MODRET 7.0 HELP

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What's new in Version 7?

MODRET 7.0

The new MODRET, Version 7.0 program was fully integrated into the latest Microsoft Windows Environment. Similar to previous versions, the model is capable of generating runoff hydrographs by various methods, and for default or user specified rainfall distribution data. However, for this version, a manually created hydrograph (i.e., slug load hydrograph or non-conforming hydrograph) option was added to allow flexibility to model unusual runoff conditions. Also, an option to create a back to back storm hydrographs was added to allow modeling of ponds assuming back to back storm events. In addition, the model now has an option to add discharge from an upstream pond to a downstream hydrograph. For FDOT pond analysis, the **hydrograph module** now allows generation of batch runoff hydrographs for a series of FDOT rainfall distributions. This allows to conduct infiltration analyses by selecting the batch hydrographs and allowing the model to run the series automatically. The manual input of runoff in the Infiltration Module has been eliminated to simplify data entry.

The **Infiltration module** has been changed to enter a stage-area table and allow the model to calculate the average pond area and effective pond volume. This eliminates erroneous entry of pond data and allows automatic routing of the inflow and infiltration for every model run. **The routing module** in this version has been eliminated and the routing was integrated into the infiltration module for automatic routing. The routing has been further improved to extend the routing time beyond the storm event as specified by the user. The routing in the infiltration module now allows determination of peak discharge rates and peak water elevation in the ponds, using runoff, infiltration and stage-storage data every time the infiltration module is executed. The model generates discharge hydrographs, as wells as a number of cumulative hydrographs, such as runoff volume, infiltration volume, stage. Graphic presentation of all hydrographs and modeling results are provided. The MODFLOW model is a modified version that allows weir flow and orifice flow from retention ponds. A brief description of the three modules of MODRET follows:

Hydrograph: This module allows generation of stormwater runoff hydrograph using the SCS Unit Hydrograph, the Rational Hydrograph, and the Santa Barbara Urban Hydrograph and the Manual Runoff Volume methods. The rainfall distribution data are selected from a list of 21 options, of which 19 are fixed distributions (selected SCS, FDOT and other Florida distributions) and the last two (2) are **changeable** distribution options, which can be specified by the user. The limitations of this module are that it can only generate a runoff hydrograph for a single watershed. However, the Infiltration module for this version was developed to accept runoff hydrograph from other models, such as AdICPR™, SMADA, CHAN or other similar commercially available models. The format of the runoff hydrograph is very simple (text format) and can be adapted from various sources. The changes/additions in this version include:

1. The generation of batch hydrographs for the FDOT series. These are 8 sets of rainfall distributions that often used in Florida to evaluate the controlling rainfall distribution for a particular pond system. This allows selection of the series to create 8 hydrographs and then run them through infiltration module and review the results of all 8 sets without having to model each one individually.

2. An option to create a back to back runoff hydrograph with a specified period between the storms. This option was added to create a hydrograph for 100-year storm events where recovery of the first storm can not be achieved within the specified period of time. In such cases, the back to back storms are used to assess if the second storm event

can be retained within the pond after the specified recovery period.

3. An option to add a discharge hydrograph from an upstream pond to the runoff hydrograph of the downstream pond. This option was added to allow modeling of multiple ponds in series by adding the discharge from one pond to the next.

4. A manual input option to create a slug load hydrograph or a non-conforming runoff hydrograph was added. This allows creation of a single slug load hydrograph that can be used to model recovery of the pollution abatement volume. Alternatively, for complex or non-conforming type runoff, a manual time vs runoff volume can be entered in a table format to create a hydrograph.

Infiltration: This module is the main part of MODRET, which includes calculation of infiltration losses from the pond with specified overflow structures and orifices. The data entry in this version has been significantly changed from the previous version, where the initial data set is the stage-area table. The stage-area data can be entered manually or copied from "clipboard". The "Copy from Clipboard" option allows creating the stage-area data set in a spreadsheet, then simply copy and paste.

The pond and aquifer input data lines now have a graphical representation for each field being entered to allow the user better understand each parameter. At the top of the screen a new option "zero infiltration solution?" allows running the model and routing the runoff through the pond where infiltration losses are excluded. This option allows the user to assess the effects and the magnitude of the infiltration losses by comparing results with and without infiltration. The pond volume and average area of the pond is now calculated by the model, using the remaining parameters entered by the user.

Once the user enters the pond, aquifer and overflow characteristics, the model calculates unsaturated infiltration, sets up MODFLOW data files, executes the MODFLOW program for saturated infiltration, reads the results, and calculates and displays the results. The MODFLOW model was specifically modified for use with the MODRET model, which incorporates modeling of weir and orifice overflow or overflow based on manually specified elevation vs discharge relationship (rating curve).

The routing in this version has been integrated into the Infiltration Module where every infiltration model run is automatically routed using the specified stage-storage data of the pond. The routing module allows determination of maximum (peak) discharge rate for the storm event and the maximum stage (water elevation) for the pond as well as water elevations of the pond from start to full recovery or maximum routing time specified by the user. In addition, the module produces electronic file (hydrograph) of instantaneous discharge rate. **The discharge rate** hydrograph is saved in the same format as the runoff hydrograph and can be used as input in a downstream pond or optionally added to runoff hydrograph in the Hydrograph Module.

Cross Section: This module allows for creation of a Cross-Section Graphic, which displays a series of cross sections of groundwater elevations through the retention pond along X and Y axes. The X and Y axes originate at the center of the pond. This option allows a quick review of the shape and extent of groundwater mounding within, and in the vicinity of, the retention pond. The location and extent of the cross section can be selected by the user from a series of default data set. The graphical display of the cross section can be edited by the user, in terms of selecting the extent of the X and Y axes.

Introduction

MODRET 7.0

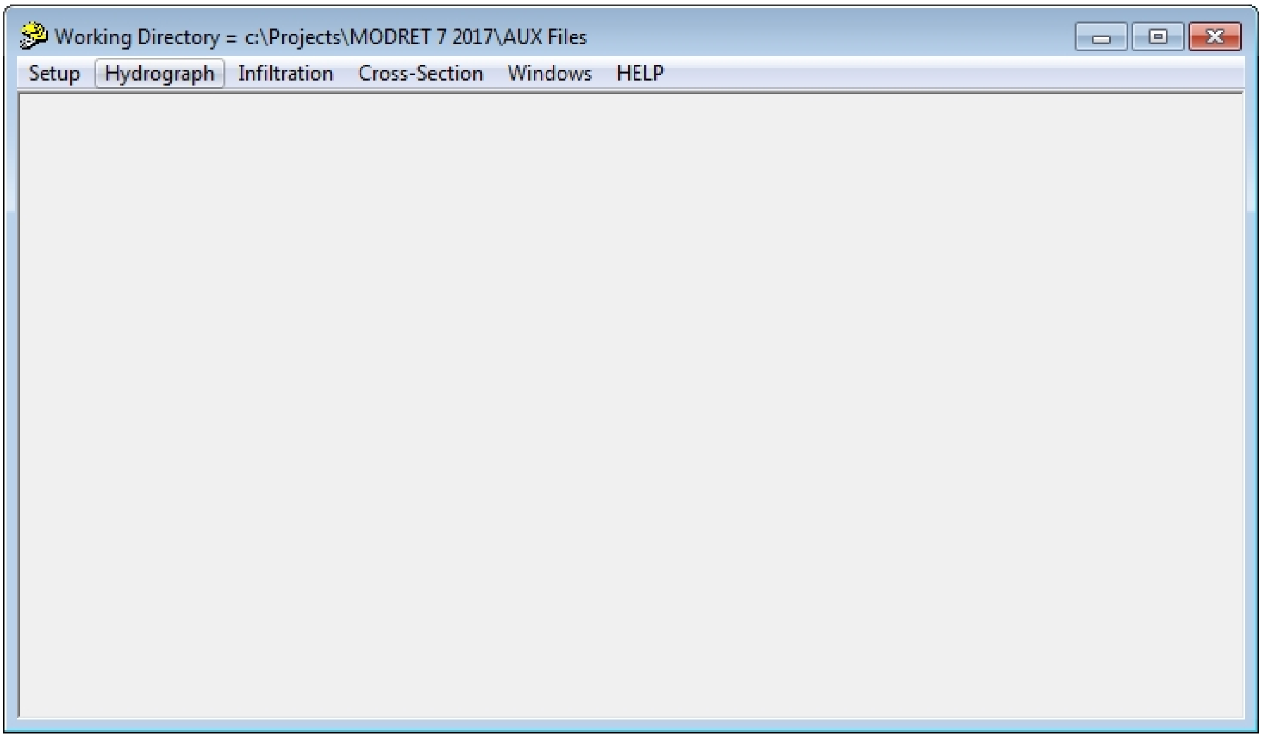
MODRET (Computer **MOD**EL to Design **RET**ENTION Ponds) was originally developed in 1990, by Nicolas E. Andreyev, P.E. as a complement to a research and development project for the Southwest Florida Water Management District (SWFWMD), Brooksville, Florida. The scope of this project was to develop a practical design manual for site investigation criteria, laboratory and field testing requirements, and guidelines to calculate infiltration losses from stormwater retention ponds in unconfined shallow aquifers. Since 1990 there have been several revisions to the original model, consisting of more options and greater flexibility. For this revision, the model was once again totally re-designed and greatly improved. MODRET 7.0 allows generation of runoff hydrographs with various methods, including slug-load hydrograph, back to back storm hydrograph, calculation of infiltration losses from a retention pond, discharge (overflow) through various types of weirs and orifices, and generation of graphical results that are suitable for inclusion in final design reports for presentation and permitting. **In this version all infiltration modeling is automatically routed through the pond's stage-storage**, allowing for more accurate determination of **peak discharge rate and peak water elevation**.

The new model capabilities, data entry, and output formats were developed based on many comments and recommendations submitted by the users of previous versions of MODRET.

This user's guide was developed to allow detailed explanations of the model menu screen prompts to assist the "first time" user in understanding the conventions and functions of each prompt. The user's guide was designed in a graphical/schematic format to allow quick access to the material and find the answers to questions. The Infiltration module of the program uses a modified Green & Ampt infiltration equation to calculate unsaturated infiltration and a modified USGS model "A Modular Three-Dimensional Finite Difference Ground Water Flow Model", McDonald & Harbaugh, 1984, to calculate saturated infiltration.

The user is assumed to be a professional with a background in hydrology and/or hydrogeology and has a good command in surface runoff and groundwater flow modeling. It is assumed that the user has read the *"Stormwater Retention Pond* Infiltration *Analysis in Unconfined Aquifers"*, manual (Andreyev, Wiseman, 1989) and understands the applicability and limitations of the MODRET program. It is also assumed that the user is familiar with the use of personal computers, Microsoft Windows operating system and its environment.

HYDROGRAPH Module



Hydrograph

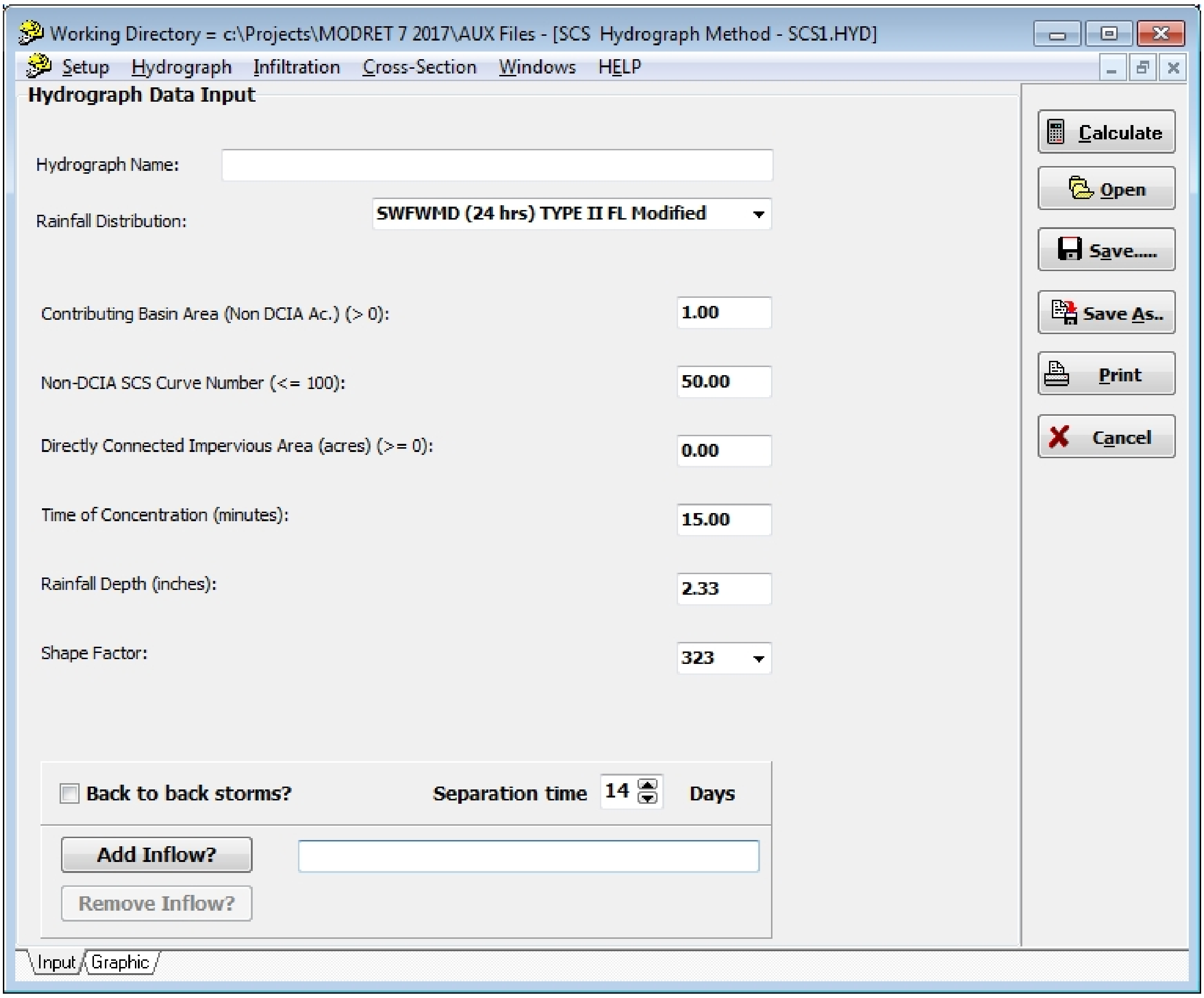
To generate a runoff hydrograph, select **Hydrograph** then clicking on the **New** button and the following options will be displayed:

SCS…

Rational…

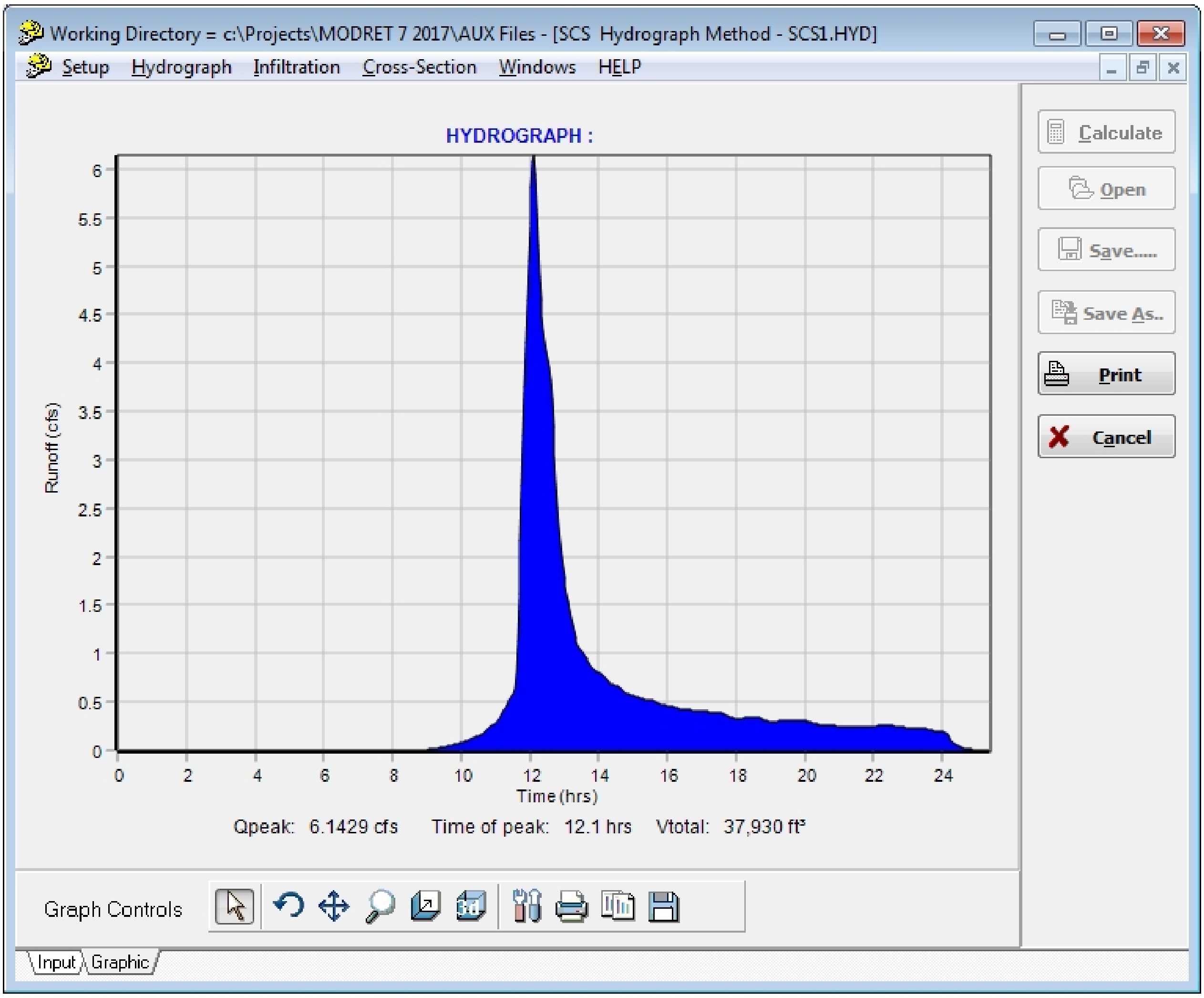
Santa Barbara…
Manual Runoff Volume

This window allows specification of the method of hydrograph calculation (i.e., SCS Unit Hydrograph, Rational Hydrograph, Santa Barbara Urban Hydrograph or a user specified Manual Runoff Volume versus Time). By selecting one of the four options a **Hydrograph Data Input** screen appears for input of the runoff parameters and generation of runoff hydrograph. After input of the required data, the hydrograph can be generated, and the results saved in the selected file name with a corresponding extension. The input data is also saved in the selected file name. However, if some changes to the input data file are made, the changes can be saved by selecting the buttons **Save...** or **Save As...** on the right side of the screen. The input data can be printed, after input is complete, by clicking on the **Print** button.

