save, Print, and Plot, these options are:

1. Add Hydrograph to Current (Hydrograph)
2. Unit Hydrograph
3. Multiple Hydrograph Analysis
4. Continuous Simulation Analysis

1. Add Hydrograph to Current Hydrograph

This option is most useful when more than one watershed hydrograph must be routed into a pond. SMADA has no option to explicitly handle multiple watersheds flowing to a single pond. These watershed can, however, be generated separately, summed and then routed to the pond.

To do this, the hydrograph(s) must first be saved as a hydrograph file. This can be done by using any one of these three methods:

1. Clicking the save button on the **Generate Hydrograph** dialog window.

2. Using the Save Hydrograph File option in the **Hydrograph** pull-down menu.

3. Using the Save, Hydrograph option in the **File** menu.

Save each hydrograph with a unique name. The hydrographs will automatically be given an HYD extension.

When the **Add Hydrograph to Current** option is selected, you will be prompted for the name of the hydrograph file you wish to add to the current hydrograph. The final runoff values from the selected hydrograph file will be added to the runoff values of your current hydrograph. If the hydrograph time steps are different - the numbers of the hydrograph being added will be adjusted to the time step of the current hydrograph.

2. Unit Hydrograph

The Unit Hydrograph sub-menu has three options: Open, Save, and Create/Edit a unit hydrograph. Notice that if you have already generated a hydrograph using the SCS method, there will already be numbers in this Create/Edit dialog window. This is because the SCS method generates a unit hydrograph based on the time of concentration of the watershed and the peak attenaution factor and uses this in the routing of the excess hydrograph to the runoff hydrograph.

Any unit hydrograph can be entered using this (the **Create/Edit Unit Hydrograph**) dialog window. The unit hydrograph must be unitless and will automatically be normalized (the sum of all values set to 1). A **Normalize** button is on the dialog window so that the user can explicitly see the effects of normalization on the numbers entered. If the entered unit hydrograph is truly unitless and normalized, there will be no effect.

These options allow for high flexibility in the routing using a user-specified unit hydrograph.

3. Multiple Hydrograph Analysis

This option is very useful if you must generate many hydrographs using the same watershed, but different rainfall files. This is best illustrated with an example.

*** Multiple Hydrograph Analysis Example ***

Regulations require you to generate hydrographs for the watershed of the previous example using a number of different rainfalls. Required are;

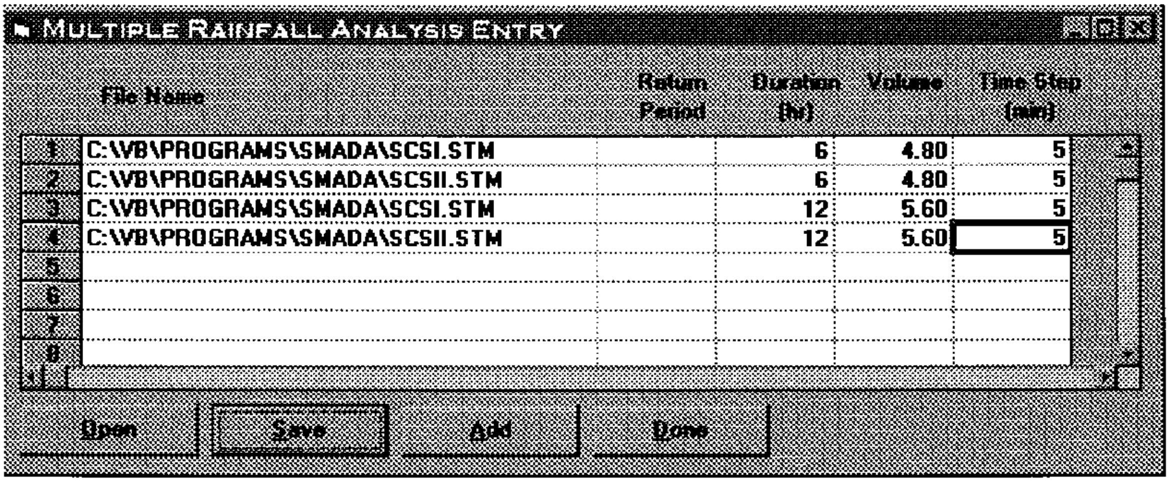
SCS Type I, 6 hour duration with a volume of 4.8 inches
SCS Type I, 12 hour duration with a volume of 5.6 inches
SCS Type II, 6 hour duration with a volume of 4.8 inches
SCS Type II, 12 hour duration with a volume of 5.6 inches

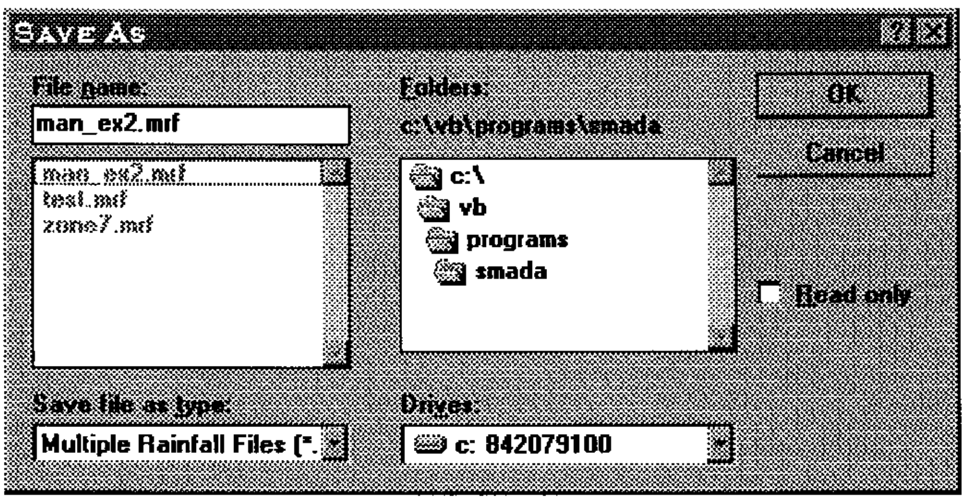
These four hydrographs could easily be generated separately using SMADA, however SMADA has the ability to do this all in a few steps.

The first step is the creation of an MRF or Multiple Rainfall File. This is accessible from the **Rainfall** menu. The rows of this dialog window can be entered by hand, but it is easiest to let SMADA automatically enter the data for you.

Click the **Add** button, and select the type of storm you require. The SCS Type I storm information is stored in an external file called scsi.stm (the SCS Type II storm is in scsii.stm).

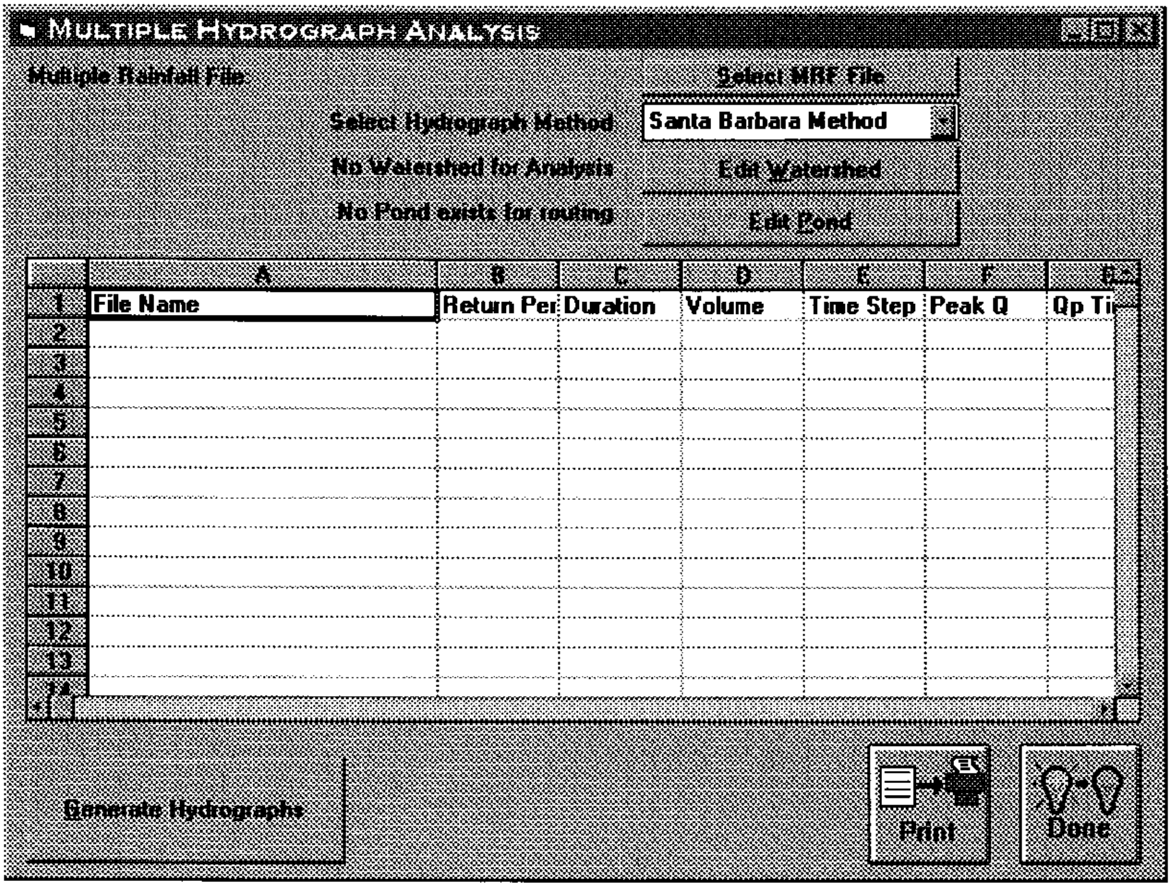
Click **Ok** and notice that the information is entered into the spreadsheet. For this example, you will want to change the time step to 5 minutes and the duration to 6 hours. Enter all the information as shown on the next page and save the file as man_ex2.mrf.





Once the MRF file has been created and saved, you will need to ensure that the watershed parameters have been entered. This is outlined in the previous Multiple Hydrograph Analysis example and will not be covered in this example.

At this point, select the **Multiple Hydrograph Analysis** option from the **Hydrograph** menu item.



In this dialog window, enter the required information by selecting the buttons *in order* as they appear on the dialog window:

1. Click on the **Select MRF File** button and identify the MRF file you wish to use (this is the one you just saved; man_ex2.mrf).

2. Next select from the **Select Hydrograph Method** pull-down combo box the hydrograph generation method you wish to use for the generation of all hydrographs in the analysis. (Selected for this example is the SCS 484 method).

If you have already entered the watershed information there will be no need to use the next button (**Edit Watershed**). If you wish to have all the hydrographs generated then routed through a pond, this can be done by opening a current pond file or creating a pond with the pond dialog window using **Edit Pond**. This will not be done in this example.

When all information is entered, click the **Generate Hydrographs** button and all the hydrographs will be generated and summary information will be put into the spreadsheet.

This information should appear as;

File Name	Return Period	Duration	Volume	Time Step	Peak Flow	Peak Time	Runoff Volume
C:\VB\PROGRAMS\SMADA\SCSI.STM	0.00	6.0	4.80	5.0	26.94	2.83	2.48
C:\VB\PROGRAMS\SMADA\SCSII.STM	0.00	6.0	4.80	5.0	43.29	3.33	2.48
C:\VB\PROGRAMS\SMADA\SCSI.STM	0.00	12.0	5.60	5.0	25.51	5.33	3.08
C:\VB\PROGRAMS\SMADA\SCSII.STM	0.00	12.0	5.60	5.0	45.25	6.33	3.08

You may wish more detail on any of the generated hydrographs. This information can be obtained by double clicking on any row of the spreadsheet.

For example, double click on the spreadsheet the **peak flow number for row 2** (43.29) and you will get a detailed hydrograph for the storm of that row. You can also print the contents of the spreadsheet by clicking the print button.

*** End of Multiple Hydrograph Analysis Example ***

4. Continuous Simulation Analysis

SMADA also allows for continuous simulation analysis. This analysis requires that the infiltration method used be Horton infiltration with a recovery coefficient.

To perform a continuous simulation in SMADA, you must first generate the rainfall files which will be used as the input to the continuous simulation analysis. This can be done with the **Rainfall Properties** editor by selecting **Rainfall, Create/Edit Rainfall**. The rainfall editor has two optional fields; **Start Time** and **Start Date**. These fields are required for performing a continuous simulation analysis. **Start Time** should be entered as a military time (e.g. 1 PM would be 1300). **Start Date** should be entered as MM/DD/YY format.

In continuous simulation the start date and start time are used to determine the amount of time until the next rainfall or the **interevent period**. Each rainfall in a continuous simulation must be saved to a separate file. These files are then listed by name in a separate file with a CSR extension (**C**ontinuous **S**imulation **R**ainfall File). If we desired to see the results of two consecutive days worth of rainfall, we could save the rainfall information of the first day in the file DAY1.RNF and the second day in DAY2.RNF. We would then need to make a CSR file with the contents;

```
***** BEGINNING OF FILE ********
c:\smada\day1.rnf
c:\smada\day2.rnf
****** END OF FILE ************
```

This CSR file can be created with any text editor. The contents of this file would serve as the input to the continuous simulation. Remember, the extension of this file should be **CSR**.

Continuous simulation analysis will be performed using the current watershed. Only watersheds using the Horton Infiltration Method with a recovery coefficient should be used for continuous simulation. The **Horton Recovery Coefficient** relates the speed at which the groundwater conditions will recover before the next rainfall event. An explanation of this coefficient is included in the detailed continuous simulation report included with this documentation.

Limitations of Continuous Simulation

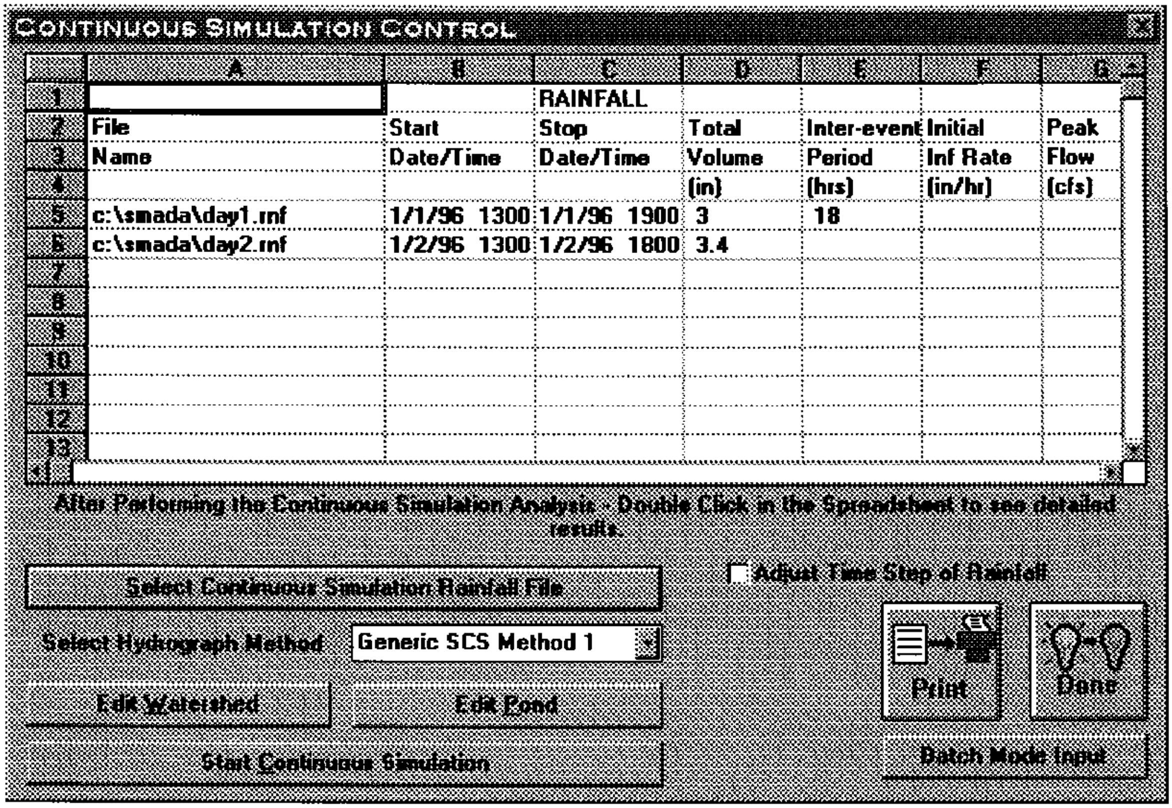
1. Continuous simulation is only valid with the Horton Infiltration Method with an entered recovery coefficient.