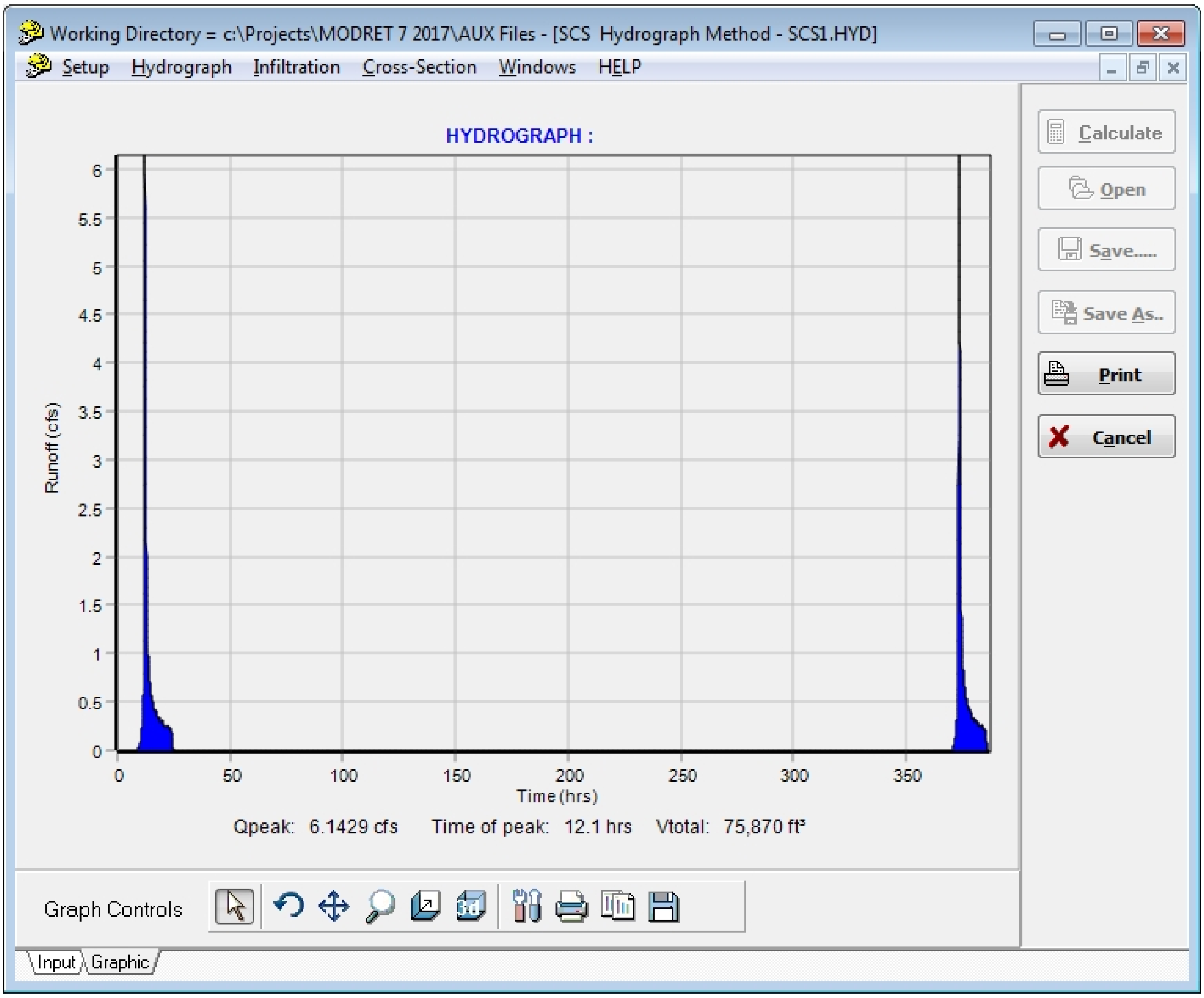


On the bottom-left corner of the screen, two tabs will appear, **Input** and **Graphic**. The **Input** tab allows input of basin and runoff parameters, open new files, save data, print and calculate the runoff rates. The **Graphic** tab allows a graphical view of the hydrograph. The graphical display can be activated **ONLY after Calculate** button has been clicked (top-right) and the calculations have been completed.

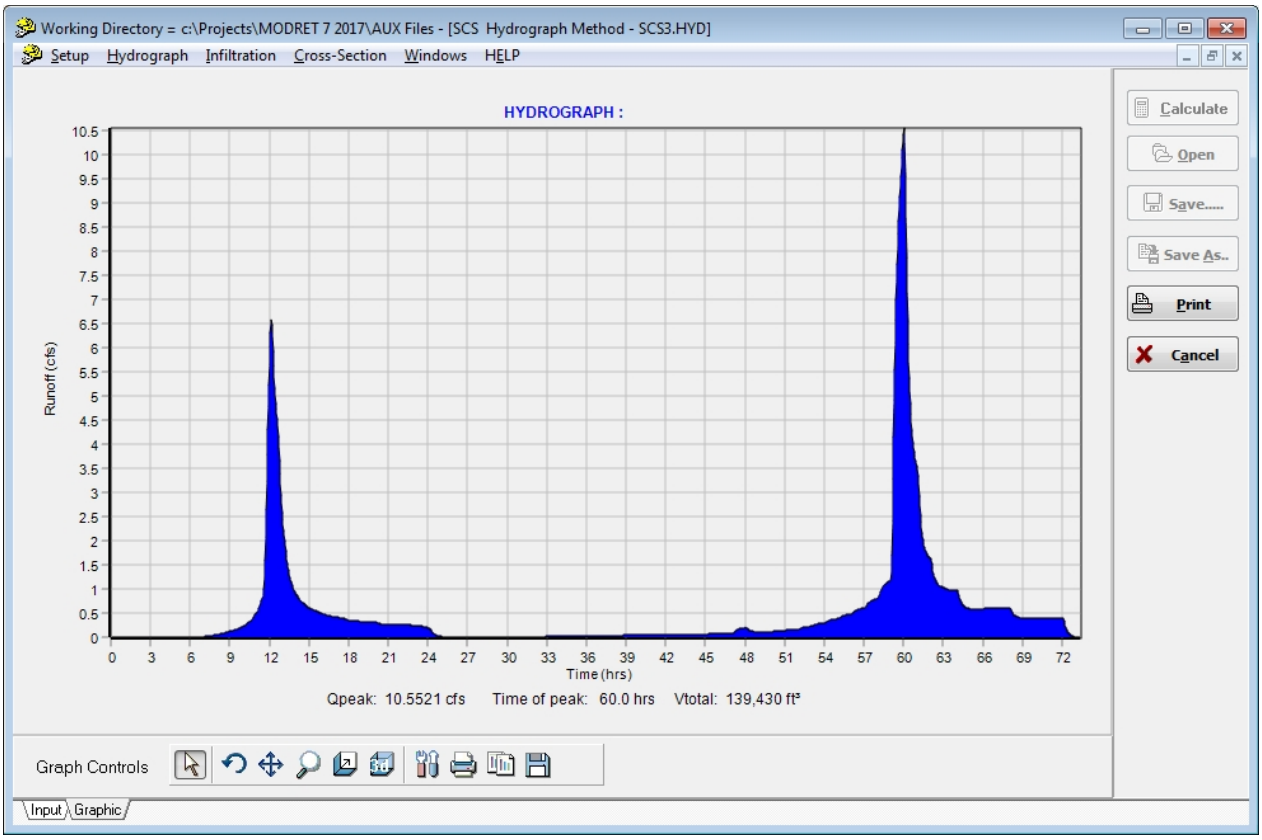
Once the hydrograph is displayed, the graph can be printed by clicking on the **Print** button, see below. At the bottom of graph, a "Graph Controls" bar appears, which can be used to customize the graph for viewing and printing. The model is set up with a default graph display options, which can be used or modified.
The input data field have been changes slightly in this version, where the non-DCIA areas and DCIA areas are specified separately, instead of specifying the DCIA as a percent of total area. The entry method in the previous version has proved to be confusing and resulted in erroneous specification of non-DCIA areas or CN values. The revised entry field should eliminate this problem.



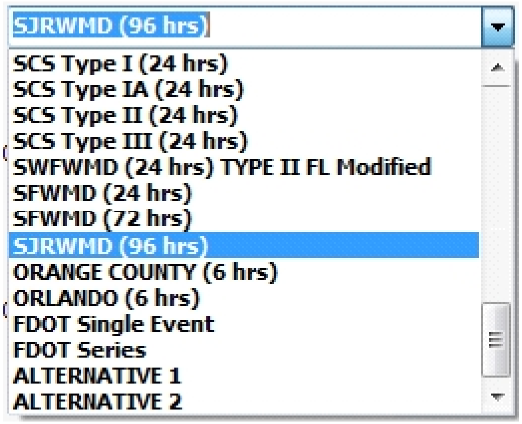
In this version, two new options have been added at the bottom of the input data field. The option of "**Back to back storms?**" selection allows creating two identical runoff hydrographs with a specified "**Separation time**" between the two storms. The other option is to allow adding a discharge hydrograph or a runoff hydrograph to the hydrograph being created, "**Add Inflow?**" option. This option is useful to allow adding discharge from an upstream pond or a runoff from an adjacent drainage basin. The following graph show an example back to back hydrograph:



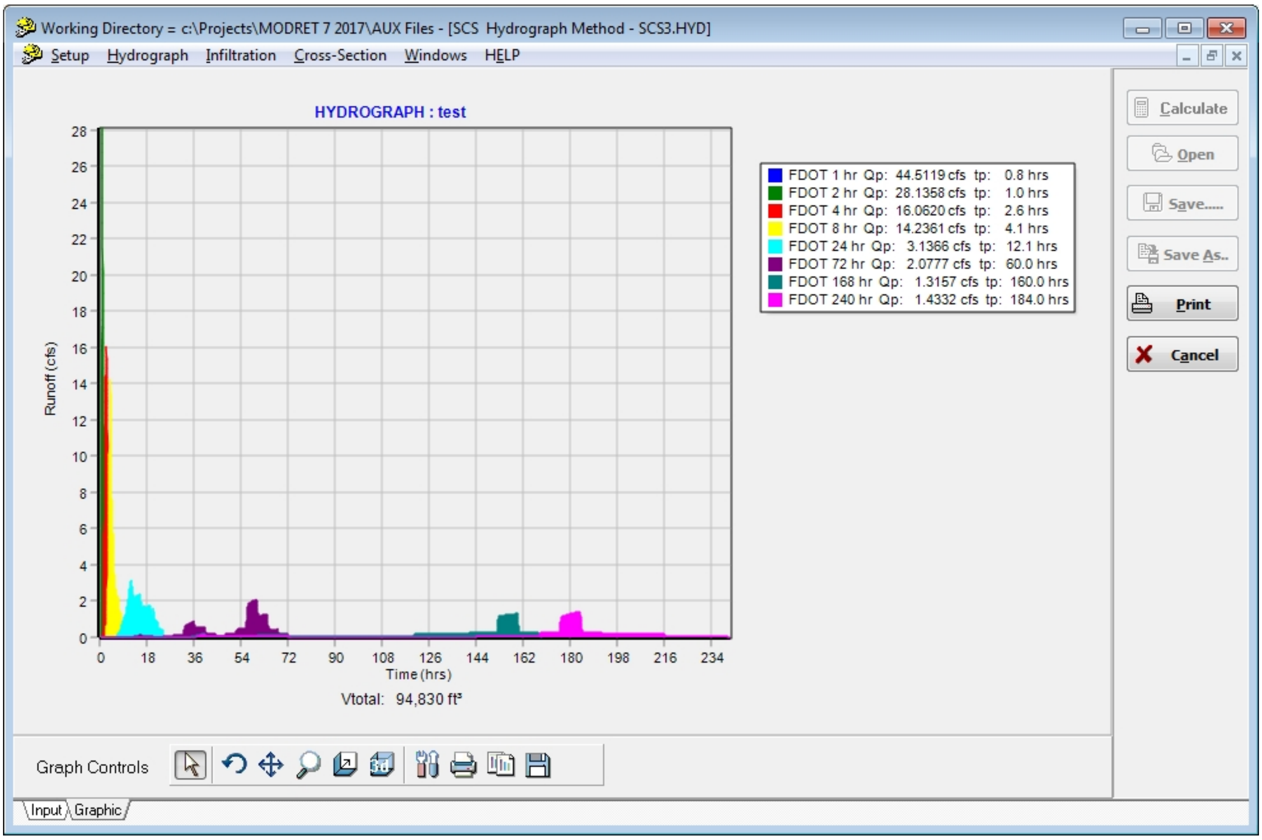
For the second option, **Add Inflow**?, the user must first create a hydrograph for a specific basin area, then click on the **Add Inflow?** button and select the second hydrograph or a discharge hydrograph. The model will add the selected hydrograph flow to the created hydrograph. This combined hydrograph can then be saved with a new name and used in the infiltration and routing analyses. The following are samples of a created hydrograph and a combined hydrograph where discharge from an upstream pond was added:



The **Rainfall Distribution** prompt has an option for the following rainfall distributions from a pre-selected list:



To access this list, click on the down-arrow of the Rainfall Distribution line. To select one of the pre-selected rainfall distribution options, simply click on the desired option. The program will return to the data input screen and the name of the new rainfall distribution will appear on the prompt line. A new option in this version allows selection of the "**FDOT Series**". When selecting this option, the model will run pre-selected 8 hydrographs and display the results in a multi-graph as shown below with a summary table for each rainfall distribution:



In the Infiltration module, these FDOT series can be imported as a batch and the model will run all storms and display the results one by one. Alternatively, if the user would rather run each FDOT storm event separately the model allows that by selecting “FDOT Single Event”.

To specify a new rainfall distribution (User Specified) it is necessary to select one of the "ALTERNATIVE" options at the bottom of the list. Once selected, **DOUBLE CLICK** on the selected alternative to allow a new rainfall distribution input prompt to appear. For this prompt it is necessary to specify a user defined **NAME** (could be any identification name with up to 20 characters), the **Time Increment (minutes)** of the distribution and the **Storm Duration (hours)**. The **File Name** cannot be entered directly on the screen. Instead, it must be entered by clicking on the **Open** button, then selecting an existing file from the appropriate directory. The selected user specified rainfall distribution name and file name will continue to reappear on the list and can be used by simply selecting it from the list. To change it once again, simply double click on the Rainfall Distribution line, when one of the changeable options is selected. New rainfall distribution data files must be created by the user, with appropriate time increment and duration (see format of existing files). For example, for a **10 hour** storm event at **15 minute** increment, the unit rainfall distribution file must have a total of 41 data points (one for the first line of 0,0 and 40 for the distribution, i.e., 10 x 60 /15 = 40).

The **Non-DCIA Basin Area (acres)** prompt allows specification of the contributing basin (catchment) area that is not directly connected impervious area (DCIA). Non-DCIA area is all other basin areas that are not DCIA. The area must be specified in **Acres**.

The **Non-DCIA SCS Curve Number** prompt allows specification of the weighted average **CN** (curve number) value for the surface runoff characteristics for all areas that are not DCIA. Technical material for selection of an appropriate CN value is not included in this User's Guide. The user is recommended to obtain the necessary reference material to select an appropriate CN value for this analysis. The CN value is for the weighted average conditions of the entire non-DCIA area, including pervious and impervious surfaces.

Directly Connected Impervious Area (acres) prompt allows specification of the total directly connected impervious area of the contributing basin. The area must be specified in **Acres**. In MODRET the runoff calculation for the DCIA assumes a CN=98.

The **Time of Concentration** prompt allows specification of the time of concentration, **in minutes**, for the effective contributing basin.

The **Rainfall Depth** prompt allows specification of the total accumulation of rain, **in inches**, for the duration of the specified storm event.

The **Shape Factor** prompt has a total of three (3) default shape factors for the rainfall distribution used with the SCS Unit Hydrograph Method, specifically, **256, 323 and 484**. Click on the down-arrow and select one of the three default options. At this point, if one of the first three options is selected for the shape factor, the program accepts it and displays it on the **Shape Factor** line. The fourth "OTHER" option allows specification of a **User Defined** shape factor that could be installed as a semi-permanent option. If a new Shape Factor is desired, select the OTHER option. Then double click on the **Shape Factor** line with this selection. The **uhgNNN.uhg** files will appear from which the appropriate file must be selected. This file must be **created by the user and must have a name** that starts with **uhg** followed by **3 numbers** then an extension of **uhg** (i.e., uhg585uhg). The model will read the data and display the number on the **Shape Factor** line (i.e., 585).

Rational & Santa Barbara

Selecting the Rational or the Santa Barbara options, a similar data input screens will appear. The following is a description of the parameters that are different and not described in the SCS option:

The **Runoff Coefficient C** of the Rational option requires specification of the runoff coefficient as developed by Mulvaney (1851) and used by Kuichling (1889). The C coefficient is based on the equation of Qp = CiA, where Qp is peak discharge, C is runoff coefficient, I is precipitation rate and A is contributing basin area. In this equation it is assumed that the rainfall intensity is constant over the time it takes to drain the watershed (time of concentration) and the runoff coefficient remains constant during the time of concentration. These assumptions are reasonable for watersheds with short time of concentration (about 20 minutes). As developed by Williams (1950), Mitchi (1974) Pagan (1972) and Wanielista (1990), a hydrograph shape can be assumed for the rational method.

The user is referred to the cited literature for details of the development of a runoff hydrograph using the Rational method.