2. Continuous simulation will not be performed across separate years, for example storms which occur on December 31 will not be considered when performing hydrograph analysis for storms which occur on January 1 of the next year. Each year is considered separately.

3. No recovery is performed during dry periods <u>within</u> a rainfall file. Recovery is only calculated during the dry period between two separate rainfall files.

The **Continuous Simulation Control** window is available through the **Hydrograph, Continuous Simulation Analysis** menu. To perform a continuous simulation follow the steps as they are shown in the Continuous Simulation Control window.

1. Select a **CSR** file. This file must be prepared prior to the analysis. All the rainfall files that are listed in the CSR file must be in order and in the location (directory) specified by their file name in the CSR file. Once the CSR file has been selected, the spreadsheet in the continuous simulation control will display the name of each of the rainfall files, start time, start date, stop time, stop date, total volume of rainfall, and inter-event period for each rainfall.

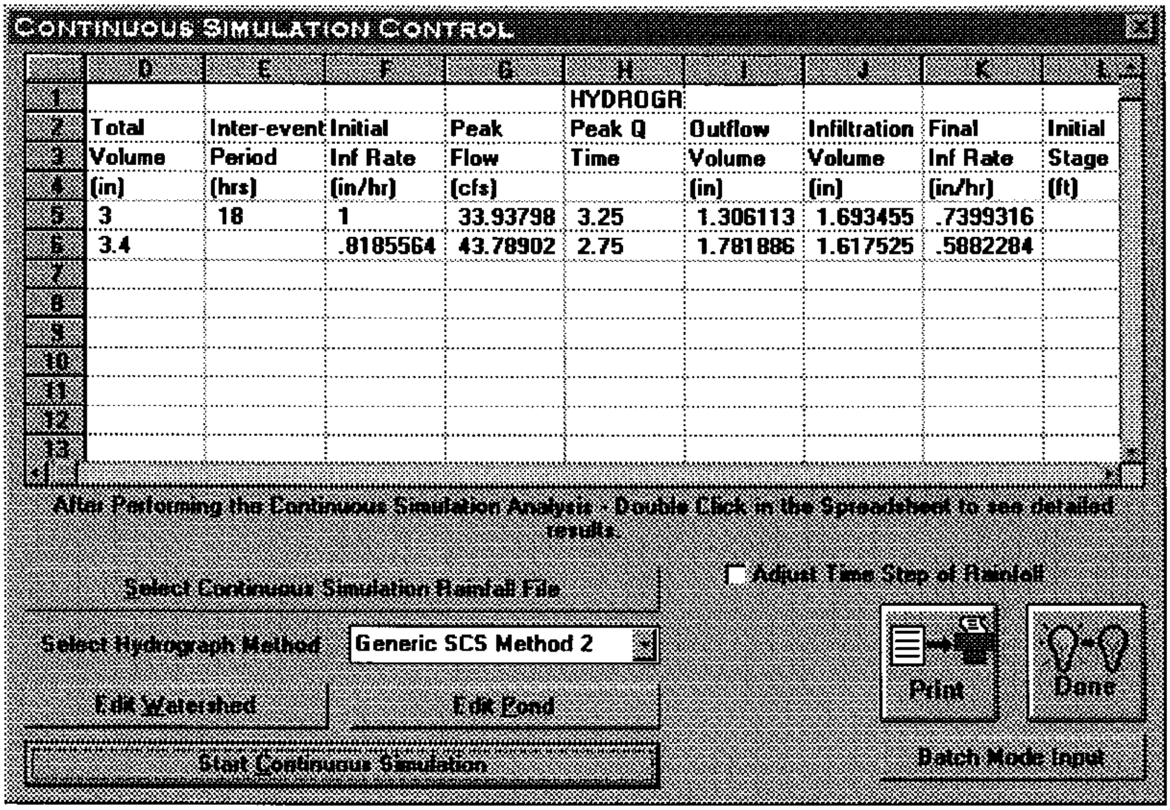


2. **Select Hydrograph Method** to be used for the generation of the hydrograph.

3. Enter (or edit current watershed) watershed information for the hydrograph generation. To access the watershed, click the **Edit Watershed** button.

4. If you wish to have the generated hydrographs routed through a pond, enter or edit the current pond information. This information is accessible through the **Edit Pond** button.

5. Click the **Start Continuous Simulation Analysis** button. The analysis will begin and values in the continuous simulation spreadsheet will be entered as they are calculated. After analysis is complete you can see a detailed report of any hydrograph by double clicking on the spreadsheet.



	D	E	F	G	H	I	J	K	L
1					HYDROGR				
2	Total	Inter-event	Initial	Peak	Peak Q	Outflow	Infiltration	Final	Initial
3	Volume	Period	Inf Rate	Flow	Time	Volume	Volume	Inf Rate	Stage
4	(in)	(hrs)	(in/hr)	(cfs)		(in)	(in)	(in/hr)	(ft)
5	3	18	1	33.93798	3.25	1.306113	1.693455	.7399316	
6	3.4		.8185564	43.78902	2.75	1.781886	1.617525	.5882284	
7									
8									
9									
10									
11									
12									
13									

Information which will be presented in the continuous simulation spreadsheet includes;

Infiltration Rate - This is the initial infiltration rate at the start of the storm. For the first storm in the analysis and any fully recovered storms, this value should be equal to the Horton initial infiltration rate. For storms which are not fully recovered, this value will be between the initial infiltration rate and the limiting infiltration rate.

Peak Flow - This is the peak flow for each of the generated hydrographs in the analysis.

Peak Flow Time - The time at which this peak flow occurred.

Outflow Volume - The total volume of the hydrograph runoff (in inches over watershed area).

Infiltration Volume - The total volume of infiltration which occurred in the hydrograph in inches over watershed area.

Final Infiltration Rate - The infiltration rate at the end of the rainfall excess. This rate will be recovered (fully or partially) before the next storm.

Initial Stage (POND ONLY) - The initial stage in the pond at the beginning of the storm.

Peak Stage (POND ONLY) - The peak stage which occurred during the storm.

Peak Flow (POND ONLY) - The peak flow from the pond during the storm.

Continuous Simulation Options

Adjust Time Step of Rainfall - To prevent numerical instability it is sometimes advantageous to adjust the rainfall time step (and therefore the hydrograph generation time step) to a lower number. This option will adjust this time step if the rainfall time step is greater the 50% of the watershed time of concentration. The time step will be adjusted to 1/3 of the time of concentration and the rainfall values will be adjusted accordingly.

Batch Mode Input - This advanced feature allows for the routing of multpile CSR files in the same run. The Continuous Simulation Batch (CSB) file is a file which contains the listing of all the CSR files and watersheds which are to be run. The continuous simulation batch file contains rows which each include the file name of the CSR file and the watershed file to be used in the analysis (separated by a comma). The CSR file and the watershed will be loaded into the computer. The full continuous simulation analysis run, and all output saved in a file. You will be prompted for the name of this output file before starting the CSB analysis.

Ponds

SMADA has the ability to perform complex routing using a stage-storage-discharge (SSD) relationship and inventory routing. The basis of this routing is the definition of a pond using a stage-storage-discharge relationship. Many of the steps involved with this are simplified using SMADA. The theory section of this manual has a more detailed discussion of inventory routing using a stage-storage-discharge relationship.