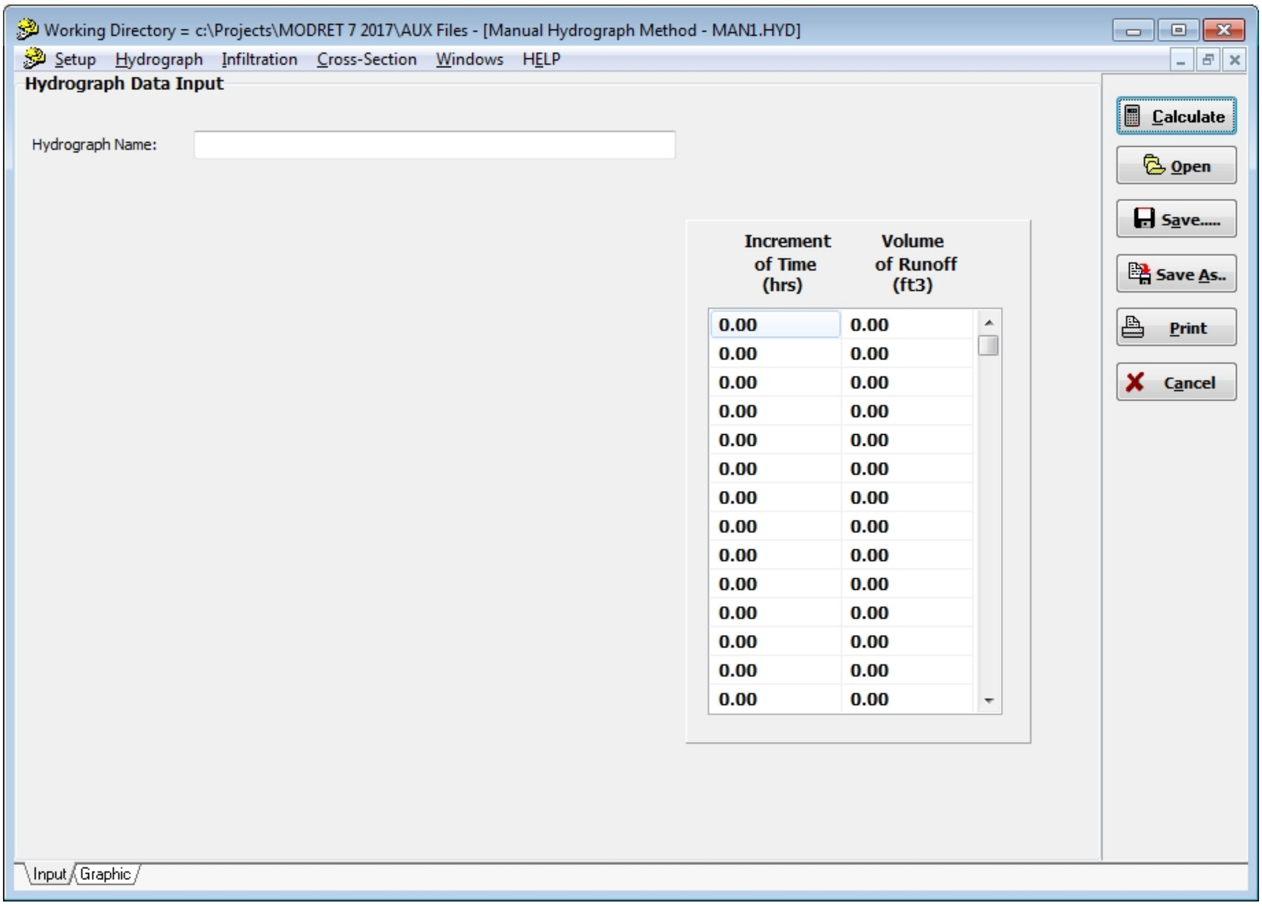
NOTE:

*In the Rational method, a reasonable and meaningful **Storm Duration** time is approximately equal to the **Time of Concentration**. For td=tc, the calculated peak discharge and the volume of runoff are accurate. However, if the time of concentration is specified to be **less** than storm duration, the peak discharge will be proportionally reduced from the Q=CiA formula to compensate for runoff volume calculation. The user is again referred to the references cited* *above to familiarize himself/herself with the development and assumptions of hydrograph generation when using the Rational method.*

In the Santa Barbara method, the same input parameters as the **SCS** method apply. MODRET utilizes the simplest form of the SBUH equations, originally develop by Stubchaer. The infiltration volume for each time increment is calculated from soil storage capacity, using the specified CN value, uniformly distributed over the storm event. The user is referred to Stubchaer (1975) for details of the derivation of the Santa Barbara Urban Hydrograph method, and its application to calculate runoff from directly connected impervious areas and pervious areas. **Since its original development, the SBUH runoff equations have gone through various modifications and refinements and some of the SBUH models incorporate a variety of additional surface parameter options (i.e., abstraction of pervious and impervious area, etc.) that are not included in MODRET.**

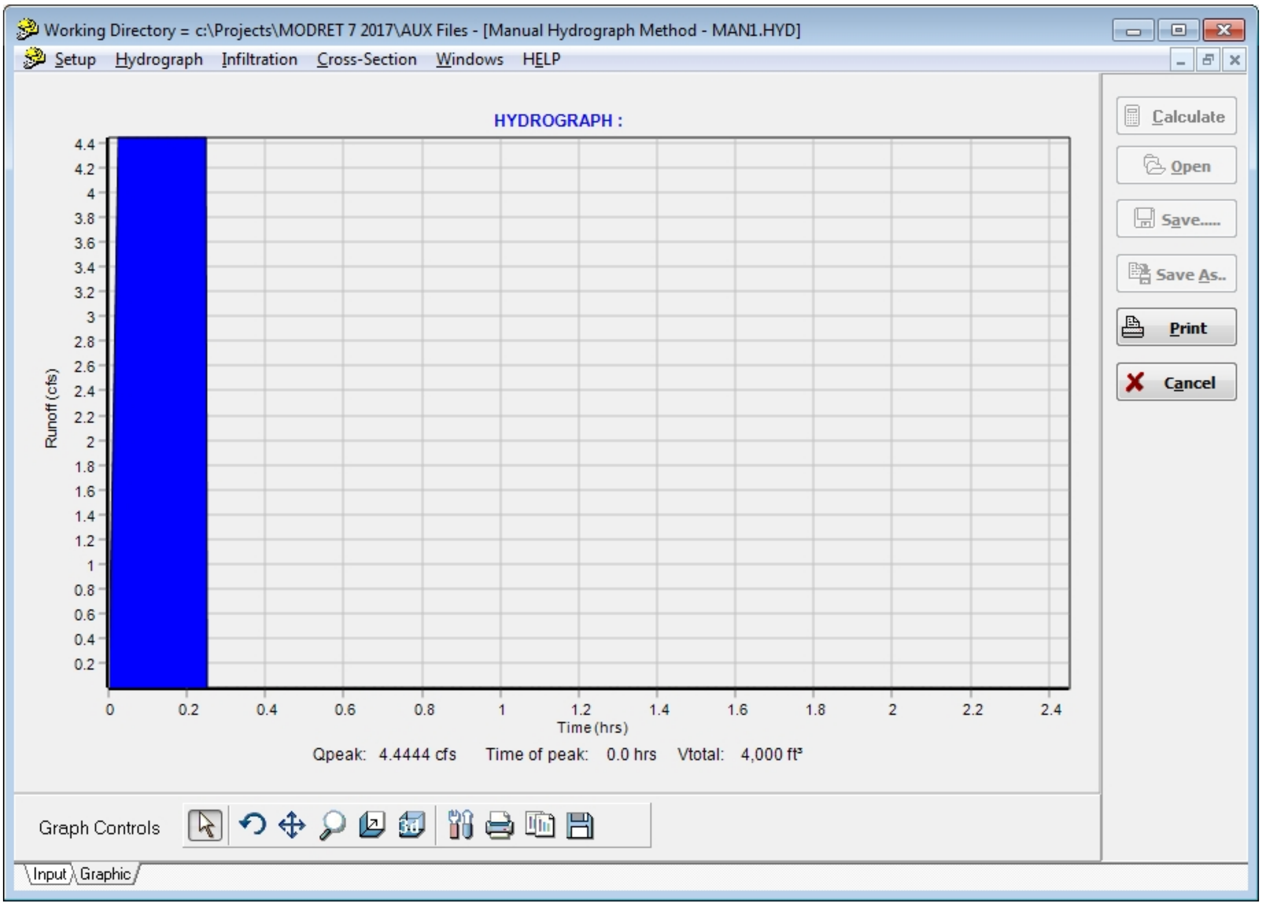
Manual Runoff Volume

Selecting the Manual Runoff Volume option, the user can create a runoff hydrograph for specific time vs runoff conditions. The option to model a slug load (often referred to as pollution abatement volume) can be modeled by creating a slug load hydrograph. For this runoff option, the following input screen will appear:



The input table allows input of incremental time (hours) vs runoff volume (ft^3). The user can specify as many data pairs as necessary. For example, if the user desires to specify only 3 or

4 points, the rest of the entry lines **need not** be filled in. Click on **Calculate** button (top-right) to create the manual hydrograph and then click **Graphic** tab (bottom-left) to view the hydrograph. Below is a sample of a manual hydrograph graphic for a slug load. Click the **Cancel** button to exit this option.



Open

To open a previously saved input file for hydrograph, click on **Hydrograph**, then **Open** and the following options will appear:

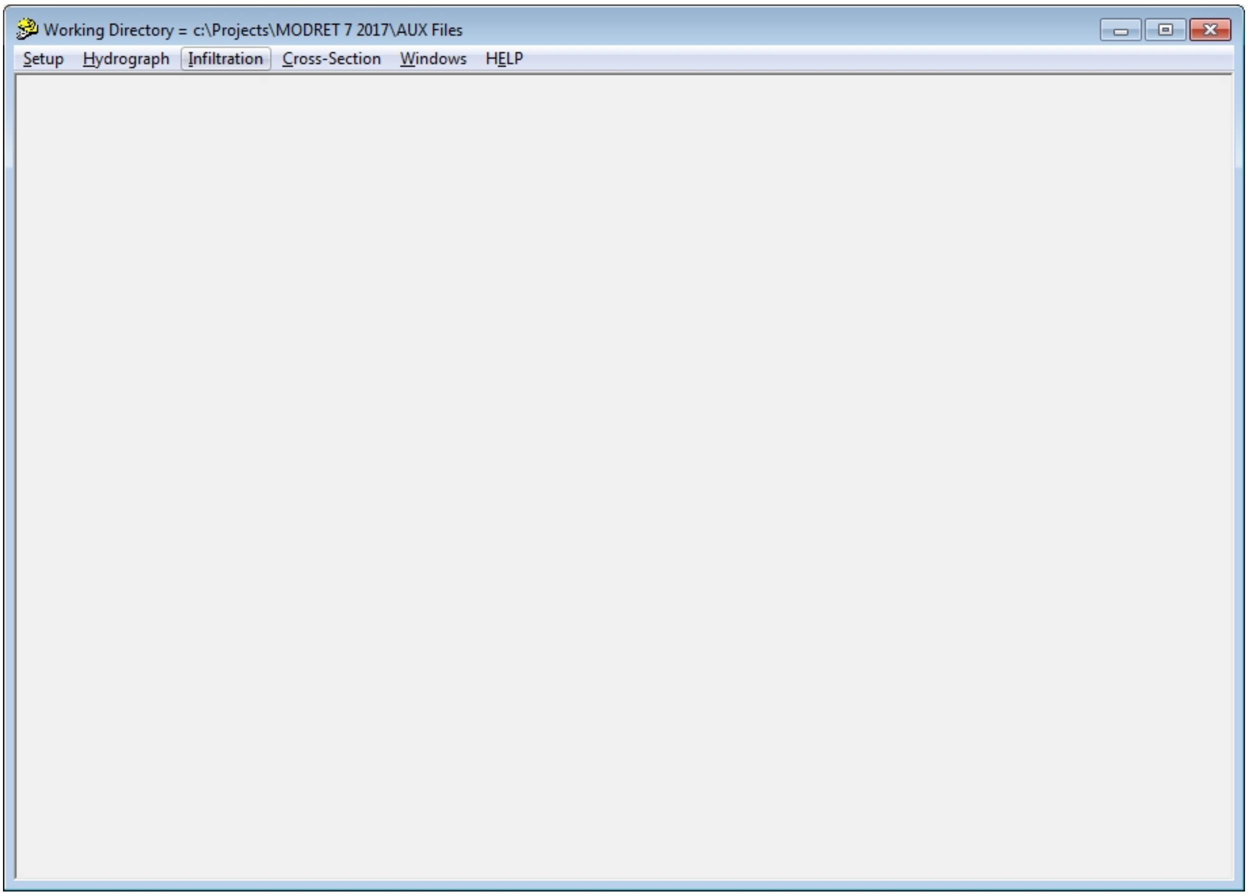
Input/Graphic…
Graphic…

Clicking on the **Input/Graphic** button will display a list of input data file names that were previously created by MODRET. These have the extension **hyd**, however, another file extension can be specified by the user. To bring the input data files on the screen for review and editing, simply double click on the desired file name. After review and/or modification of input data, clicking on the **Calculate** button, and the graphic can then be displayed as with new input and execution.

Clicking on the **Graphic** button will display a list of hydrograph graphic file names that were previously created by **MODRET or by other models** (i.e., AdICPR, SMADA, others). The MODRET created file names will have the extension of either **SCS, RAT, SAN, MAN, or DHY**, representing SCS, Rational, Santa Barbara, Manual or discharge hydrographs, respectively.

However, other file extensions can be specified by the user. To display the hydrograph graphically, simply double click on the desired file name. After reviewing and/or customizing the graphical hydrograph, it can be printed by clicking on the **Print** button.

INFILTRATION Module

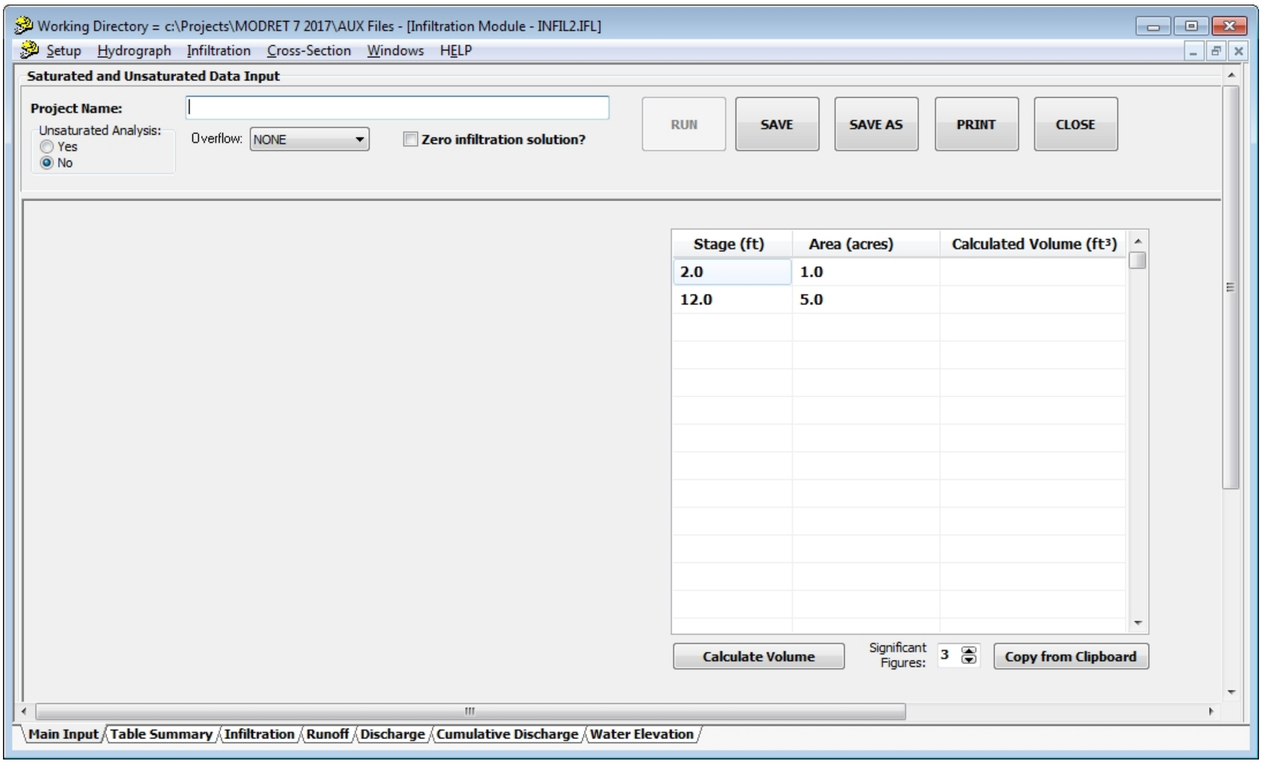


Infiltration

Clicking on **Infiltration** then **New** allows setting up a new infiltration input data set. Clicking on the **Open** option allows opening and editing an existing infiltration data set, print the input data set with the **Print** button, run the MODFLOW model with the **Run** button, and save the new or modified data set with the **Save or Save As** buttons. **Note that the MODFLOW model is a modified version, only applicable to the MODRET application, since the original DRAIN package of MODFLOW has been modified to allow specification of WEIR/ORIFICE overflow**. See INTRODUCTION section of this User's Manual (What's New in MODRET Version 7.0) for more details of weir/orifice overflow options.

New

Clicking on the **New** button, the following screen will appear allowing input of new infiltration data. If an existing infiltration data is desired to be imported for review and/or modification, it can be achieved by clicking on the **Open** button and selecting a desired file name:



The **Project Name** line requires specification of a name for the infiltration input data. This is for identification purposes only (**it is not a file name**). This **Name** will appear on the tabular and graphical printouts and on graphical view screens.

Unsaturated Analysis

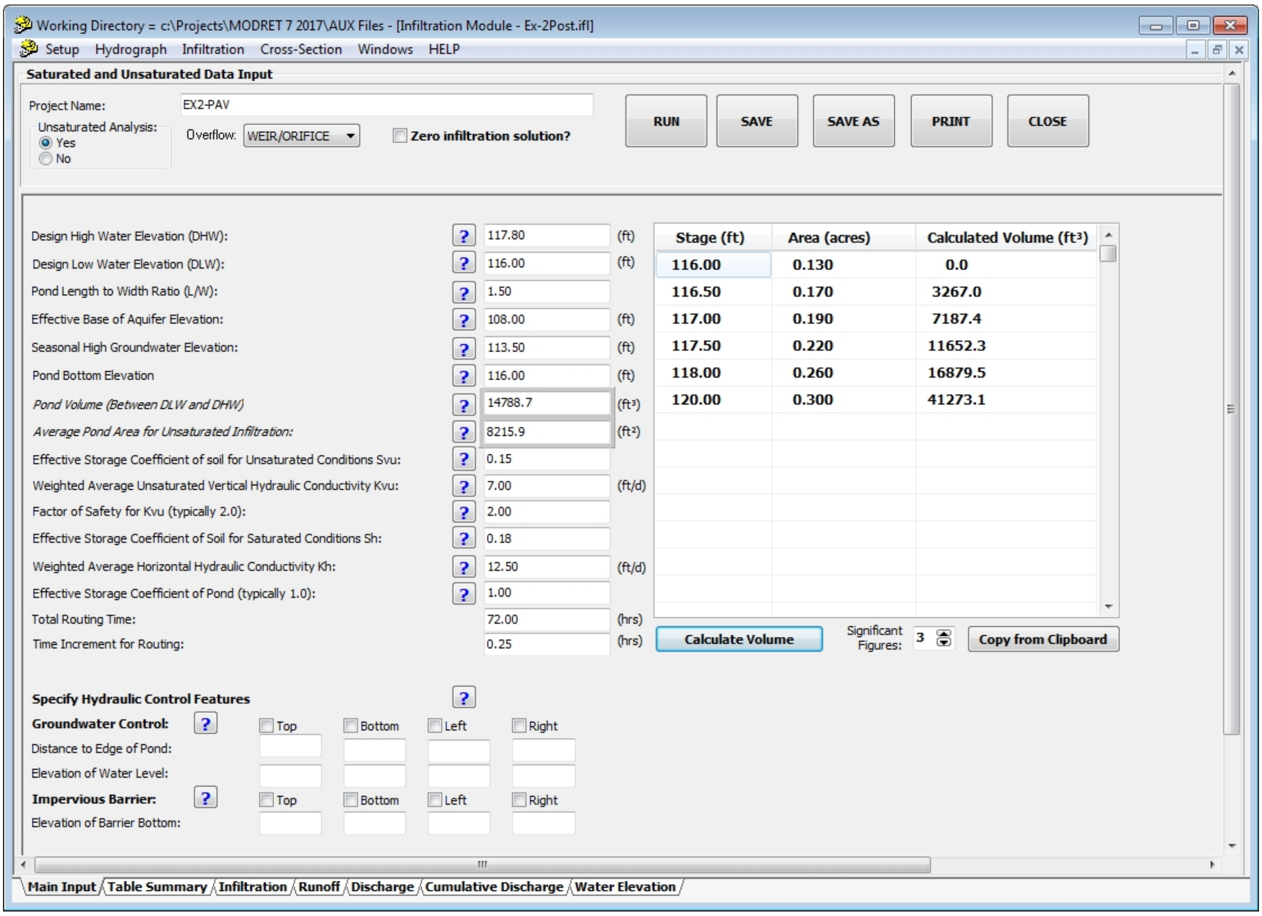
The **Unsaturated Analysis** box allows specification to include unsaturated analysis in this simulation "**Y**" or exclude it "**N**". If "**Y**" is specified, MODRET automatically calculates unsaturated infiltration at the beginning of the saturated analysis and incorporates it into the overall water balance analysis. The unsaturated volume and the effective time on the hydrograph curve is automatically calculated by MODRET and the starting time for saturated analysis is adjusted accordingly.