Stage - Elevation of a water level in the pond. This can be an imaginary level in the case of a SSD relationship (i.e. if the stage were 100 ft, the storage would be 2.5 acre-feet).
Storage - the amount of water stored in the pond at a given stage.
Discharge - the flowrate of water from the pond at a given stage.

NOTE: The SSD relationship often includes area, which is the surface area of water in the pond at a given stage.

SMADA has a lot of tools to assist the engineer in the creation of the SSD relationship. These tools are useful in getting a rough idea for the primary pond shape to meet the flood control objectives, which can later be refined. These tools are accessible from the **Pond, Create/Edit Pond Design** menu.

To use this dialog, the stage values must first be entered, from this point the storage and discharge values can also be entered or calculated using the area, storage, and discharge calculations tools.

Pond design is illustrated in an example.

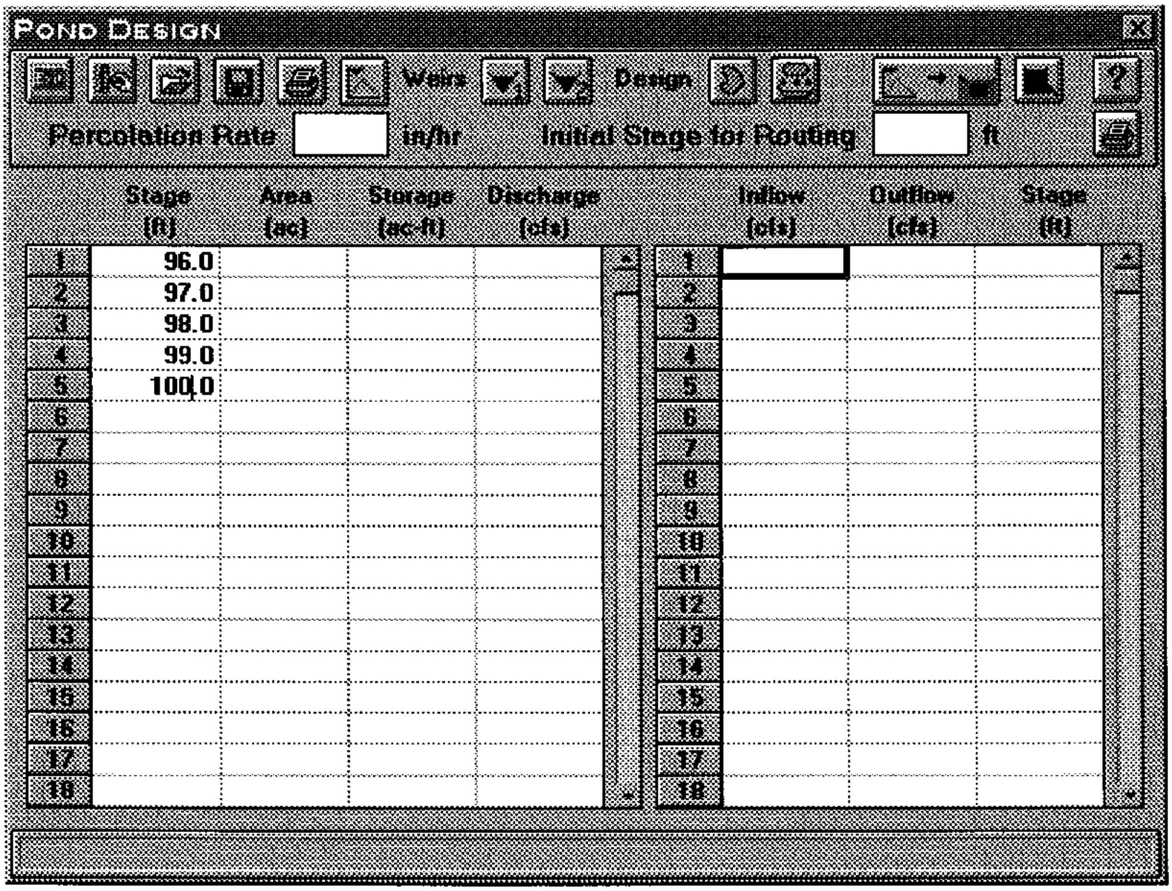
*** Pond Design and Routing Example ***

Problem statement:

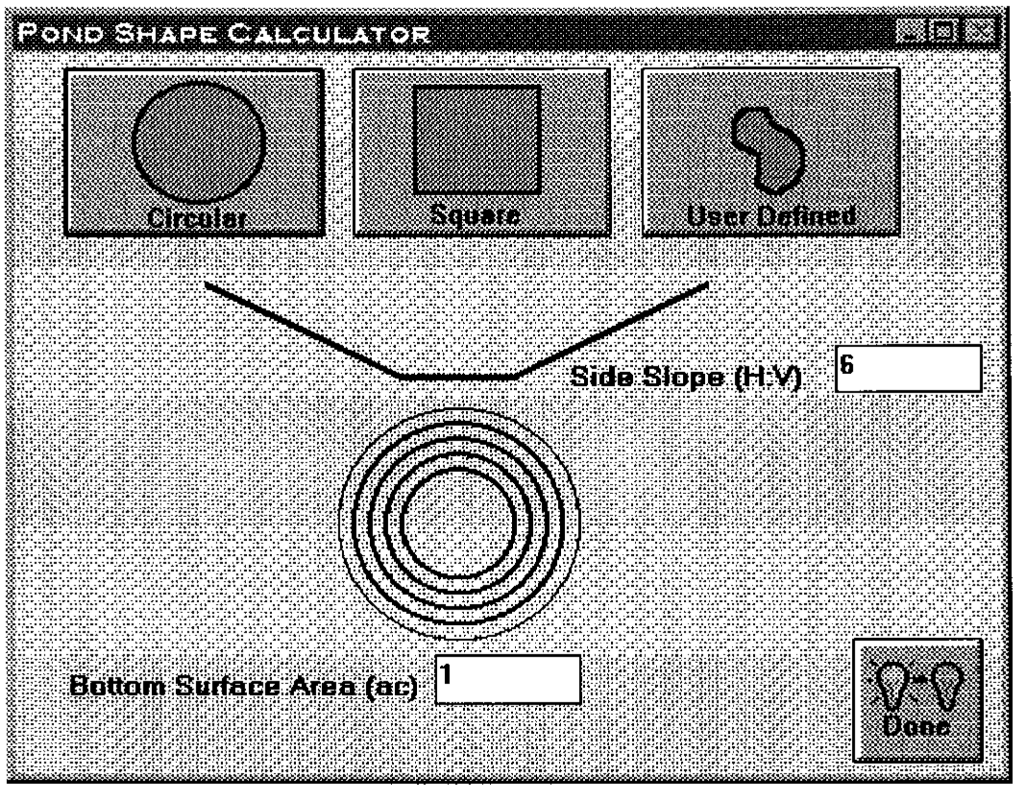
The hydrograph generated in the Hydrograph Generation Example should be routed through a pond which should reduce the peak flow by at least 50%. The ground elevation will be 100 feet and the groundwater elevation will be at 96 feet. This gives 4 feet of usable storage.

Problem solution:

Using rough engineering judgment, a circular pond with a bottom area of 1 acre and 6:1 side slopes should provide sufficient storage. Open the **Pond, Create/Edit Pond Design** window and enter the stages values of 96, 97, 98, 99, 100.