*The **Overflow** option can be entered now or later, after the pond and aquifer parameters have been specified. Details for this option will be presented later in this section of the manual.*

The **Zero Infiltration Solution?** Option allows to user to set the calculated infiltration losses from the pond to zero and simply route the runoff through the pond. This option is useful when comparing the effects of infiltration to a condition where infiltration losses are minimal or non-existent. **This option is also useful for initial design of ponds when soils data is not yet available and the user simply routes the runoff hydrograph through a pond system without infiltration**.

Stage-Area Table: In this version of MODRET the input begins by entering the stage and area of the pond to be modeled (stage in elevation and area in acres). This data is typically available from the design engineer or it needs to be created to allow modeling of the pond. The entry can be manual on the table provided or copied and pasted from a spreadsheet. The convention for data entry is starting at the bottom of pond and increasing stage to the very top of pond berm. It is not important where the start and end of the stage-area is provided in the table as long as the range includes the "Design high water elevation (DHW)" and the "Design low water elevation (DLW)".

The subsequent specification of the DHW and DLW allows automatic calculation of the pond volume and the average pond area needed for MODRET to create the MODFLOW model grid for infiltration modeling. If the stage area table already existing, it is possible to copy the data and paste it directly into the table using the "**Copy from Clipboard**" button at the bottom-right. The stage-area table also allows specification of the number of decimals for the data entry. Once the stage and area for the pond are entered, the "**Calculate Volume**" button at bottom allows calculation of the volume for each stage (elevation) and opens the table for the remaining parameters to be entered. The following screen will appear after stage-area entry and **Calculate Volume** button is pressed:



The populated data set to the left of the stage-area table are dummy numbers and need to be entered to correspond to the elevation specified in the stage-area table. The following is a line by line explanation for the infiltration module input data. In addition to the below explanation of data entry, each line entry in MODRET 7.0 displays a graphical prompt showing the parameter to be entered:

Design High Water Elevation (DHL) allows specification of the expected high water elevation in the pond during the simulation period for this pond. This elevation shall be within the range of stage-area specified in the table to the right. Typically, this elevation corresponds to the design high water level of the pond.

Design Low Water Elevation (DLW) allows specification of the design low water level of the pond. This elevation shall be within the range of stage-area specified in the table to the right. Typically, this elevation corresponds to the pond bottom of a dry pond or a normal water level of a wet pond system.

The **Pond Length to Width Ratio (L/W)** allows specification of the approximate ratio of the length of pond divided by the width of pond. This can be obtained from approximate measurement or approximation of the overall geometry of the pond. For irregular pond shapes, outline the overall area it occupies, and select the approximate length and width that a rectangular pond may occupy within the same area. Minor differences of the length to width ratio should not affect the results. A graphical sample of irregular ponds and their equivalent rectangles are provided with the prompt entry.

These DHL and DLW values together with calculated "Pond Volume" and the "Pond Length to Width Ratio" are used by MODRET to calculate the average length and width of pond for subsequent sizing of the finite difference grid system for MODFLOW. The "Pond Volume" between DLW and DLH water levels is automatically calculated by interpolation using the specified stage-area data. Similarly, the *"Average Pond Area for Unsaturated Infiltration" is automatically calculated to minimize erroneous entry by the user.*

The **Effective Base of Aquifer Elevation** refers to the base of aquifer (permeable portion of soil strata hydraulically connected to the pond) located directly below and around the pond, and which is effectively connected to the pond with permeable soil strata. Typically, this will be the **TOP OF THE FIRST RESTRICTIVE SOIL** stratum below the pond (i.e., Hardpan, Clayey Sands, Clays, Organic Materials, Silts, Rock, etc.). Sometimes, if the bottom of pond is excavated to a depth below a shallow restrictive soil layer, the base of effective aquifer may be extended to the top of the next restrictive soil stratum. It is very important to carefully evaluate the value of this input data, as it can affect the results significantly, if it is not properly established. Based on the research by Bouwer (Groundwater Hydrology, Bouwer, 1978), the effective depth of an unconfined aquifer below an infiltration pond is equal to one (1) width of the pond. Therefore, the MODRET model checks this condition, and if the specified aquifer base is deeper than one width of pond, it automatically adjusts the aquifer base elevation and the new elevation is displayed on the input screen. A message will appear in a box indicating that the aquifer base has been adjusted to the minimum elevation allowed.

The **Seasonal High Groundwater Elevation** must be established by a qualified soil scientist or a geotechnical engineer, with local experience.

The **Pond Bottom Elevation** is used only to check the vertical effect of the pond on the aquifer and to print the actual value of the pond bottom for wet retention ponds.
The **Pond Volume and the Average Pond Area for Unsaturated Infiltration** are calculated by the MODRET model using the stage-area and the specified DWL and DLW. The display of the calculated values on this page is for verification purposes only.

The **Effective Storage Coefficient of Soil for Unsaturated Conditions, Svu,** prompt allows specification of the appropriate effective storage coefficient or **fillable porosity** for the zone between the pond bottom and the seasonal high groundwater elevations. This value depends on the soil types, in-situ moisture content of the soil, and the depth to groundwater below the pond bottom. MODRET automatically calculates this value, based on the South Florida Water Management District data of Soil Storage Curves (depth to water table vs cumulative available storage). MODRET calculates this value using Table A-1 included in this document, for Uncompacted Soil. The calculated value can be accepted by the user or changed.

The **Weighted Average Unsaturated Vertical Hydraulic Conductivity Kvu** prompt allows specification of the average hydraulic conductivity or permeability of the soil **between pond**

bottom and the seasonal high groundwater elevations. Typically, the reported hydraulic conductivity values are for saturated condition and need to be adjusted. The saturated vertical hydraulic conductivity should be multiplied by a factor of 2/3 to achieve an approximate value of unsaturated hydraulic conductivity (Andreyev & Wiseman, 1989). This prompt also displays the equation for weighted average Kv calculation. For multiple soil layers between pond bottom and seasonal high groundwater, a weighted average value shall be calculated and used.

The **Factor of Safety for Kvu** prompt allows the user to enter a factor of safety for the vertical infiltration portion of the analysis. Typically, a factor of safety of 2.0 is used and it is intended to allow for long term clogging effects of soils at the pond bottom. The clogging can occur from a variety of effects, such as silt, clay, organics or other debris that enters the pond with runoff water.

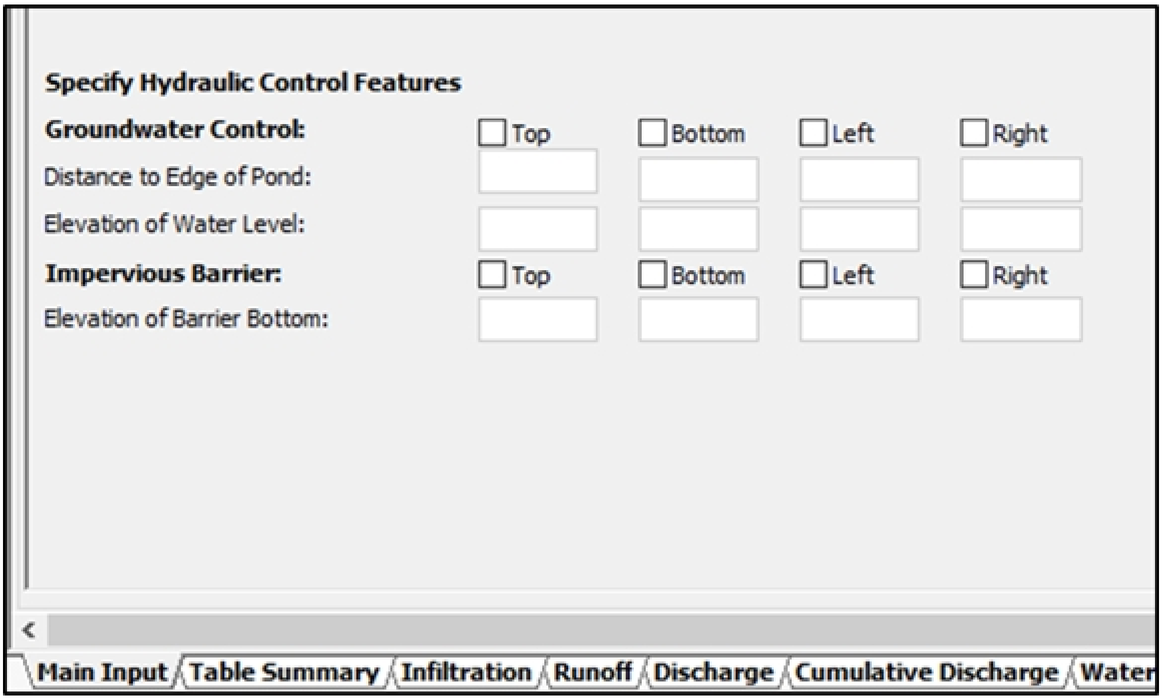
The **Effective Storage Coefficient of Soil for Saturated Conditions Sh** prompt allows specification of the appropriate effective storage coefficient or **fillable porosity** for the zone between the average groundwater mound (average of DHW and DLW) and the seasonal high groundwater elevations. This value depends on the soil types, in-situ moisture content of the soil, and the average groundwater mounding during the model simulation. MODRET automatically calculates this value, based on the South Florida Water Management District data of Soil Storage Curves (depth to water table vs cumulative available storage). MODRET calculates this value using Table A-1 included in this document, for Uncompacted Soil. The calculated value can be accepted by the user or changed.

The **Weighted Average Saturated Horizontal Hydraulic Conductivity** prompt allows specification of the average hydraulic conductivity or permeability of the soil **between the average mound height (average of DHW and DLW) and the effective of aquifer base**. Typically, the permeability tests provide values for portions of the effective aquifer system (specific soil strata) and it is necessary to calculate an average value by utilizing the measured data with estimated data to obtain a representative weighted average value. This prompt also displays the equation for weighted average Kh calculation. For multiple soil layers between the base of aquifer and average water level in pond (average of DHW and DLW), a weighted average value shall be calculated and used.
The **Effective Storage Coefficient of Pond** prompt allows specification of an average fraction of pond volume that is unobstructed. Typically, an open pond will be completely unobstructed and a value of 1.0 should be specified for this prompt. However, in the case of underground exfiltration trenches, the gravel pack and solid portions of pipes are an obstruction and the effective storage coefficient could be in the range of 0.4 to 0.6.

The **Total Routing Time** prompts allows the use to specify the total time for model simulation and subsequent routing. In this version MODRET all infiltration simulation are automatically routed through the stage-storage of pond and the resulting water levels are calculated for the entire specified period of time, including the time of runoff hydrograph and the time after runoff has stopped.

The **Time Increment for Routing** prompt allows the user to specify the increments for routing for the duration of the routing time. Although MODRET will allow specification of shorter time increments, time increments are recommended to be 0.25 hour or larger for infiltration losses modeling. Due to the method of calculation (3-dimensional groundwater flow model MODFLOW) short time increments, may result in some error of convergence of the finite difference equations. If small time increments are used and MODFLOW fails to converge, MODRET will detect this error, during reading of output data, and will display an error message, indicating that MODFLOW failed to converge. This could happen with small time increment or when unrealistic (or wrong) data is entered. If this occurs, try changing time increments or correct input data and then re-run the program.

Specify Hydraulic Control Features



At the bottom of the Infiltration main screen two optional hydraulic control features can be activated by the user.

The **Groundwater Control** prompt allows specification of ditches, canals, rivers or lakes in the vicinity of the pond that have a constant controlled water level, which could affect the performance of the retention system modeled. The MODRET convention of pond layout assumes that the **length of pond runs up and down along y-axis** and **the width of pond runs from left to right along the x-axis**, and the **origin of the x and y axes originate at the center of the pond**. When selecting this option, a graphic representation of the pond appears on the screen to remind the user of this specific convention of pond layout. The user can select the location of a groundwater control feature, if there is any, by clicking the box next to the appropriate designation (Top, Bottom, Left or Right). If a flag is set at any one or more than one of the locations, the user **must specify** the **Distance to Edge of Pond**, which is the average distance as measured from the average edge of pond to the edge of the water feature (canal, ditch, lake, etc.). A graphic will appear when entering this data, showing the specifics of this entry. The second prompt of the water feature is the **Elevation of Water Level**, which is the average water elevation in the water feature that will prevail throughout the pond infiltration model simulation. A graphic will appear when entering this data, showing the specifics of this entry.

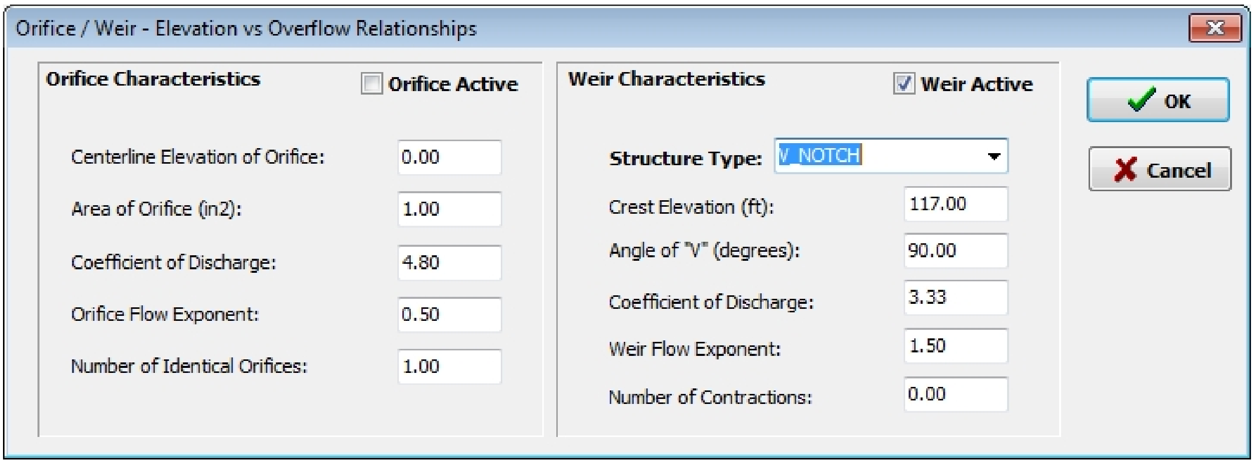
The **Impervious Barrier** prompt allows specification of concrete walls, clay liners, plastic liners, building footings and other features that obstruct lateral flow of groundwater away from the pond. For this prompt the user is allowed to select the location of a impervious barrier feature, if there is any, by clicking the box next to the appropriate designation (Top, Bottom, Left or Right). If a flag is set at any one or more than one of the locations, the user **must specify** the **Elevation of the Barrier Bottom**, which is the average elevation of the obstruction located along the edge of pond. This option only allows specification of barriers along the perimeter of the pond, **not** at some distance from the pond. MODRET accounts for the impervious barrier by reducing the weighted average horizontal hydraulic conductivity for the effective aquifer along the entire length or width of the pond, on the specified side of the pond. If the impervious barrier bottom is below the bottom of aquifer base, then the horizontal hydraulic conductivity is set to zero and no flow occurs on the specified side of the pond.

Overflow

Clicking the **Overflow** down-arrow allows selection of one of three options for overflow devices of the pond, i.e., **NONE, WEIR/ORIFICE & MANUAL**. To select, click on the desired option. If **NONE** is selected, then the pond is modeled without overflow option. When **WEIR/ORIFICE** option is selected, the model allows selection of **only weir, only orifice or both**. If **WEIR** option is selected, it is necessary to select one of three types of typical weirs; **V-notch, Sharp Crested and Broad Crested**. If **ORIFICE** option is selected, it is possible to specify any number of symmetrically identical orifices. The **MANUAL** option is provided to specify an overflow rating data set for overflow devices that do not fall into one of the other options. The manual specification can also be used when a combination of different overflow devices is present.

WEIR DISCHARGE

The **following** weir data input screen prompt appears when **WEIR - V_NOTCH** option is specified:



The **Crest Elevation** prompt allows specification of the actual elevation of the Vortex of the V_Notch weir. The **Angle of "V"** prompt allows specification of the angle (in degrees) of the v-notch of the weir. The **Coefficient of Discharge** "C" and the **Weir Flow Exponent** "a" prompts refer to parameters of the following weir equation:

$Q = C \tan(1/2) H^a$

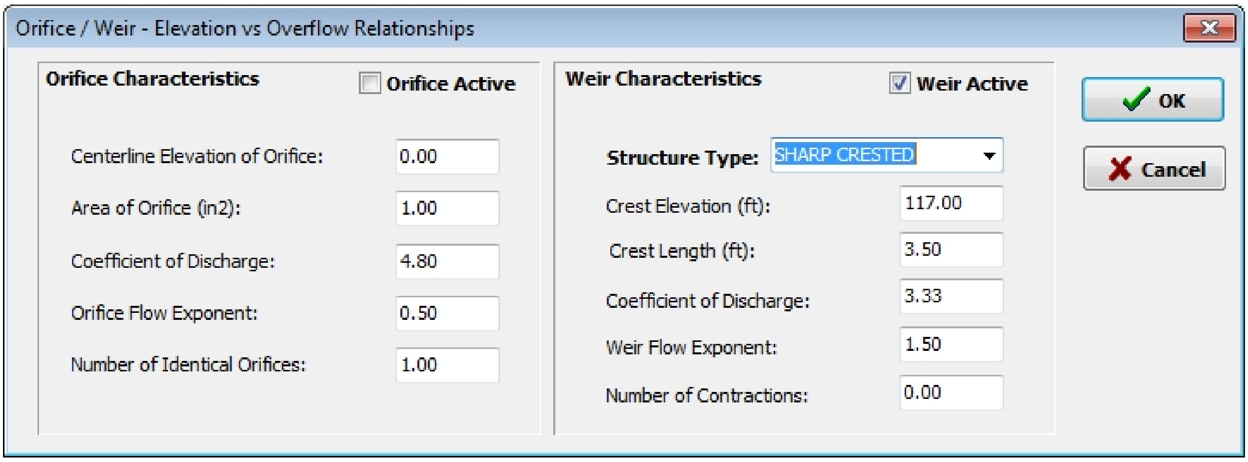
Where,

Q = Flow rate (cfs)
C = Coefficient of Discharge
1 = Angle of V-Notch (degrees)
H = Head on the weir (feet)
a = Weir flow exponent

The crest elevation **MUST** be set below the **Design High Water Elevation** to avoid model run errors. The reason is that MODRET develops a rating curve (to be used by MODFLOW) between the weir crest elevation and the design high water level.

Once all weir input data prompts are answered, MODRET returns to the **Main Input** screen and the Overflow option box is displayed with the selected overflow device. If a new weir device is selected at this point, the previously selected data will be ignored and prompts for a new set of data will appear.

The following weir data input screen prompt appears when **WEIR - SHARP CRESTED or BROAD CRESTED** option is selected:



The input prompts of **Crest Elevation, Coefficient of Discharge, Weir Flow Exponent and Design High Water Elevation** are the same as presented for the V-Notch weir option above.

The **Crest Length** prompt allows specification of the actual length of a rectangular sharp crested or broad crested weir.

The **Number of Contractions** prompt allows specification of the number of weir end contractions (i.e., 0, 1 or 2). The following equation is used to calculate overflow over a sharp crested or broad crested weir:

$$Q = C\,(L - 0.1Hn)H^{a}$$

Where,

Q = Flow rate (cfs)
C = Coefficient of Discharge
L = Crest length (feet)
H = Head on the weir (feet)
n = Number of weir end contractions
a = Weir flow exponent

General Conditions and Assumptions for Weir Flow Calculations

For **ALL** weir flow calculations, it is assumed that the discharge is free flowing and **is not** submerged. It is assumed that the upstream water depth below the weir crest level is at least 2 times the maximum head on the weir. For weir flows with end contractions it is assumed that the horizontal distance from the end of the weir crest to the side wall of the channel is at least 2 times the maximum head on the weir.