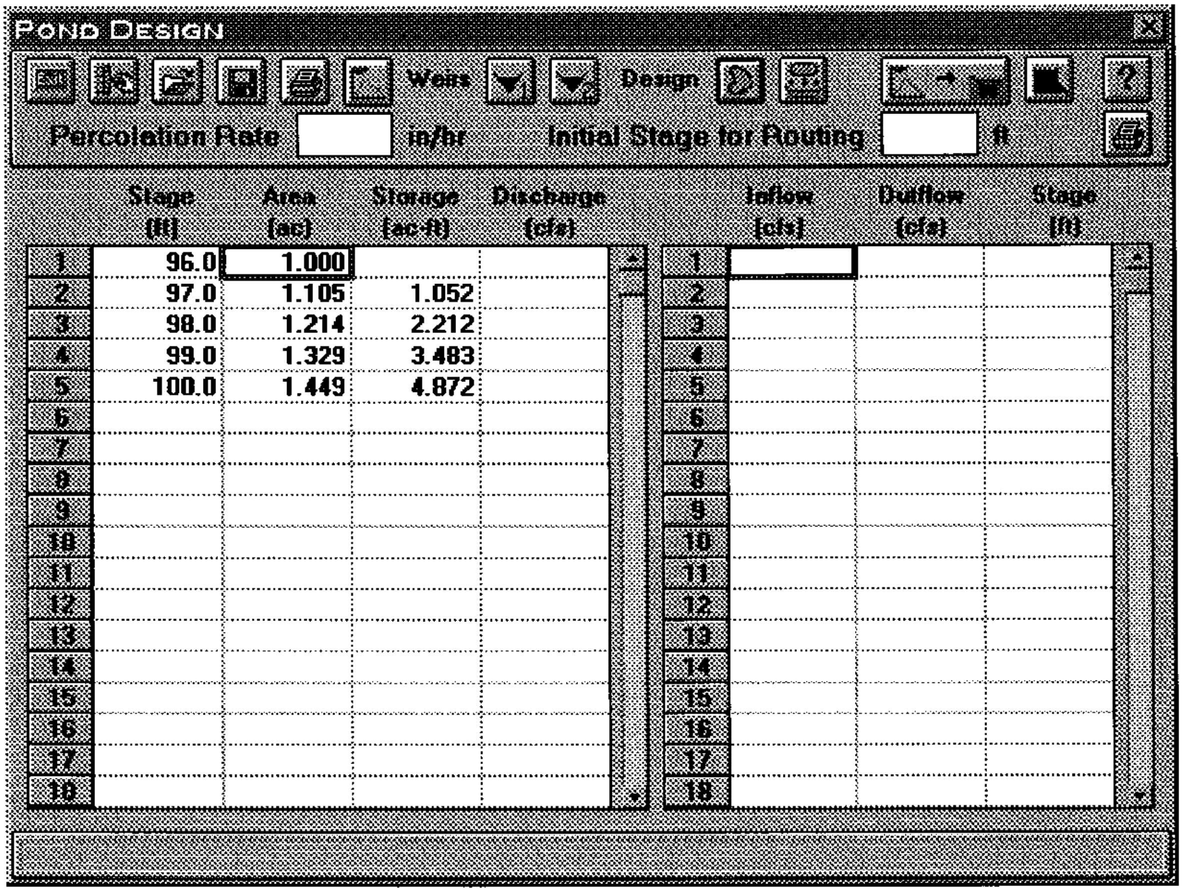
Next click on the Pond Shape parameters button  which will bring up the **Pond Shape Calculator** dialog window.



The pond side slope can be set to 6:1, the bottom surface area set to 1 acre, and the shape set to circular.

Click **Done** and you will return to the **Pond Design** dialog window.

Note that the **Area** and **Storage** columns of the stage-storage-discharge spreadsheet now have values filled in.

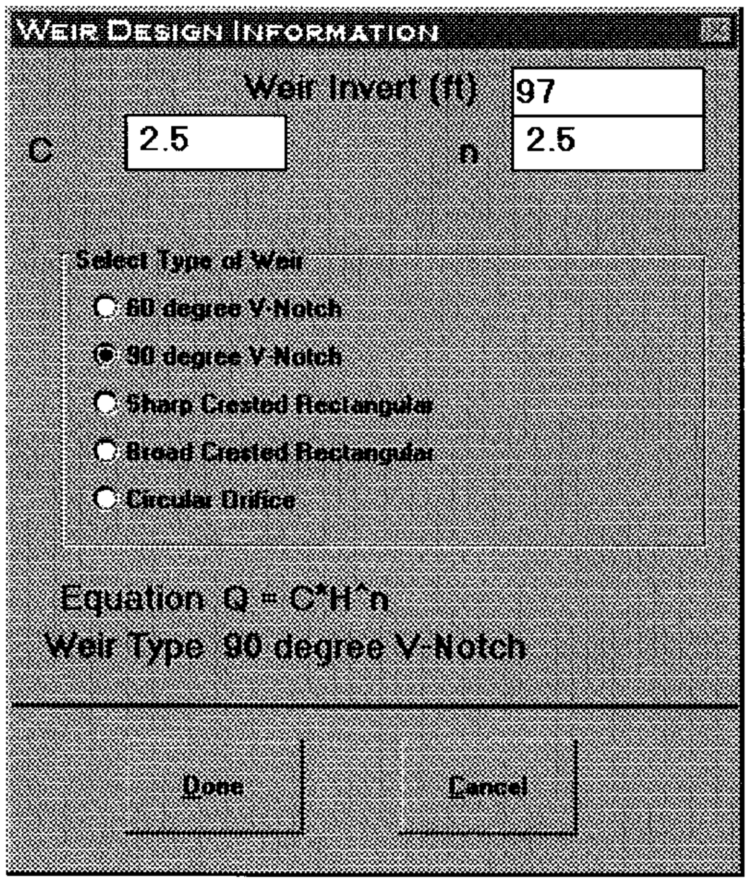


Once the **Stage**, **Area**, and **Storage** have been calculated the **Discharge** can be set. We can start by placing a weir at 97 feet. This will give us a storage of 1.052 ac-ft before any discharge occurs.

SMADA will automatically calculate up to 2 weirs on a pond.

Weirs can be placed by clicking the **Weirs** button .

The **Weir Design Information** dialog window will calculate the discharge and place it in the Discharge column of the spreadsheet.

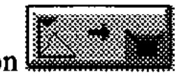


By starting with a single 90 degree V-notch weir placed at a stage of 97 feet, we will get the full SSD relationship as shown. When the **Done** button is clicked, the **Discharge** column of the stage-storage-discharge spreadsheet will be filled in.

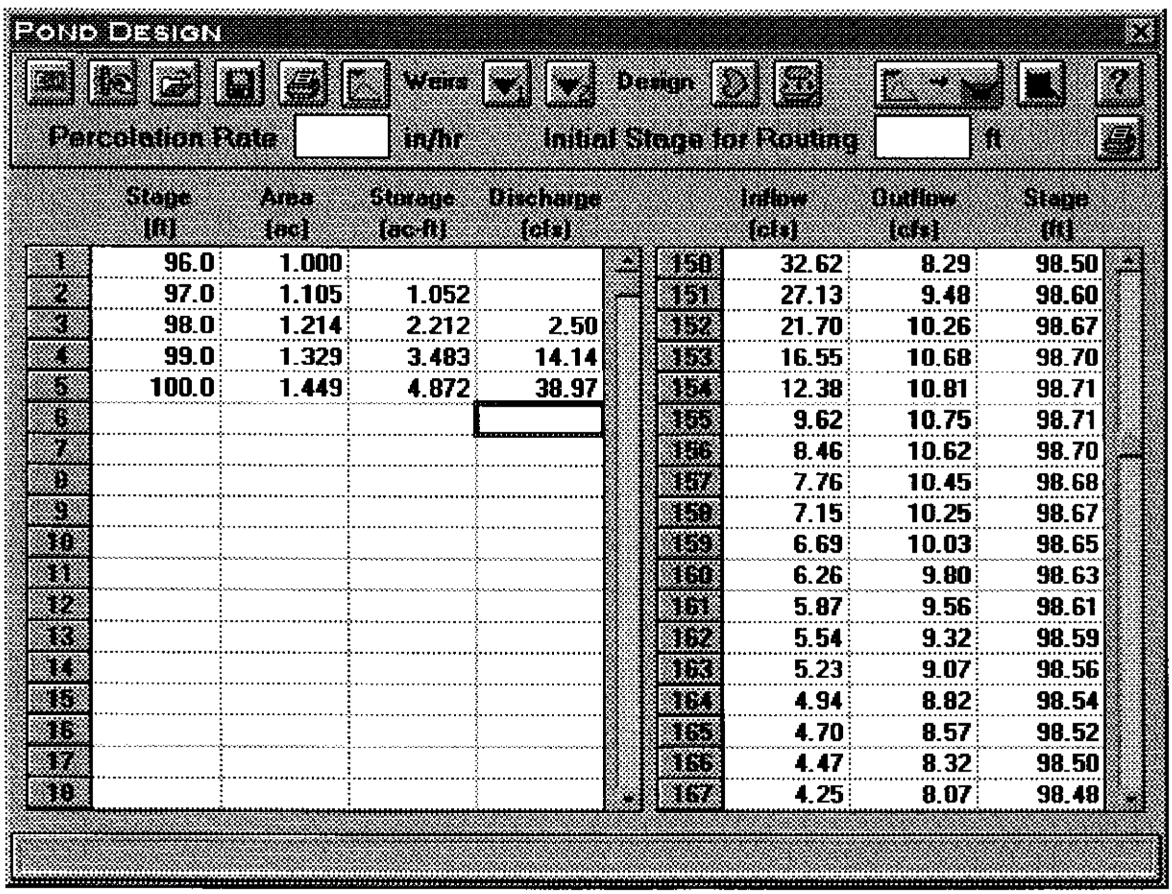
Stage (ft)	Area (acres)	Storage (ac-ft)	Discharge (cfs)
96.0	1.000		
97.0	1.105	1.052	
98.0	1.214	2.212	2.50
99.0	1.329	3.483	14.14
100.0	1.449	4.872	38.97