ORIFICE DISCHARGE

The screen prompt for orifice option appears together with the weir option, as shown above. The input parameters of **Coefficient of Discharge and Orifice Flow Exponent** are similar to the Weir flow options above. However, the coefficient of discharge in this equation **is not the same** as the coefficient of **typical** orifice equation. For MODRET the coefficient $C = Co * (2g)^{0.5}$

The **Centerline Elevation of Orifice** prompt allows specification of the actual elevation of the centerline of a **circular or symmetrical** orifice to be **modeled**. The orifice is assumed to be **unobstructed and without tailwater condition.**

The **Area of Orifice** prompt allows specification of **the** total area (**in inches squared**) of individual orifice being specified.

The **Number of Identical Orifices** prompt allows specification of the total number of identical orifices to be modeled, which must exist at the same **elevation** and have the exact same size and flow conditions. The following equation is used to calculate flow through the orifice:

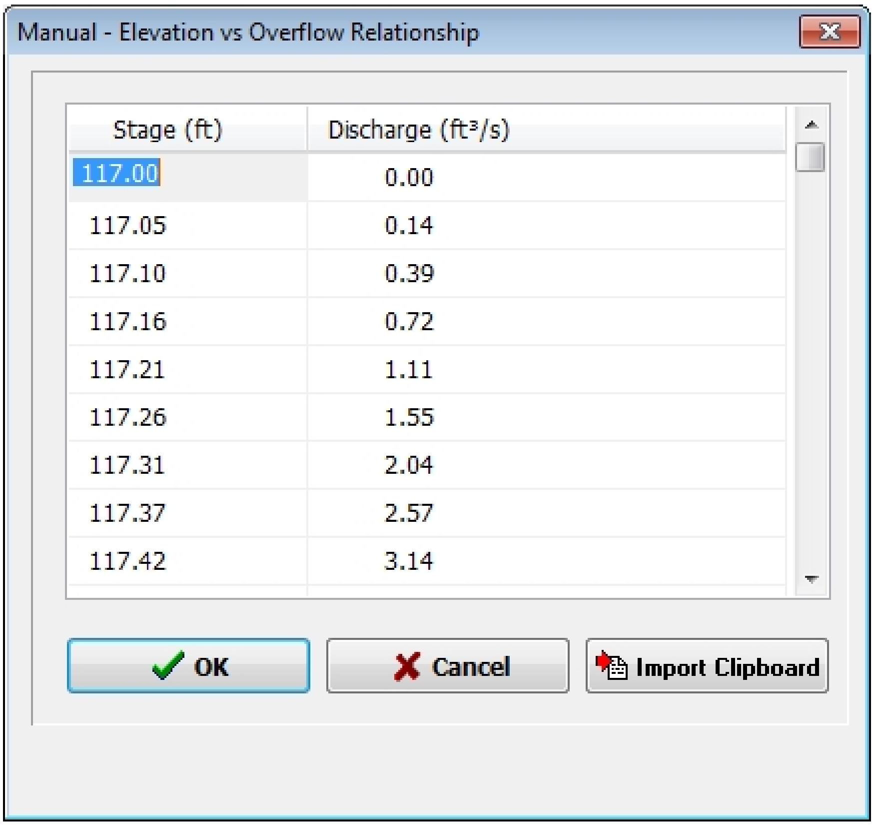
$Q = n\ C\ A\ H^a$

Where,

Q = Flow rate (cfs)
n = Number of identical orifices
C = Coefficient of Discharge **[$C=Co * (2g)^{0.5}$, where Co = 0.6 to 0.9, typ.]**
A = Area of Orifice (ft^2)
H = Head over the centerline of orifice (feet)
a = Orifice flow exponent

MANUAL DISCHARGE

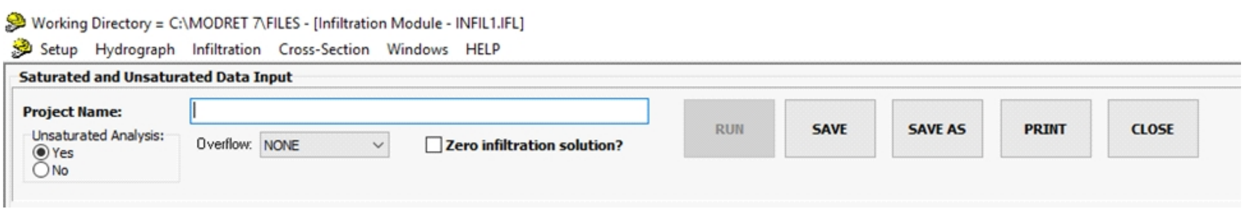
The following data input screen appears when **MANUAL** option is specified for the Overflow device:



The data input for this option is typically referred to as the overflow rating curve method. The first data point line prompts the user to specify only the elevation and a zero (0) is automatically assigned to the **Discharge** column. This indicates that the first entry must be the starting point of overflow (i.e, crest elevation of weir). Subsequent data point inputs have no restriction of any kind. The user can specify as many data points as necessary. In this version of the model the rating curve data can be created externally (i.e., spreadsheet, note pad, etc.) then imported using the **Import Clipboard** button. Simply copy the eternally created data set, then click the **Import Clipboard** button. Once all the data has been entered simply click **OK** to return to Main Input screen. When previously saved data is recalled for editing, the saved rating curve data will be displayed. To edit, simply over-write or add as needed.

Runoff Data

In **MODRET 7.0** the runoff data box has been eliminated and all runoff for the **Infiltration** module is now created in the **Hydrograph** module. Please refer to the **Hydrograph** module for details. Once all the pond and aquifer data are entered and the RUN button is pressed, the program will request selection of the hydrograph for each model run. For slug load modeling, the manual hydrograph option can be selected in the **Hydrograph** module to create a slug load hydrograph.



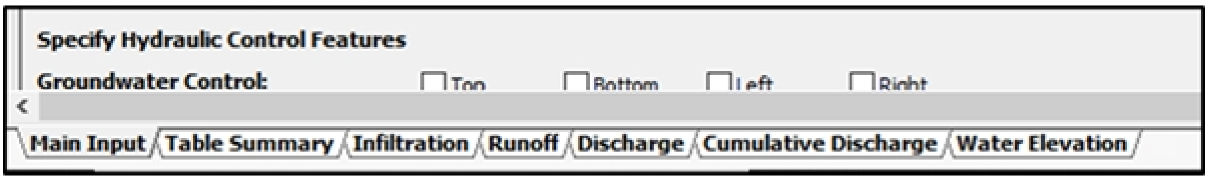
File Management Control & Model Execution

On the top-center of the Main Input data screen, several command buttons are displayed. These include **RUN, SAVE, SAVE AS, PRINT AND CLOSE**. Once all the input data has been specified, the data should be saved by clicking on the **SAVE** or the **SAVE AS** button. Saving the file with the extension **ifl** will help locate the file easier when re-opening the file later. At this point the input data can be printed by clicking on the **PRINT** button. The **PRINT** command allows significant amount of print customization, such as orientation, paper size, margins, color, printer selection, etc.

Once all the input data is specified and saved, the infiltration analysis can be executed by clicking on the **RUN** button. The **RUN** option will ask to select a runoff hydrograph and then it will create the needed MODFLOW files and execute the MODFLOW model from within the MODRET program. It may take some time to execute MODFLOW, depending on the computer and the time of simulation (total routing time). A message box will appear indicating that MODFLOW is running. When execution of MODFLOW is complete, a message will appear in the box, prompting the user to click **OK** to continue. If the MODFLOW model crashes during execution, an error message will appear in a message box. To exit the Infiltration module, simply click on the **CLOSE** button.

Viewing and Printing Results

Along the bottom of the Main Input screen of the Infiltration module seven tabs are displayed, **Main Input, Table Summary, Infiltrated, Runoff, Discharge, Cumulative Discharge and Water Elevation**. *Prior to selecting one of these options, the infiltration analysis must be executed by clicking on the* **Run** *button*. The following is a quick explanation for each tab:



Main Input allows input and editing of the infiltration model input data parameters.

Table Summary presents a tabular view of model results for each time increment as routed for the current model run. The data in the table is for information only, as the same data is presented in the graphical format by selecting the tabs to the right. No printing options are included for the Table Summary data. However, the data can be copied and pasted if desired. To copy all data in the table to the clipboard, right click on the data screen, then click **Select All**, then right click again and click **Copy**. The data can also be exported in CVS format (comma delimited file) using the button on the top-right of the table. The file can then be opened by excel spreadsheet or other program.

Infiltration generates a graphical view of the cumulative volume infiltrated vs time. The total infiltrated volume (ft^3) is displayed at the bottom.

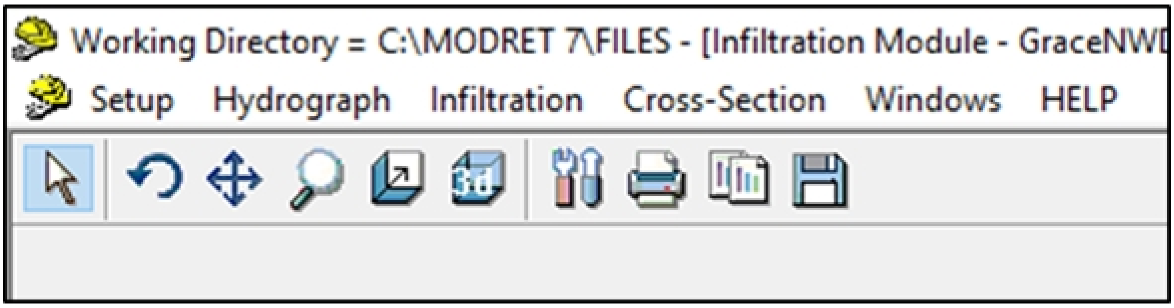
Runoff generates a graphical view of the cumulative runoff vs time. The total runoff volume (ft^3) is displayed at the bottom.

Discharge generates a graphical view of the instantaneous discharge (overflow) from the pond through the specified weir and/or orifice structures vs time. The discharge is in cubic feet per second (cfs) and the maximum discharge rate is displayed at the bottom.

Cumulative Discharge generates a graphical view of the cumulative volume discharged vs time. The total discharge volume (ft^3) is displayed at the bottom.

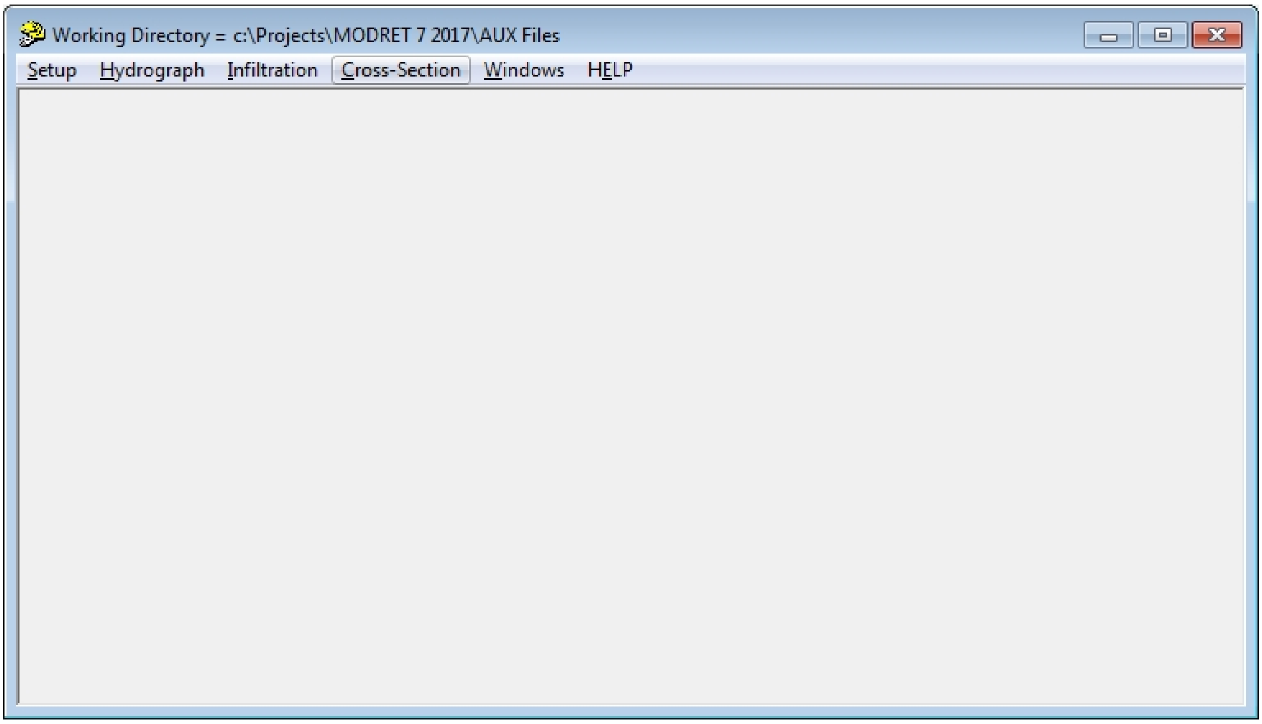
Water Elevation generates a graphical view of the water elevation in the pond vs time. The maximum water elevation is displayed at the bottom.

PRINTING & EXPORTING RESULTS



All displays of graphical results are provided with a tool kit (top-left corner) to customize the graphs for printing or saving. Each graphical result can be printed as displayed or customized by changing axis to print only the portion of the graph of interest. In the tool kit there are options to view the data sets, export them to excel or other format and/or edit other parameters.

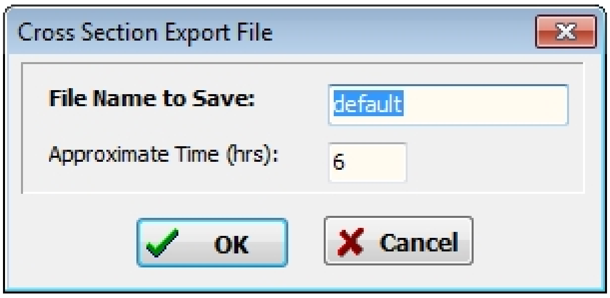
CROSS-SECTION Module



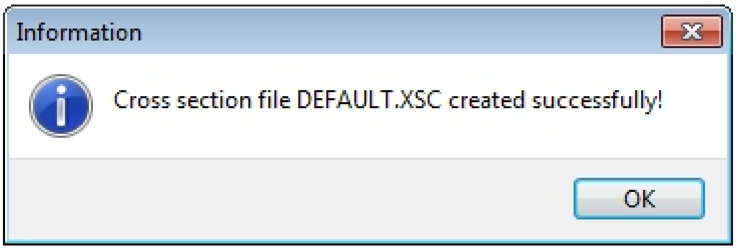
Cross-Section

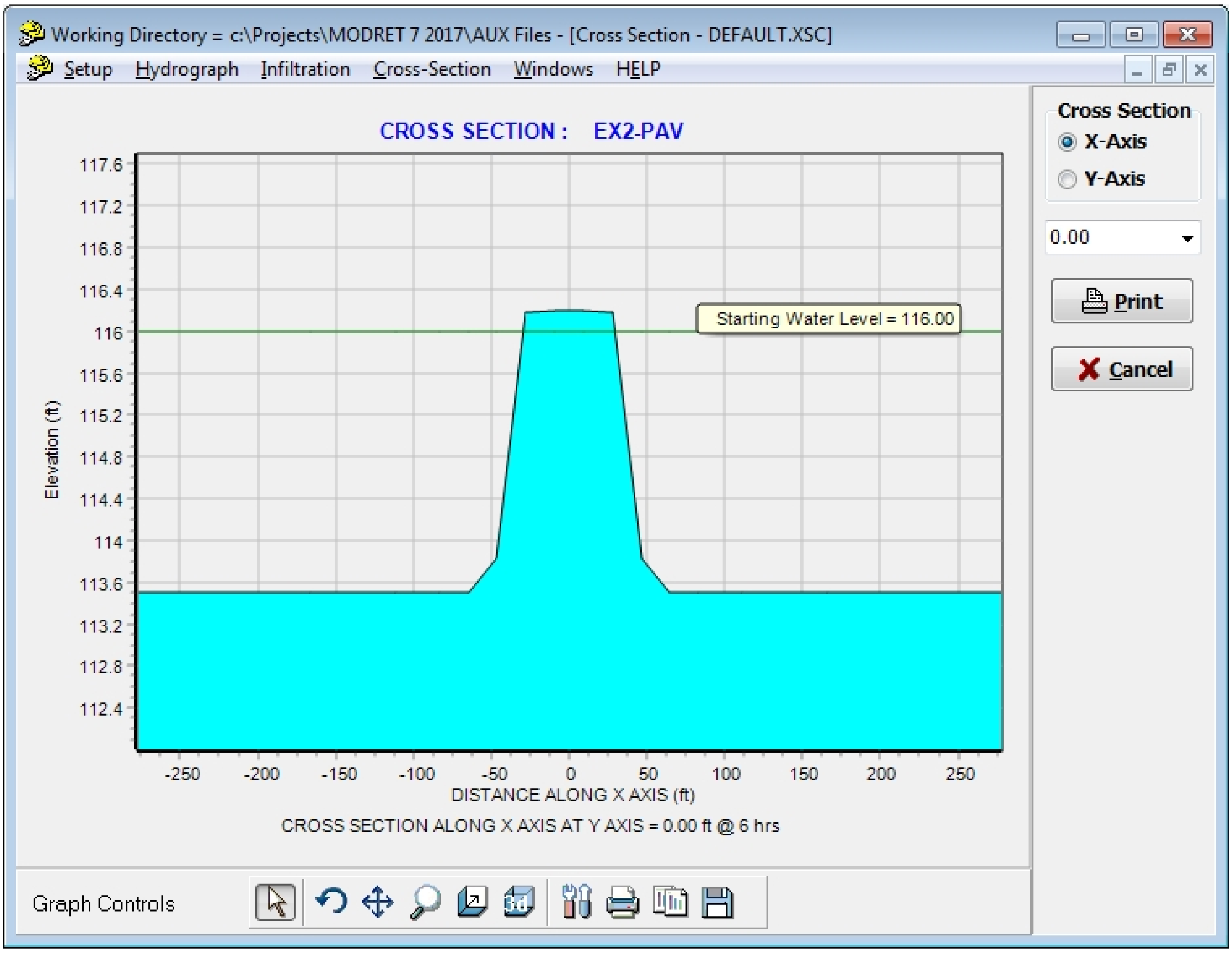
The **Cross-Section** module allows creation of various cross sections through the pond at preset lines (through center, edges and beyond). The resulting cross section graphical plots can be viewed and printed. Clicking on **Cross-Section** then **New** to create a file with a series of present cross sections through the pond and surrounding areas.