Enter a **Percolation Rate** in inches/hour if your design includes percolation. This example problem does not include percolation.

Enter an Initial Stage for Routing in feet if you want SMADA to start the routing process at an elevation other than the bottom of the pond.

Click the **Route the Current Hydrograph to the Pond** button 
to route the current hydrograph through the pond.

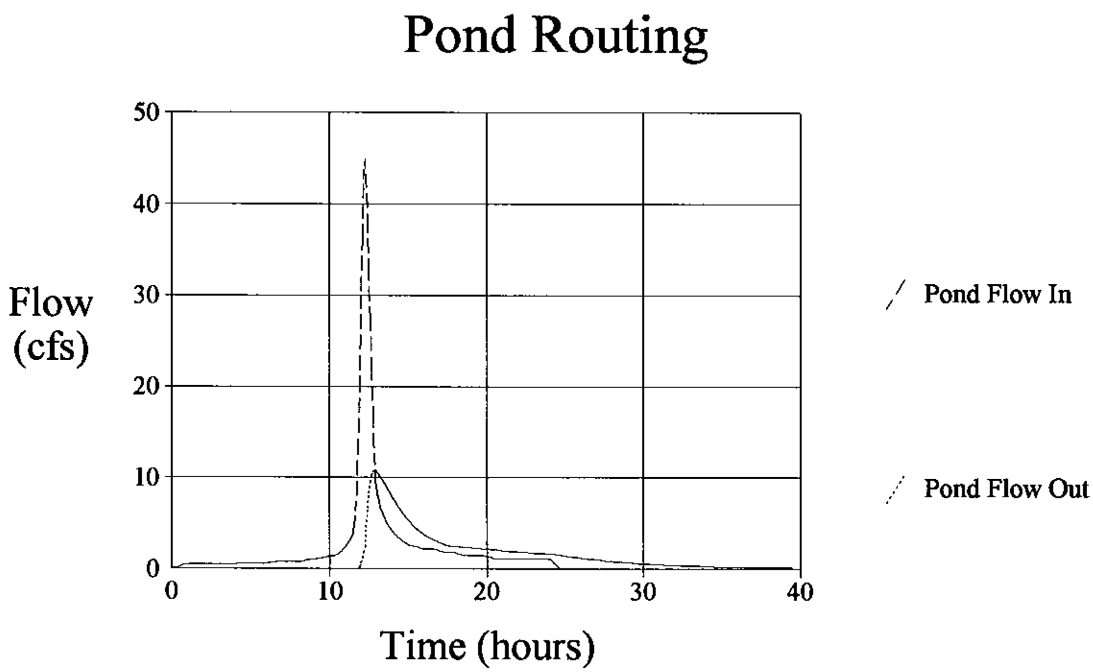
Once the routing is complete, the **Inflow**, **Outflow**, and **Stage** values on the right side of the spreadsheet will be filled in.



	Stage [ft]	Area [ac]	Storage [ac-ft]	Discharge [cfs]		Inflow [cfs]	Outflow [cfs]	Stage [ft]
1	96.0	1.000			150	32.62	8.29	98.50
2	97.0	1.105	1.052		151	27.13	9.48	98.60
3	98.0	1.214	2.212	2.50	152	21.70	10.26	98.67
4	99.0	1.329	3.483	14.14	153	16.55	10.68	98.70
5	100.0	1.449	4.872	38.97	154	12.38	10.81	98.71
6					155	9.62	10.75	98.71
7					156	8.46	10.62	98.70
8					157	7.76	10.45	98.68
9					158	7.15	10.25	98.67
10					159	6.69	10.03	98.65
11					160	6.26	9.80	98.63
12					161	5.87	9.56	98.61
13					162	5.54	9.32	98.59
14					163	5.23	9.07	98.56
15					164	4.94	8.82	98.54
16					165	4.70	8.57	98.52
17					166	4.47	8.32	98.50
18					167	4.25	8.07	98.48

Click the **Plot Pond Routing Information** button  to plot the pond routing.

Pond routing can also be plotted from the main menu using the **Pond, Plot Pond Routing** menu option.



Note that the peak flow into the pond is about 45 cfs, and that the peak has been reduced to about 12 cfs. This meets the objectives of at least a 50% decrease in the peak flowrate.

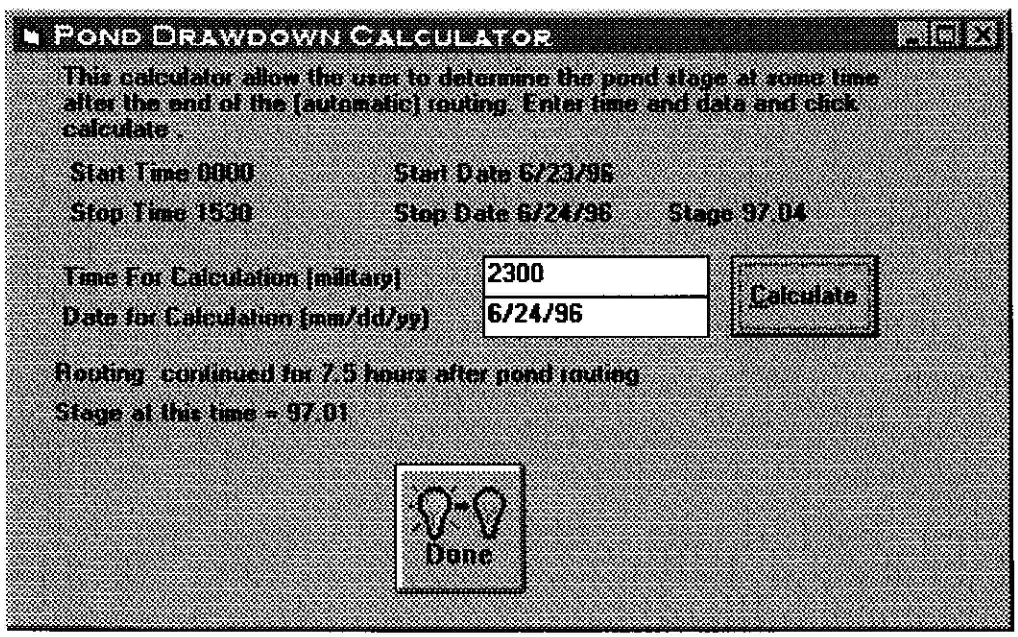
*** End of Pond Design and Routing Example ***

The routing also allows for the calculation of the pond stage at any time past the plotted (and printed) routing time.

Use the **Calculate drawdown at different times after routing** tool to calculate this stage.

This tool can be extremely useful if a pond elevation is required when using a drawdown device such as a weir to draw down the pond over the course of days.

An example of the use of this calculator for the previous **Pond Design and Routing Example** problem is shown below.



Routing Flow Values through a Pond

SMADA can route values other than generated hydrographs through a pond. This option is accessible through the **Pond, Route External File through Pond** menu.

This option requires an external file which contains an array of flow values in cfs. No other information should be included in this file. The option will prompt for name of the file containing the flow values, time step, and initial stage for routing. The flow values will then be routed through the pond.

*** External File Routing Example ***

The following flow data have been collected from a channel during a storm event.

Time (hr)	Flow (cfs)
0.0	0
0.5	10.0
1.0	18.0
1.5	24.0
2.0	12.0
2.5	6.0
3.0	0.0

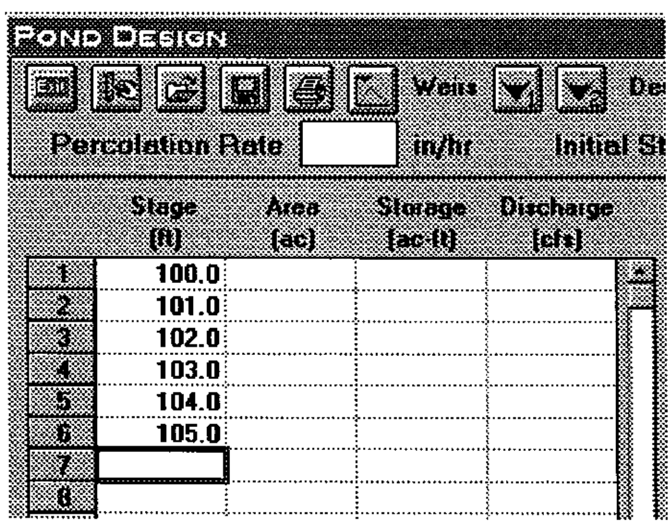
To reduce the peak flow the flow is diverted into a basin with a surface area of 0.25 acres and vertical sides. A 60° V-notch weir controls the flow through this basin and the weir invert is placed at the bottom of the basin. What effect will this basin have on the peak flow and how deep must the basin be for these flow values?

Solution:

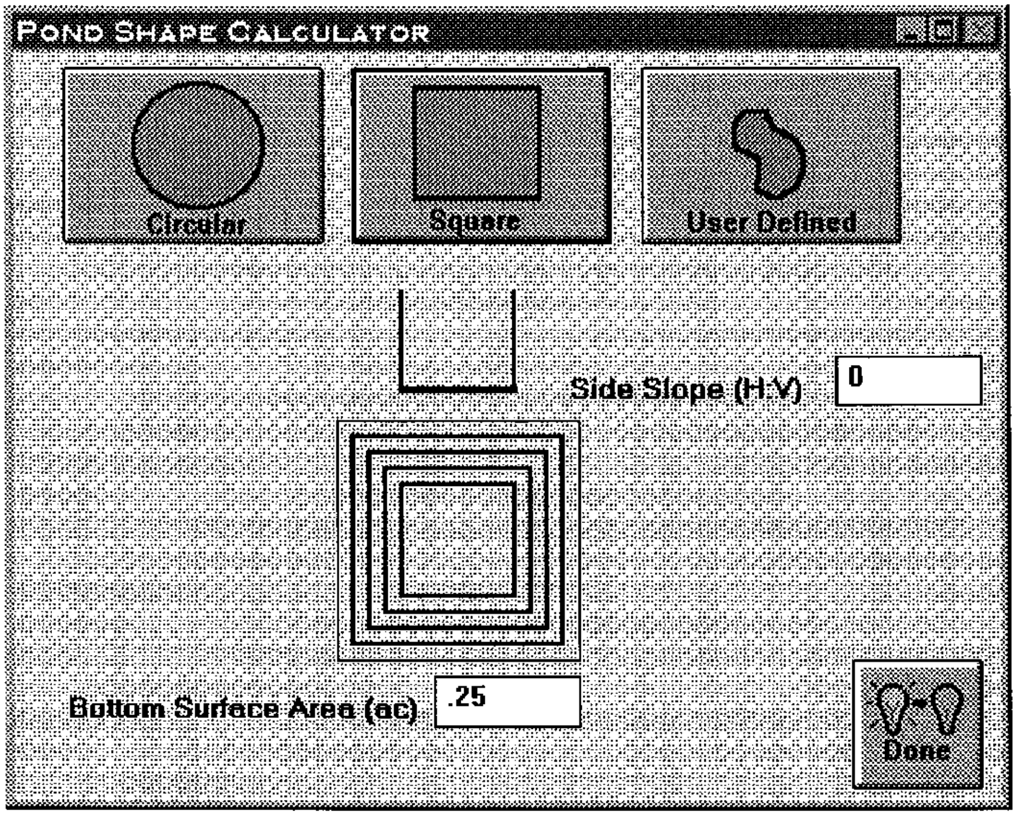
Using any text editor (Notepad, etc..) the flow values can be saved into an external file. The file should be saved in ASCII format. For this example the file will be saved with the name DATA.TXT.

```
** BEGINNING OF FILE **
0
10
18
24
12
6
** END OF FILE **
```

We must next create the pond design. Use the **Pond, Create/Edit Pond Design** options from the main menu in SMADA. Assume an invert elevation (100) and enter sufficient stage values in the **Pond Design** dialog window.



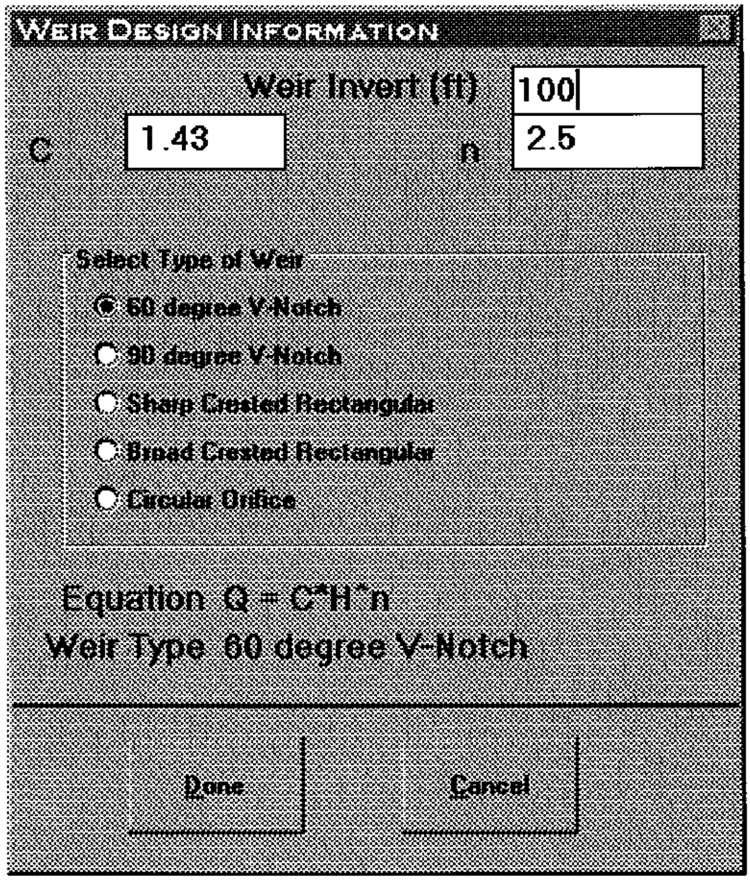
The **Edit Pond Shape Parameters** button can be used to enter information about the actual pond shape. The pond will have a side slope of 0 and a bottom area of 0.25 acres.



Click **Done** when the information is entered.