Clicking on **New** will display the following window:



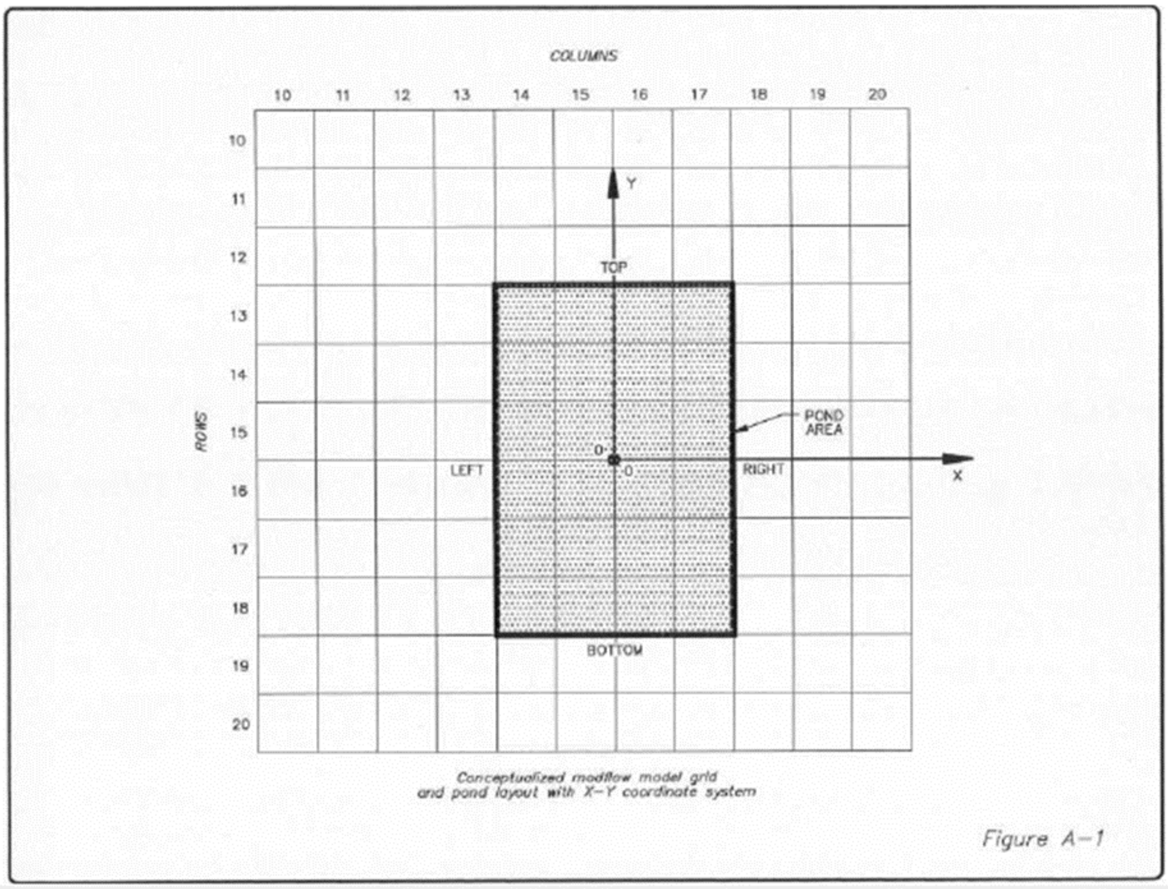
The program prompts the user to specify the File Name to be created and saved, and the approximate Time of the model simulation, see above. The model then selects the closest Stress Period modeled for the file creation. Note that MODRET uses the latest MODFLOW output file to create this data file. **Therefore, this should be created immediately after executing the infiltration model**. After specifying the name and time the model will create the cross section file and the following message will appear if successful.





Clicking **Cross-Section** then **Open** will allow the user to select the newly (or previously) created cross section file with the extension *.**xsc**. Double click on the desired file name or type in the desired name and extension, then click **Open**. This option allows a graphical display of various groundwater elevation cross sections through the pond and vicinity. On the top-right corner of the graph display the options of X-Axis and Y-Axis will appear. Select the desired cross section for display, i.e., X or Y. Directly below the X & Y option box, the corresponding distances in the perpendicular direction are summarized. Click on the down-arrow and select the desired distance of the Cross Section for which viewing of groundwater level profile is desired. Below is an example of a cross section graphic running along X-axis at Y-axis = 0.0:

The X-axis runs along the width of the pond, starting at the center of the rectangular equivalent of the pond. Positive values are to the right and negative values are to the left of the center of pond. The Y-axis runs along the length of the pond, up and down, starting at the center of the pond. The positive numbers are to the top and the negative numbers are to the bottom. Selection of one of these options will display a set of coordinate distances along the perpendicular axis to the selected axis. The cross-sectional distances from the pond center are selected by MODRET, based on the size of pond and groundwater control features. However, as a minimum there will be a cross section through the center of pond and along the edges of pond. By selecting one of the distances, the corresponding groundwater cross section graphic will be generated. A conceptualized pond within the model grid system and X, Y coordinates are presented below:



Modify the graph axis, color, patterns, etc., as needed, using the tool kit at the bottom-left of the graph. Click the **Print** button to print the graph. To view an elevation at a particular distance from the pond, it is most convenient to select an axis range that ends at the desired distance from center of pond then view the elevation at the boundaries of the graph.

References

REFERENCES

Andreyev, N.E., and Wiseman, P.L. 1989. Stormwater Retention Pond Infiltration Analysis in Unconfined Aquifers, Research Report by Jammal & Associates, Inc., Winter Park, Florida;
for the Southwest Florida Water Management District, Brooksville, Florida.

Bouwer, H. 1978. Groundwater Hydrology, McGraw-Hill Series in Water Resources and

Environmental Engineering, New York.

Grant, D.M. 1985. Open Channel Flow Measurement Handbook, Second Edition, ISCO, Inc., Lincoln, Nebraska.

Kuichling, Emil. 1889. The Relation Between the Rainfall and the Discharge of Sewers in Populous Areas, Transactions of the American Society of Civil Engineers, Vol. 20, pp. 1-56.

McDonald, M.G. and Harbaugh, A.W. 1984. A Modular Three-Dimensional Finite Difference Ground-Water Flow Model (MODFLOW), U.S. Geological Survey.

Pagan A.R. 1972. Rational Formula Needs Change and Uniformity in Practical Applications, Water Sew. Works, October.

Stubchaer, J.M. 1975. The Santa Barbara Urban Hydrograph Method, Proceedings of the National Symposium of Hydrology and Sediment Control, University of Kentucky, Lexington.

Wanielista, M.P. 1990. Hydrology and Water Quality Control, Wiley, New York.

Wanielista, M.P., and Yousef, A.Y. 1993. Stormwater Management, University of Central Florida, Orlando, Florida.

Examples

EXAMPLE PROBLEMS

INTRODUCTION

In an effort to continue improving the analytical approach and understanding of the stormwater infiltration analysis, a series of example problems were developed to complement the computer program MODRET, Version 7.0. These example problems and the corresponding computer program MODRET are supplemental to the original research and development of analytical approach to design stormwater retention ponds in unconfined aquifers. The reader is encouraged to read and understand the methodology and analytical approach presented in the Stormwater Retention Pond Infiltration Analyses in Unconfined Aquifers manual (Andreyev, Wiseman, 1989) prior to using this supplement. A copy of the referenced document is included in the HELP menu of the model. Although there are some differences (improvements) in the latest version of the MODRET program from the original presentation of the methodology in the referenced manual, the overall approach and the technical backup have not changed.

The MODRET computer model has undergone several revisions since the original publication in 1990. The latest version (Version 7.0) incorporates the following three distinct sub-programs and a HELP module:

- Hydrograph Generation Module for single contributing area simulation
- Infiltration Analyses Module, which incorporates unsaturated and saturated analysis, the main analytical tool of the MODRET model. In this version the routing through the

retention pond is included in the Infiltration Module.

- Cross-Section Module to create groundwater elevation cross-sectional graphics through a selected set of X and Y axis.

- HELP Module, which includes all of User's Guide, reference documents and Example Problems

These revisions and upgrades were used in the example problems to help familiarize the user with all the available options of MODRET 7.0 model.

The example problems in the HELP module are intended to provide a step by step explanation of typical approach to design stormwater retention ponds (both dry and wet ponds) using the MODRET 7.0 program. The three examples present the use of the MODRET 7.0 model to estimate pollution abatement retention volume recovery, to generate runoff hydrographs, to calculate infiltration losses and variations of losses during and after a storm event, to model wet ponds with overflow weir and bleed-down orifices for determination of peak stage, peak discharge and discharge volume, and to evaluate the results in various tabular and graphical formats.

Example 1: Recovery of Pollution Abatement Problem

Example 2: Dry Retention Pond Routing Analysis

Example 3: Wet Retention Pond with Weir and Orifices

Recovery of Pollution Abatement Volume

EXAMPLE 1

Recovery of Pollution Abatement Volume

This example demonstrates the use of MODRET to evaluate recovery of pollution abatement volume of a dry retention pond system. The use of MODRET for recovery of pollution abatement volume is the simplest form of its application.

RETENTION POND DESIGN DATA

The design details of a dry retention pond are presented on Figure EX1-1. The pond was designed to retain and adequately dissipate pollution abatement volume of 0.55 acre-feet. In order to comply with the minimum requirements of the project, sufficient direct storage volume must be provided in the pond to retain the 0.55 acre-feet. Given the pond geometry and the aquifer hydraulic parameters, the MODRET model will be used to determine if the pollution abatement volume recovery is possible within a period of three days (72 hours) after the storm event (project requirements). The pond design specifies a pond bottom area of 48,500 ft^2, and a pond area at the overflow level (42.28 feet) of 51,250 ft^2. From Figure EX1-1, the approximate length of pond is 355 feet. The ratio of length to width of pond required by the MODRET model can be calculated as follows:

$\mathbf{L}_{avg}$ = 355 feet

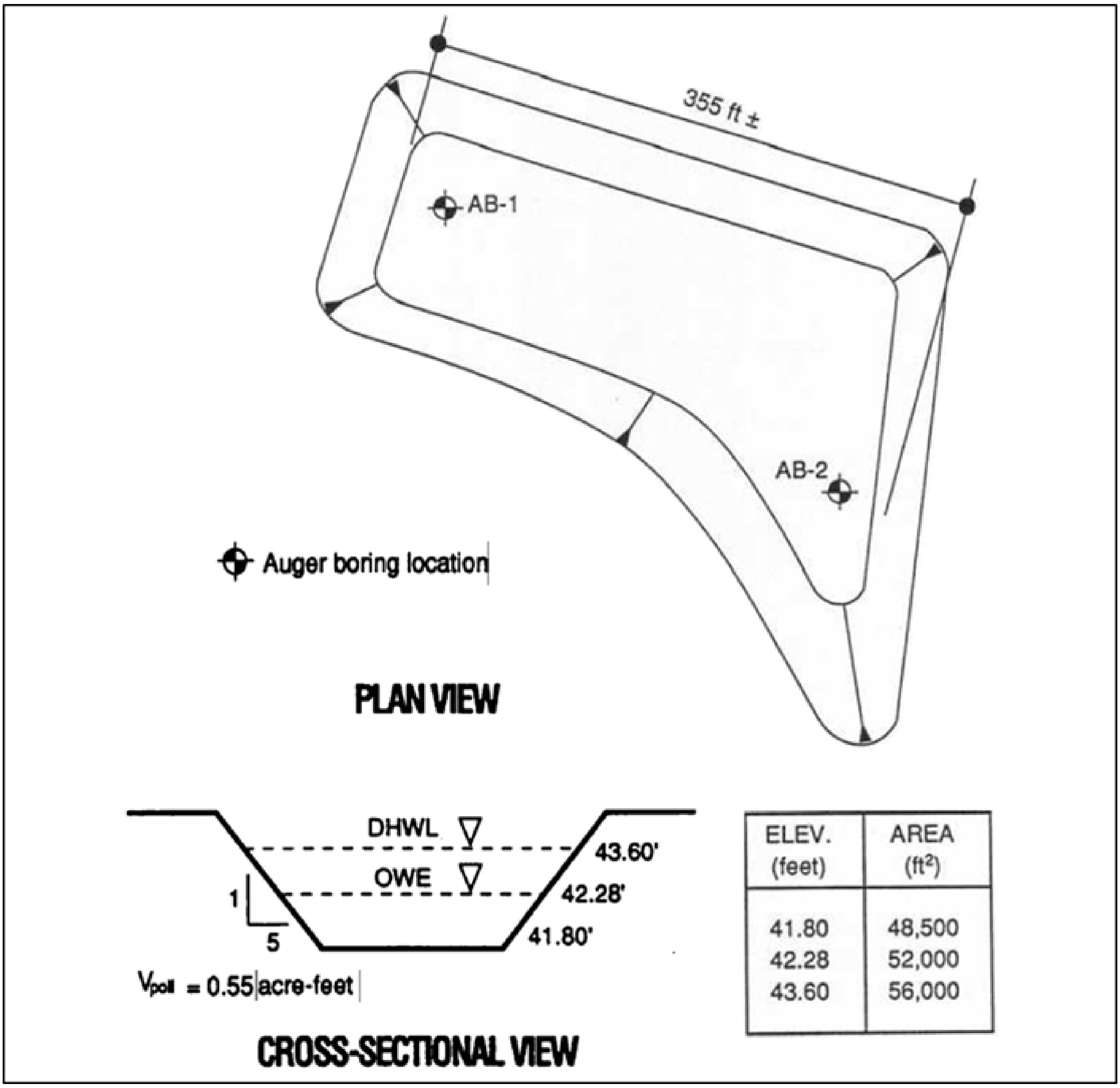
$\mathbf{A}_{avg}$ = (48,500 ft^2 + 51,250 ft^2)/2 = 49,875 ft^2

$\mathbf{W}_{avg}$ = $\mathbf{A}_{avg}/\mathbf{L}_{avg}$ = 49,875/355 = 140.5 feet Therefore, **Ratio** (L/W) = 355/140.5 = 2.53

Since pollution volume runoff is not associated with any particular storm event, the runoff duration is not known. Therefore, it is assumed that the runoff will occur in a relatively short period of time. Although the simulation of unsaturated infiltration and saturated infiltration will consume certain amounts of time, the total time of pond recovery will be evaluated based on the initial time of runoff (assuming that the entire acre-feet of runoff occurs instantaneously, i.e., a "slug" loading). This example will include both the unsaturated and the saturated analyses.

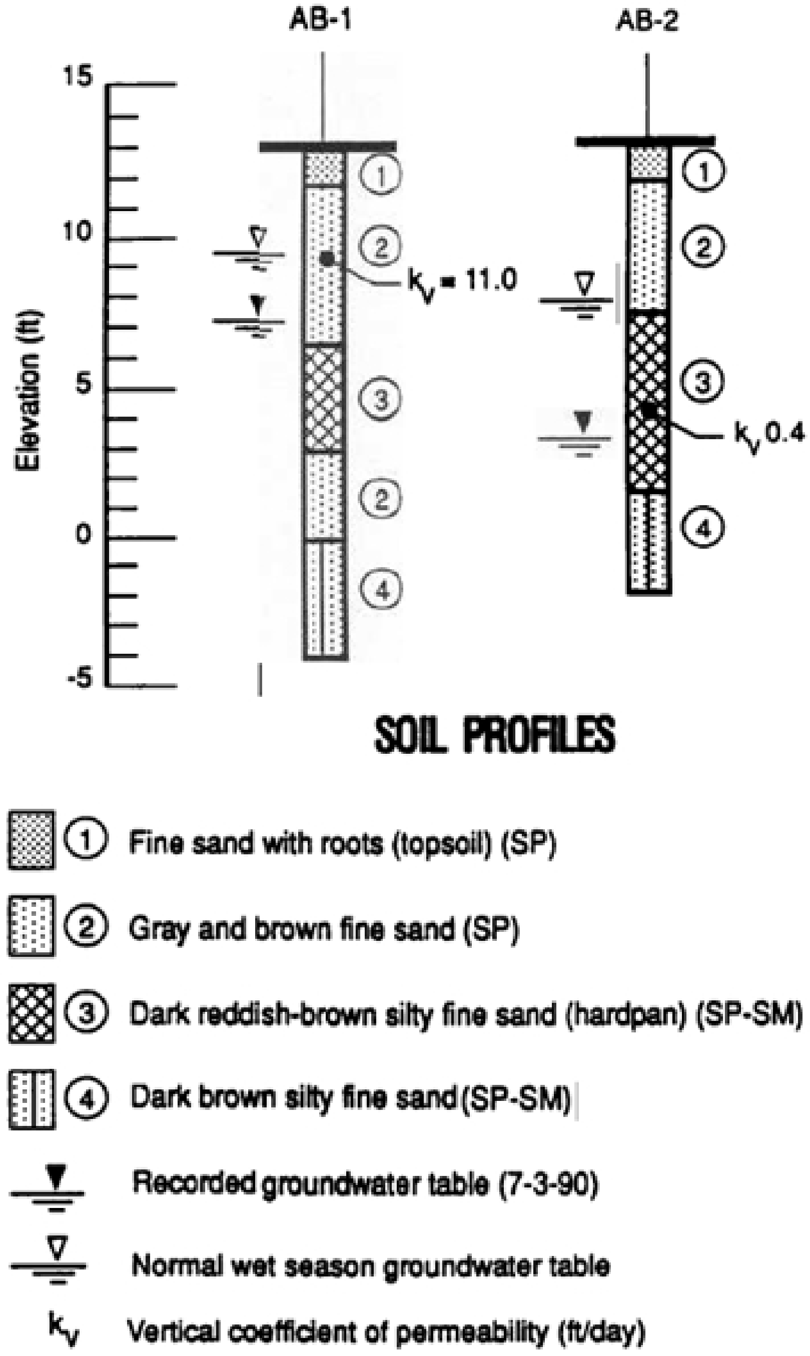
MODEL SET UP AND EXECUTION

Figure EX1-2 presents the results of soil borings and permeability (hydraulic conductivity) tests for this pond, which can be used to estimate the design aquifer hydraulic parameters as follows:



Dry Retention Pond

Figure ExI-1



Soil Profiles and Legend

Soil Profiles and Legend

Figure ExI-2

Elevation of Effective Aquifer Base: The soil profiles indicate a presence of clayey fine sands at an average elevation of about 27 feet, which can be assumed to represent the "Elevation of Effective Aquifer Base". **The effective aquifer base can be defined as the TOP of the first semi-confining soil layer or poorly permeable soil layer that occurs below the stormwater**

retention pond area.

The **Elevation of Seasonal High Groundwater Table** is estimated from the soil profile data at about 40 feet.

Effective Storage Coefficient: To estimate the effective storage coefficient for the unsaturated and saturated infiltration analyses, Table A-1 can be used, or it can be calculated from actual laboratory measurements using the following equation:

$$f = 0.9\, n\, (w\, \gamma_d / \gamma_w)$$

f = Effective Storage Coefficient n = Soil Porosity
w = Soil Moisture Content (fraction of dry weight)
γ_d = Dry Unit Weight of Soil
γ_w = Unit Weight of Water

For this example, Table A-1 will be used. For unsaturated analysis the separation between groundwater table and the pond bottom is 1.8 feet and the value of effective storage coefficient is estimated at 0.10. For saturated analysis the distance between groundwater table and the average water level of pond is 2.04 feet and the value of effective storage coefficient is estimated at 0.11.

Vertical Permeability: The results of the soil investigation indicate that only the horizontal permeability was measured. For the unsaturated analysis, the vertical permeability ($\mathbf{K}_V$) can be estimated from the horizontal permeability ($\mathbf{K}_H$) using a factor of 1.5 (established as a guideline value by the SWFWMD, hence, this factor may not apply in other areas).

Therefore,

$$\mathbf{K}_V = \mathbf{K}_H/1.5 = 17.6 \text{ fpd}/1.5 = 11.73 \text{ fpd}$$

Use the equation recommended in the research and development manual Stormwater Retention Pond Infiltration Analysis in Unconfined Aquifers (Andreyev and Wiseman, 1989) to convert $\mathbf{K}_V$ to unsaturated permeability, $\mathbf{K}_{VU}$.

$$\mathbf{K}_{VU} = 2/3\ \mathbf{K}_V = 2/3 \times 11.73 \text{ fpd} = 7.8 \text{ fpd}$$

Horizontal Permeability: The soil test results indicate a presence of clayey fine sands at an average elevation of 27 feet. The results also indicate a presence of two distinct soil layers above the clayey fine sands. A permeability test was conducted at soil boring AB-1 at a depth of about 5 feet below ground surface in stratum 2 and indicate a value of K_H = 17.6 feet per day. Permeability tests were not conducted in the slightly silty fine sands of stratum 3. As a result, it is necessary to estimate a value for K_H. This value can be conservatively estimated from local knowledge of soils or approximated from Table 3-2 (Andreyev, Wiseman, 1989), a reproduced copy of this table is presented on **TABLE A2**. Table A-2 indicates a permeability range of 0.5 to 5 feet per day for the slightly silty fine sands. For this example problem a value of 2 feet per day will be used (estimated). To calculate a weighted average horizontal permeability use the following formula:

$$K_{Havg} = \frac{K_{H1} \times m_1 + K_{H2} \times m_2 + \ldots K_{Hi} \times m_i}{\sum m}$$

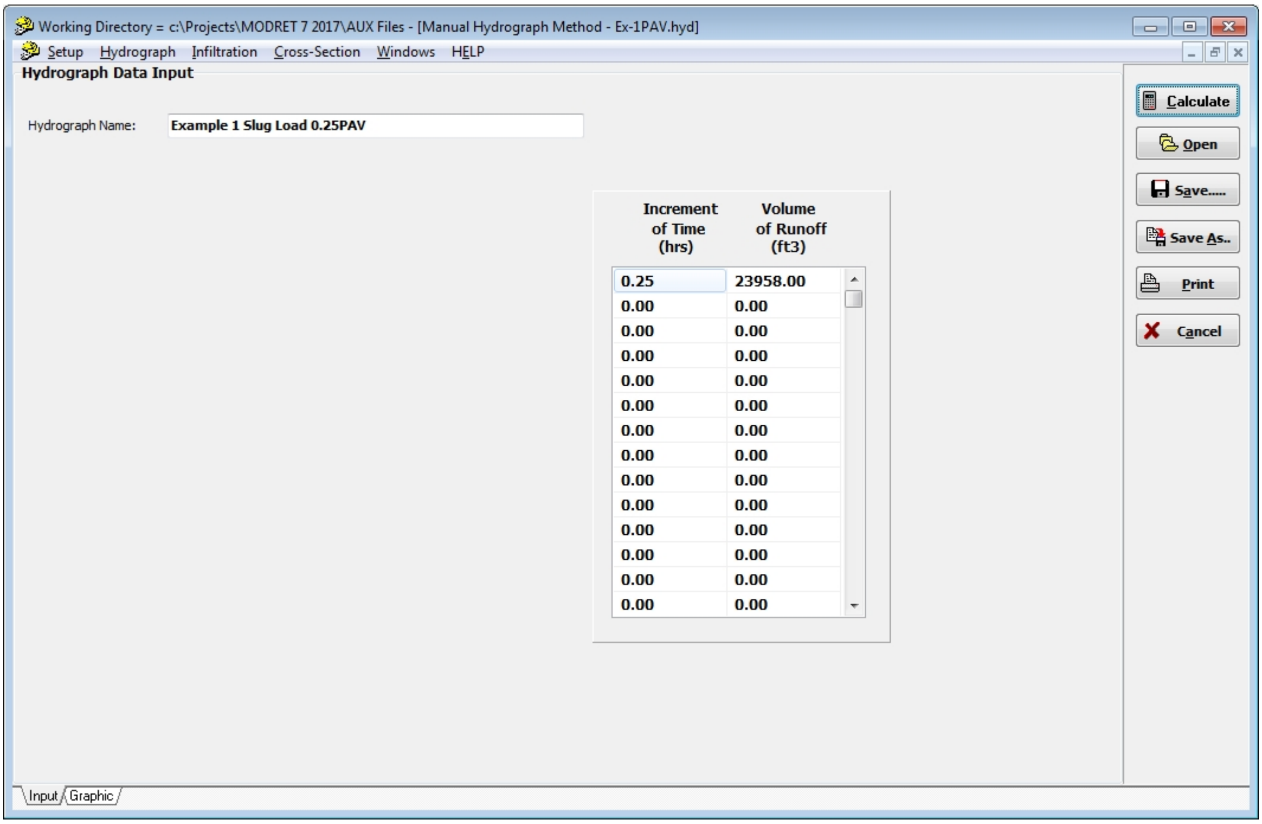
The effective aquifer layers, 1 to i, are those located between the design high water level in the pond (estimated at elevation 42 feet) and the base of effective aquifer (elevation 27 feet). For this example, the thickness of stratum 2 is estimated at 11 feet and of stratum 3 at 4 feet.
Therefore:

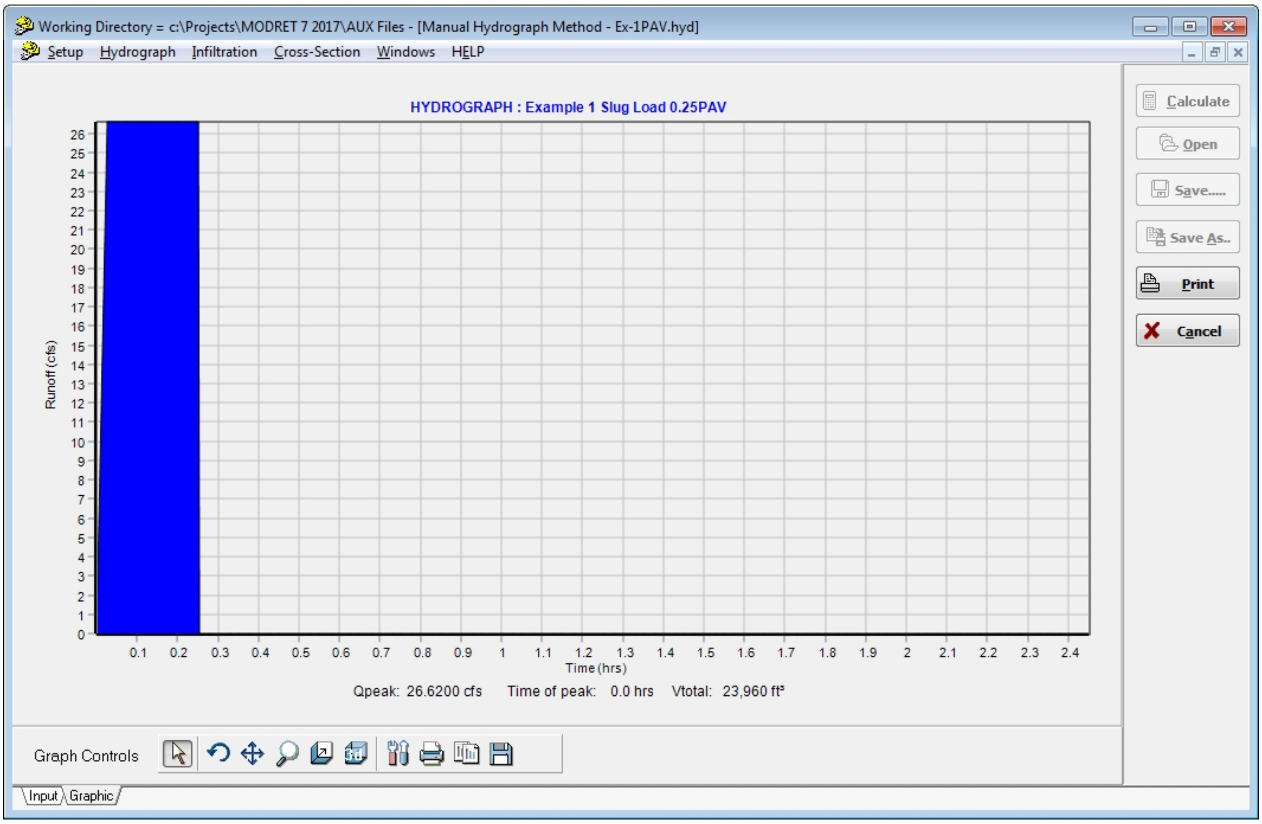
$$K_{Havg} = \frac{17.6 \text{ fpd} \times 11 \text{ ft} + 2 \text{ fpd} \times 4 \text{ ft}}{15 \text{ ft}} = 13.44 \text{ feet per day}$$

Use, K_{Havg} = 13 feet per day

Pond Volume: This version of MODRET calculates this automatically, using the stage area and the DHW and DLW data. The pond volume between the design low water level (pond bottom in this case) and design high water level (overflow level in this case) is 24,120 ft^3, which was calculated from the pond areas vs elevation data, provided on Figure EX1-1 ((48,500 + 52,000)/2) x 0.48). The pond volume between DHW and DLW **can be different** to the pollution abatement volume (in this case 0.55 ac-ft = 23,958 ft^3).

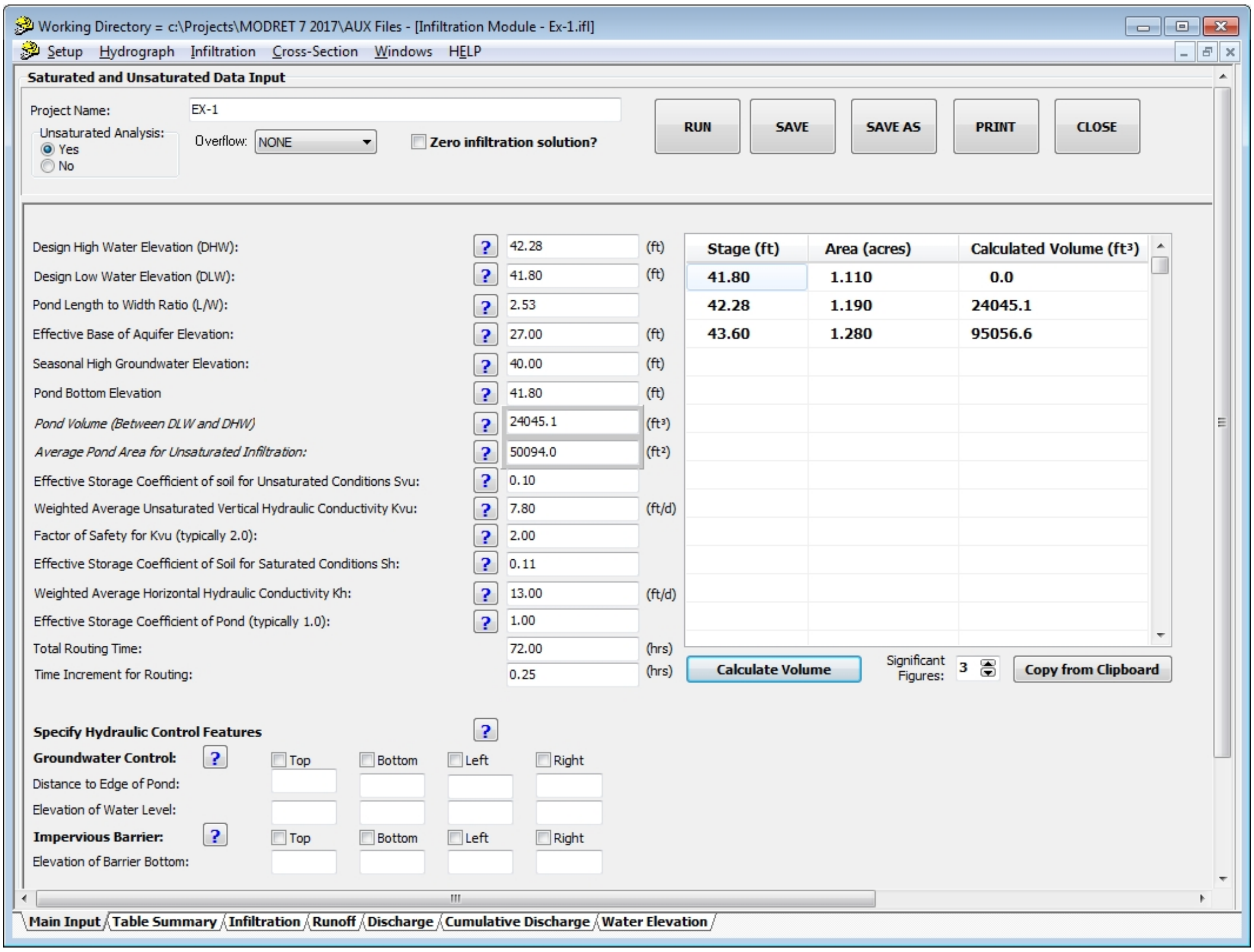
Average Pond Area: This version of MODRET calculates this automatically, using the stage area and the DHW and DLW data. The average pond area (effective area for unsaturated infiltration) is ((48,500 + 52,000)/2) = **50,250 ft^2**, from Figure EX1-1. **Slug Load Hydrograph**: In this version of MODRET the pollution abatement volume is introduced into the model in a form of “slug load hydrograph” which needs to be created in the Hydrograph module of the model. For the slug load hydrograph, the entire pollution abatement volume is entered in a single initial time increment. The time for the slug load should be short (0.25 hours is recommended to simulate typical short rainfall event). Refer to Hydrograph Module in HELP to create the slug load hydrograph. The following are the entry table and the resulting graph of the slug load hydrograph created for this example:

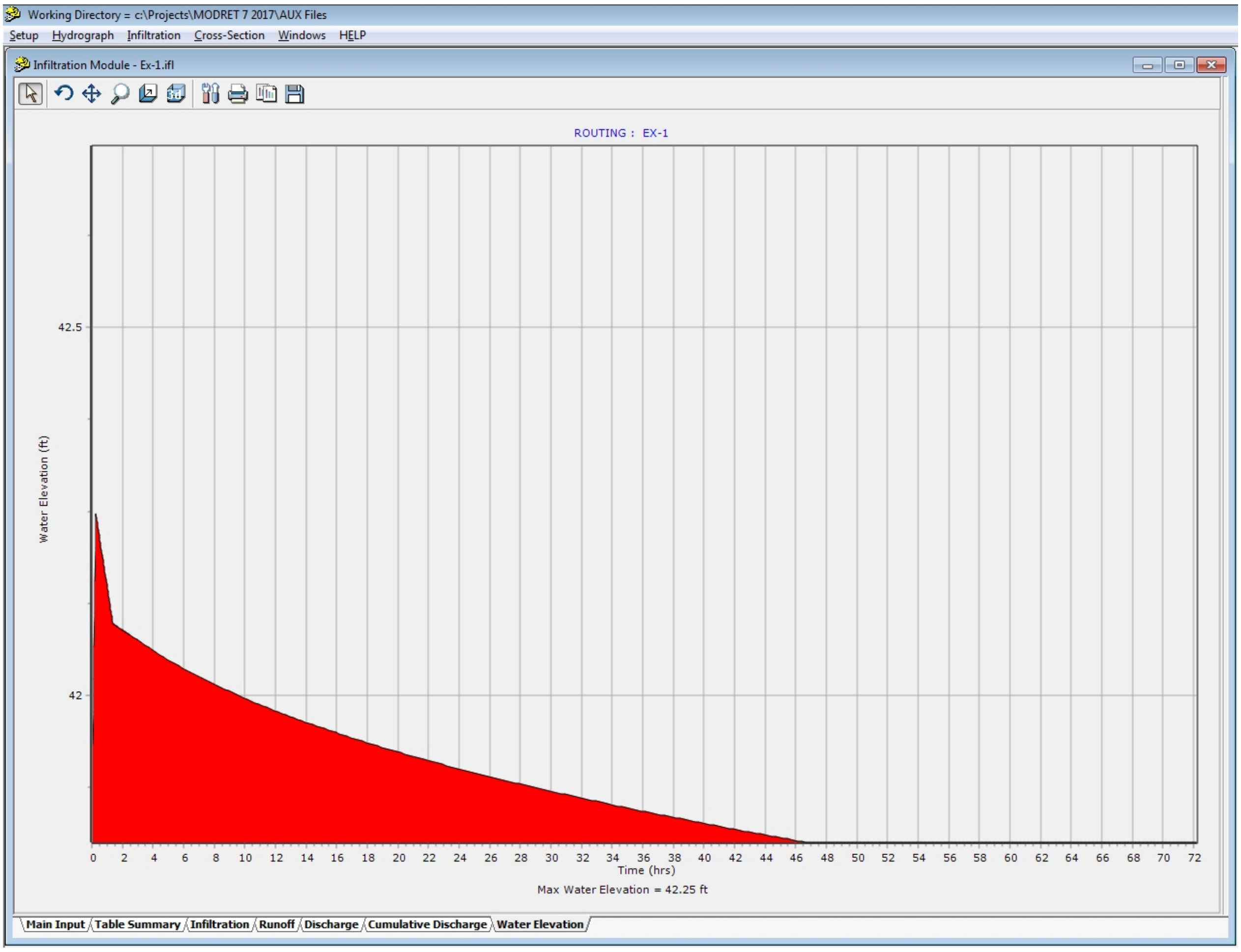




After entering the pond and aquifer parameters in the infiltration module, the Total Routing Time must be set to the total recovery time for this example, at 72 hours. The Overflow option should be set to NONE. Click on Save As and specify a file name (i.e., example_1.ifl), then click on Run to execute the MODFLOW.

When MODFLOW has finished, click on OK and review the results by clicking on the tabs at the bottom of the screen. For this example, it is only necessary to click on the Water Elevation tab and review the graph. The following data input screens and resulting water elevation screens are presented:





MODEL RESULTS AND EVALUATION

Results: The results of this analysis can be viewed graphically on the Water Elevation graph. The graph can also be printed for inclusion in a report. The results indicate that the water level in the pond will recede below pond bottom within the 72-hour period after the instantaneous runoff. Therefore, the pond is designed properly, and complies with the water quality requirements of this project.

Evaluation: The time corresponding to the elevation of water level receding to the pond bottom can be picked off from the **Water Elevation versus Time** graph. From the graphical data above it is estimated that the time of recovery (when water level receded to the pond bottom elevation) is approximately 47 hours.