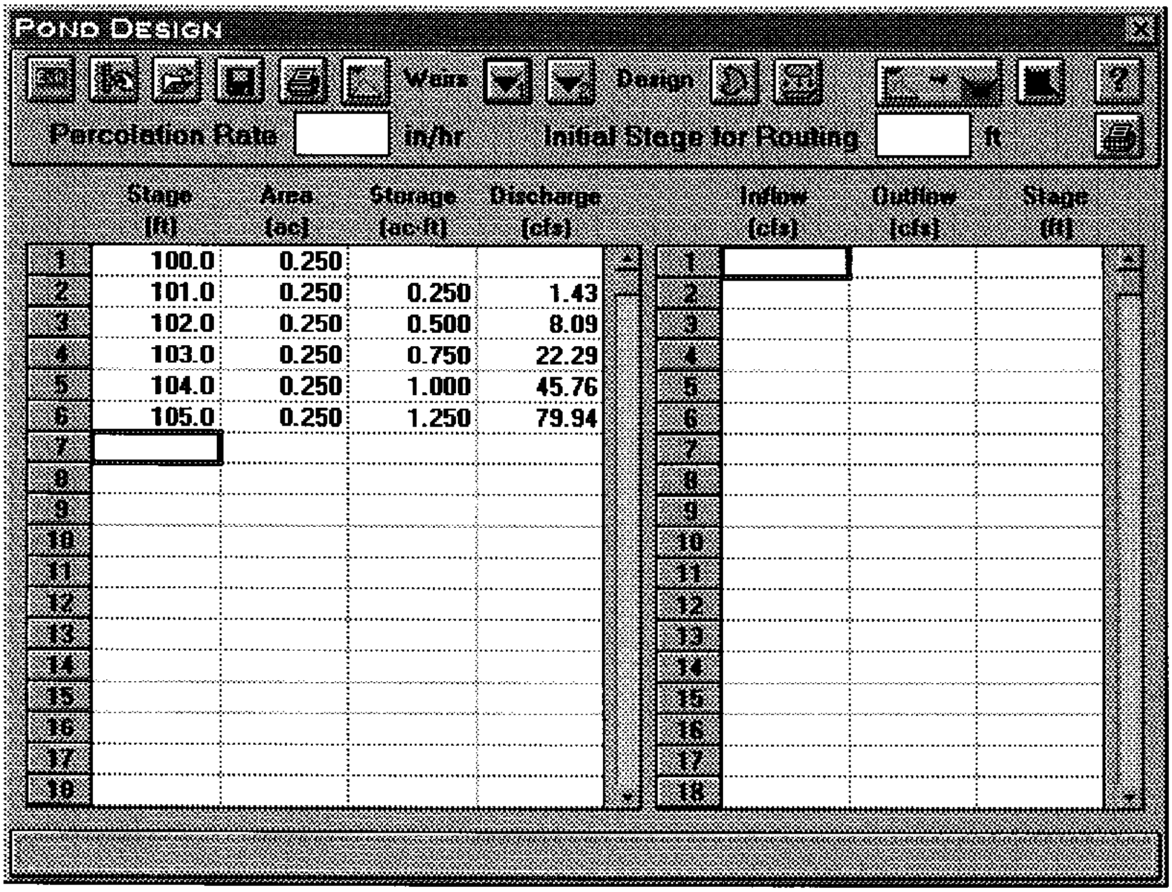
The **Area**, and **Storage** columns of the spreadsheet in the **Pond Design** dialog window will be entered.

Next use the **Weirs** button to enter a 60° V-Notch Weir into the Pond Design.



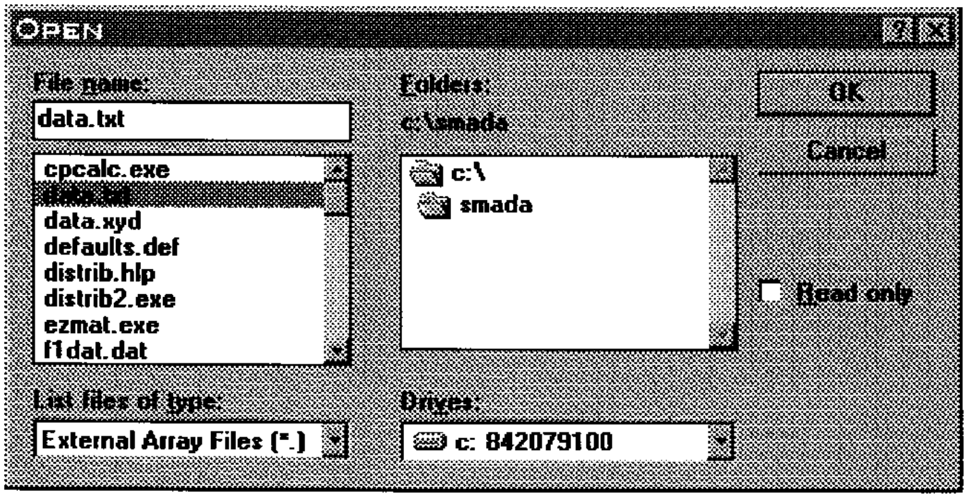
Click **Done** when the information is entered.

The **Pond Design** dialog window will now have a complete Stage-Storage-Discharge relationship.



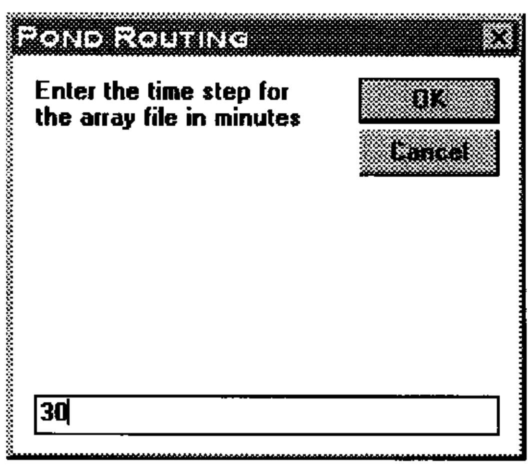
Click the **Exit** button.

From the main SMADA window use the menu option **Pond, Route External File through Pond**. Select the file which contains the saved flow data.



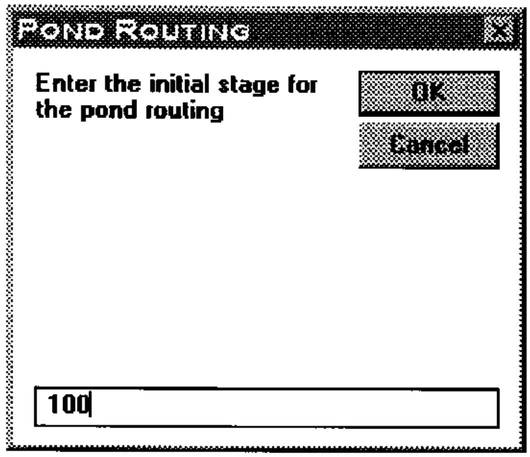
After clicking **OK** you will be prompted for the time step of the flow data.

Enter the time step in minutes.



Click **OK** when finished.

The last window will ask you for the initial stage for the routing. Use an initial stage of 100 (pond empty).



After clicking **OK** the routing will be performed.

You can view the results of the routing using either the **Pond, View/Print Pond Routing** option or the **Pond, Plot Pond Routing** option of the main menu.

The first 8 hours of the pond routing are shown here;

Time (hr)	Inflow (cfs)	Outflow (cfs)	Stage (ft)
0.50	0.00	0.00	100.00
1.00	10.00	3.63	101.33
1.50	18.00	16.13	102.57
2.00	24.00	23.69	103.06
2.50	12.00	12.99	102.35
3.00	6.00	7.22	101.87
3.50	0.00	2.48	101.16
4.00	0.00	1.26	100.88
4.50	0.00	0.99	100.69
5.00	0.00	0.78	100.55
5.50	0.00	0.61	100.43
6.00	0.00	0.48	100.34
6.50	0.00	0.38	100.27
7.00	0.00	0.30	100.21
7.50	0.00	0.24	100.17
8.00	0.00	0.19	100.13

From this output we can see that the maximum outflow is not decreased significantly (23.69 cfs vs 24.0 cfs), and that the pond stage peaks at 103.06 or 3.06 ft above the bottom.

*** End of External File Routing Example ***

Percolation in a Pond

The pond analysis and design allows for the entry of a constant percolation rate. The volume of water percolated (for each time step) in the routing is calculated as the product of this rate and the pond bottom area. The pond area will vary during the analysis and is calculated from the stage-area-storage-discharge relationship based on the pond stage for each step.