Dry Retention Pond Routing Analysis

EXAMPLE 2

Hydrograph Generation and Infiltration Routing

Dry Retention Pond with Overflow Device

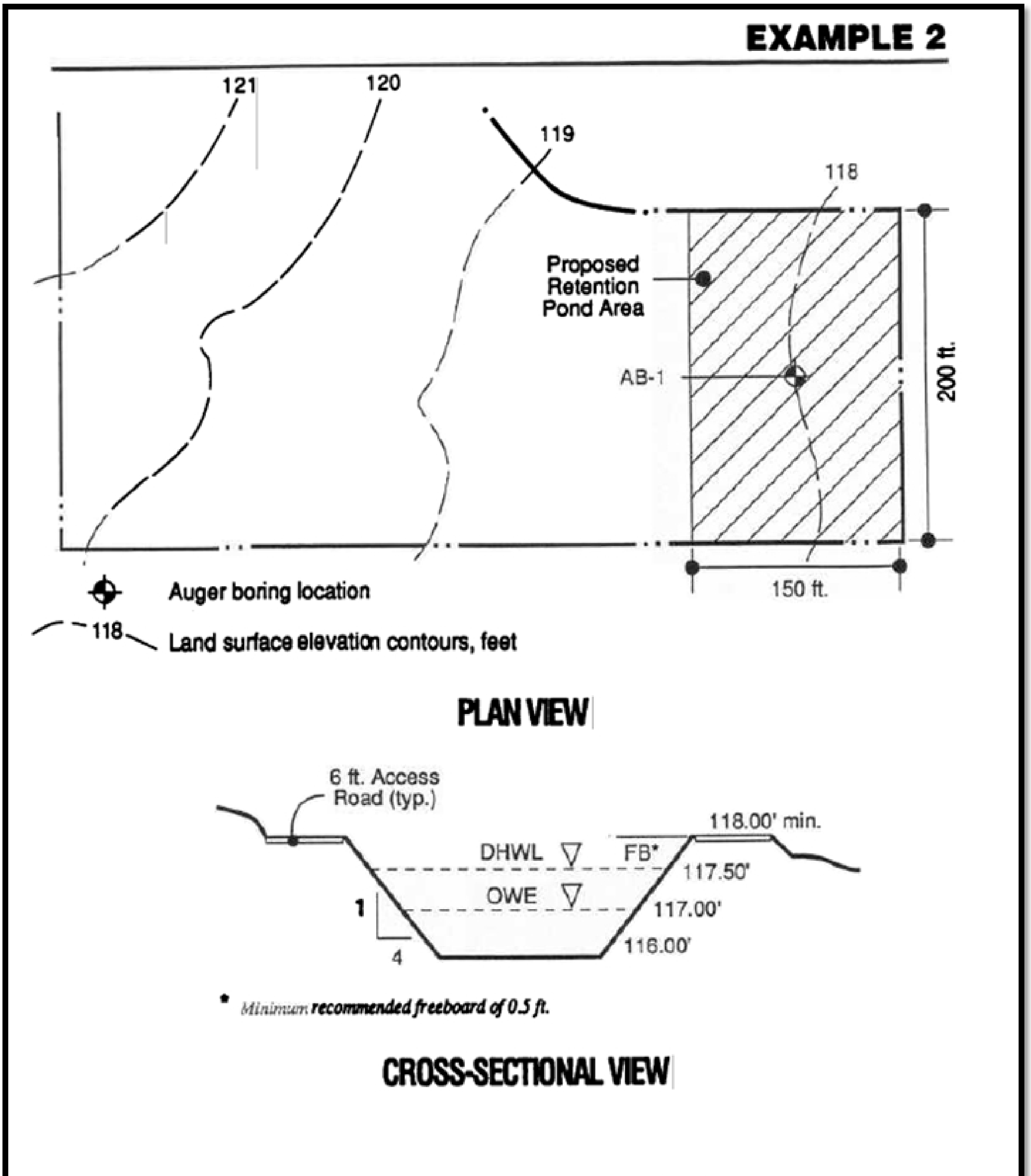
In this example, an analysis of runoff hydrograph generation, a determination of infiltration losses for a single pond, which includes automatic routing of the runoff hydrograph and recovery period, allowing peak stage and discharge determination. MODRET 7.0 has a capability to generate single watershed runoff hydrographs, using the SCS Unit Hydrograph method, the Rational Hydrograph method, and the Santa Barbara Urban Hydrograph method. The additions in MODRET 7.0 also allow creation of back to back runoff hydrographs, creation of multiple hydrograph for FDOT storms (batch hydrograph generator) and an option to add a second hydrograph (runoff or discharge) to allow cumulative effect modeling of multiple ponds. In this example, some of these options will be demonstrated, together with the presentation of the various capabilities of the model to graphically display input and output data.

RETENTION POND DESIGN DATA

The retention pond is designed to receive stormwater runoff from a single watershed with the following parameters of surface runoff characteristics:

Watershed Area: 4.0 Acres
Weighted Average Curve Number, CN: 80 (pre-development), 89 (post-development)
Time of Concentration, tc: 20 Minutes (pre-development), 17 Minutes (post-development)
DCIA Area: 0.0 acres
Design Rainfall Depth: 5.2 Inches
Storm Duration: 24 hours
Rainfall Distribution: SCS Type II - Florida Modified
Shape Factor: 323

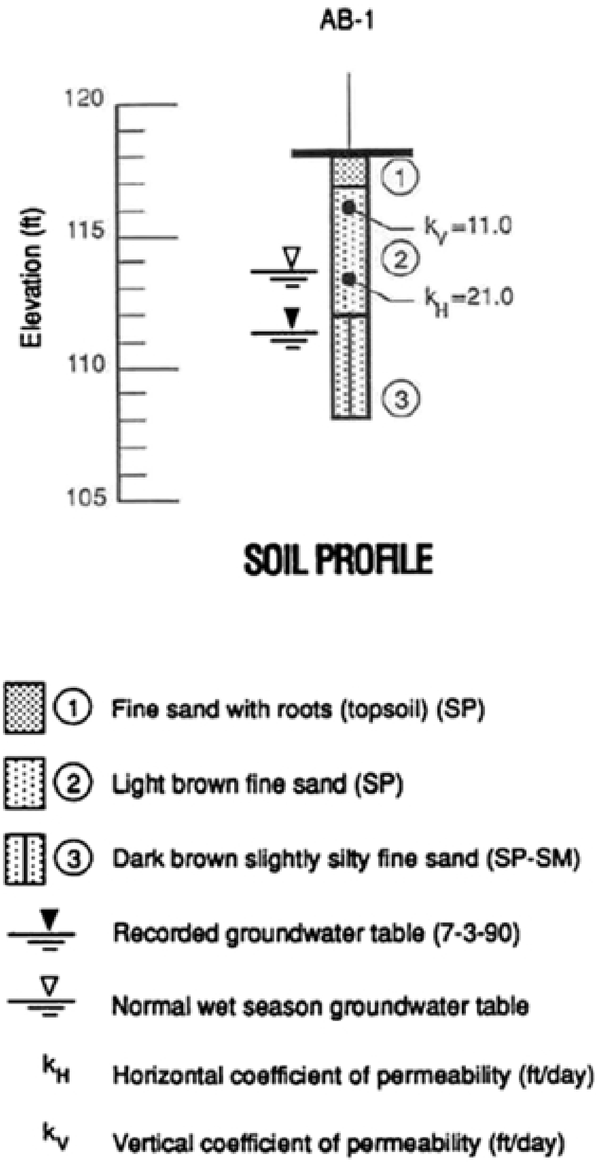
A site plan and location of soil boring are presented on Figure Ex2-1below.



Dry Retention Pond Routing Analysis
Figure Ex2-1

The design criteria for this pond is as follows:

The stormwater retention pond for this example will be assumed to be located within a designated area of 200 feet by 150 feet, at the lowest portion of the project site. The site soil conditions are to be represented by the results of one soil boring and two permeability tests, the results of which are presented on Figure Ex2-2.



Soil Profiles and Legend
Figure Ex2-2

Design a dry retention pond to retain 1/2-inch of runoff from the watershed area (pollution abatement volume), which must dissipate within a period of 72 hours. The runoff of the 1/2-inch pollution abatement volume (PAV) is not related to the 24-hour storm event to be used for pre/post development retention/detention modeling.

Design the pond and the overflow device to retain the difference between the pre-development and the post-development runoff volumes. One-half (50%) of the total pond volume between pond bottom and overflow level must dissipate within a period of 36 hours after the storm event. Calculate the time of dissipation of the remaining 50% of the pond volume. The design high water level (DHW) of the pond should not exceed 118.0 feet to minimize filling the site for development.

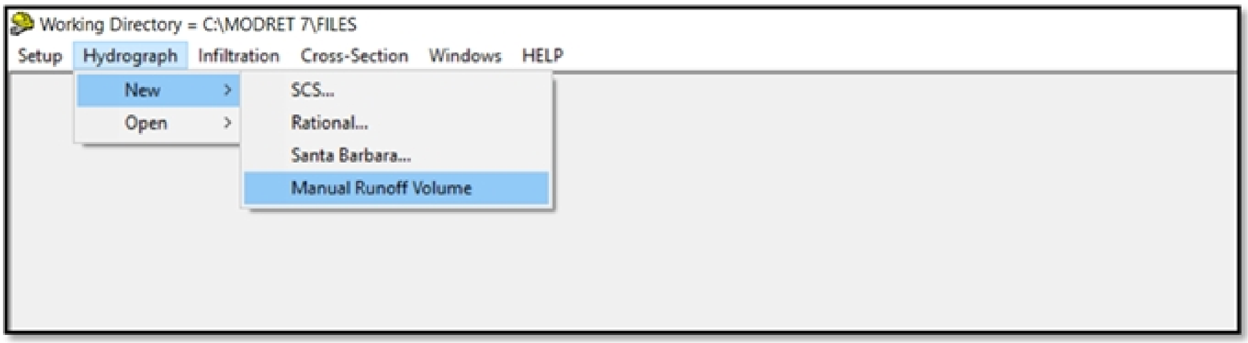
MODEL SET UP AND EXECUTION

In MODRET 7.0 all runoff forms must be specified by a runoff hydrograph. Unlike previous version of MODRET, where runoff could be specified by a PAV volume or manual runoff in the Infiltration module, MODRET 7.0 is set up to create all runoff hydrographs in the "Hydrograph" module. Initially, the pollution abatement volume (PAV) will be calculated and the runoff hydrographs for PAV, pre-development and post-development conditions will be created. Then the modeling for PAV and pre/post scenarios will be presented.

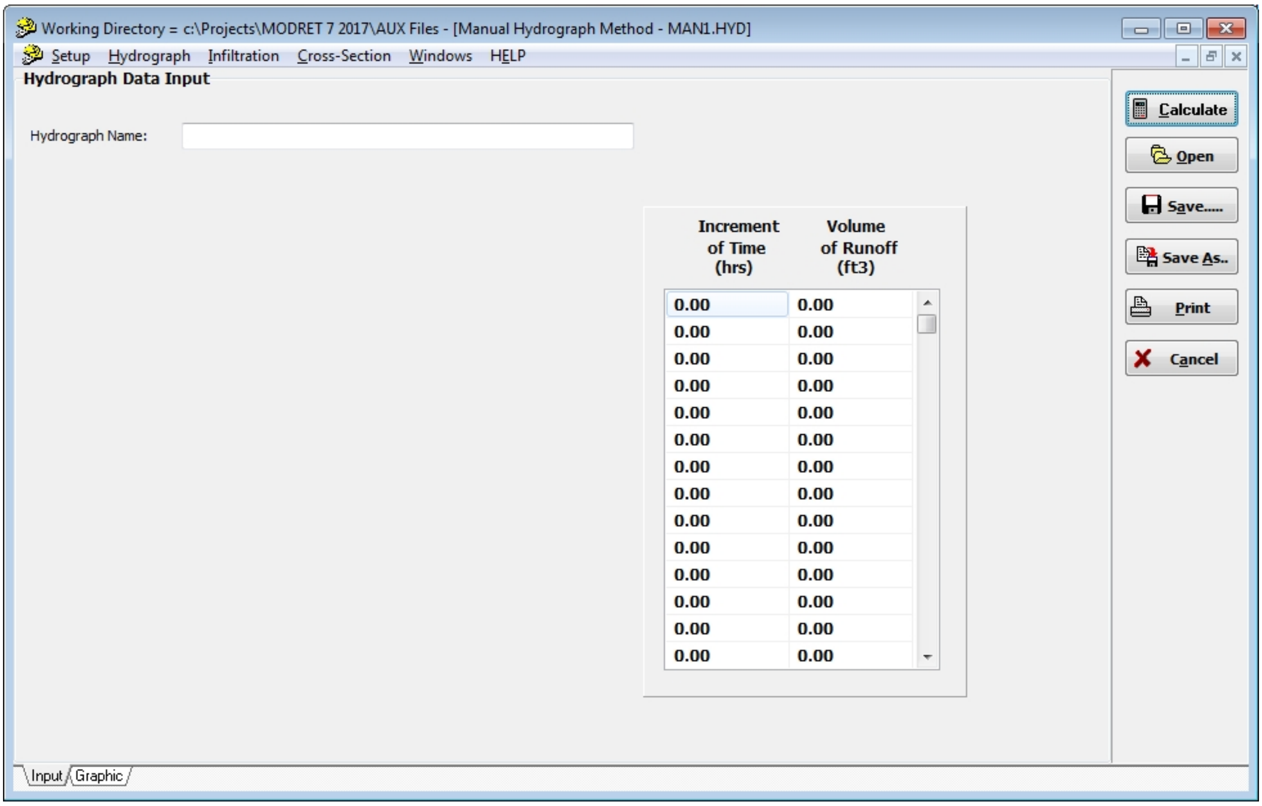
Calculate PAV:

$$PAV = 0.5 \text{ in} \times 1 \text{ ft}/12 \text{ in} \times 4.0 \text{ acres} \times 43{,}560 \text{ ft}^2/\text{acre} = 7{,}260 \text{ ft}^3$$

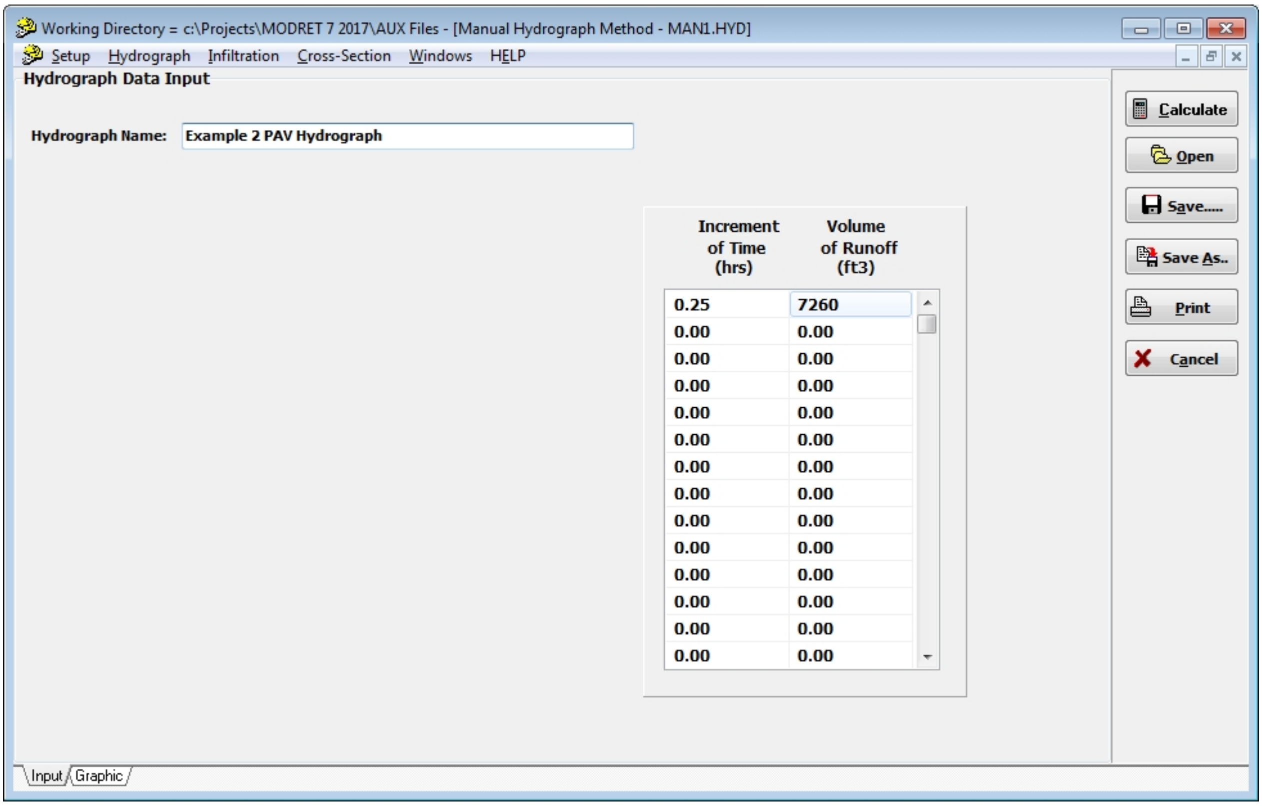
Create the PAV, Pre & Post Runoff Hydrographs and Volumes:



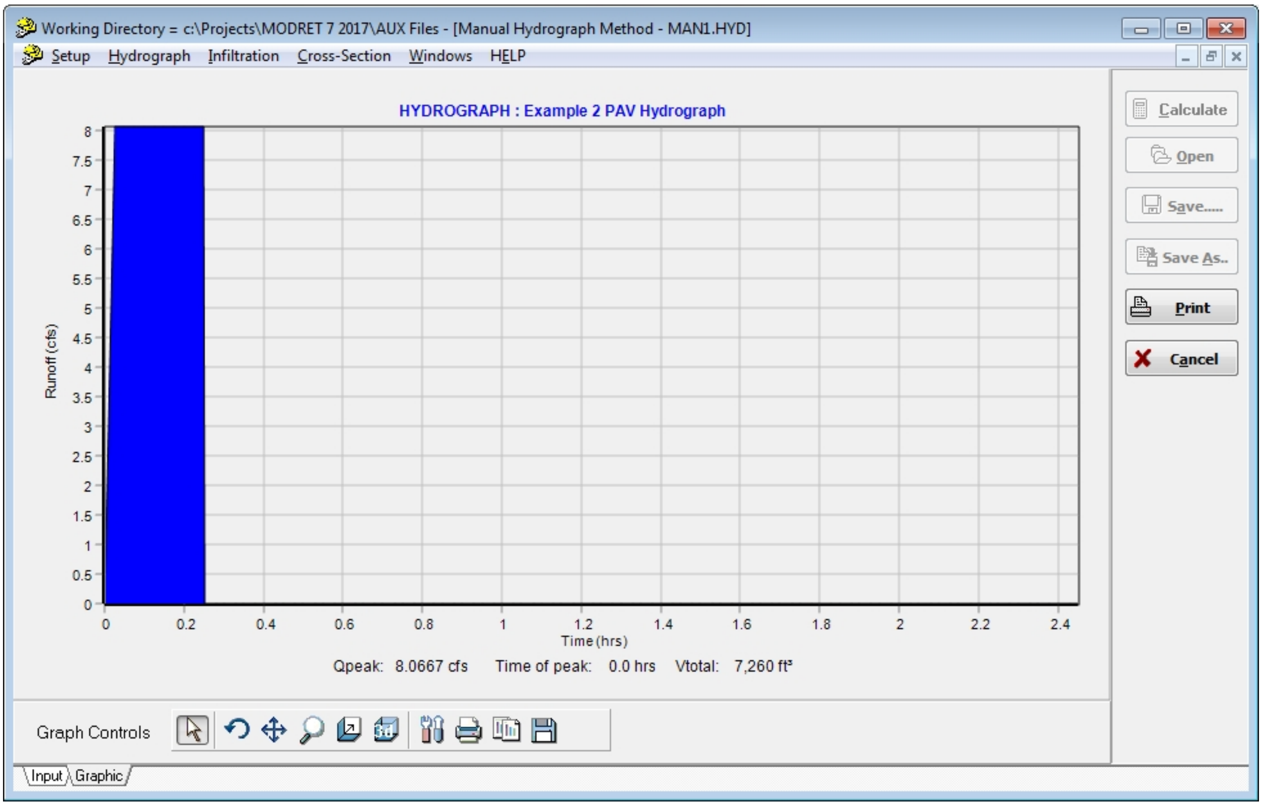
To create the PAV hydrograph (a slug load hydrograph), select **Hydrograph**, then select **New** and then Manual **Runoff Volume**. The following screens will appear:



For slug load (i.e., PAV loading), specify the entire volume of runoff over a short period of time. A time increment of 15 minute (0.25 hours) is typically appropriate for an afternoon storm event. For this example, we will specify the entire 7,260 ft^3 of runoff over a period of 0.25 hours.

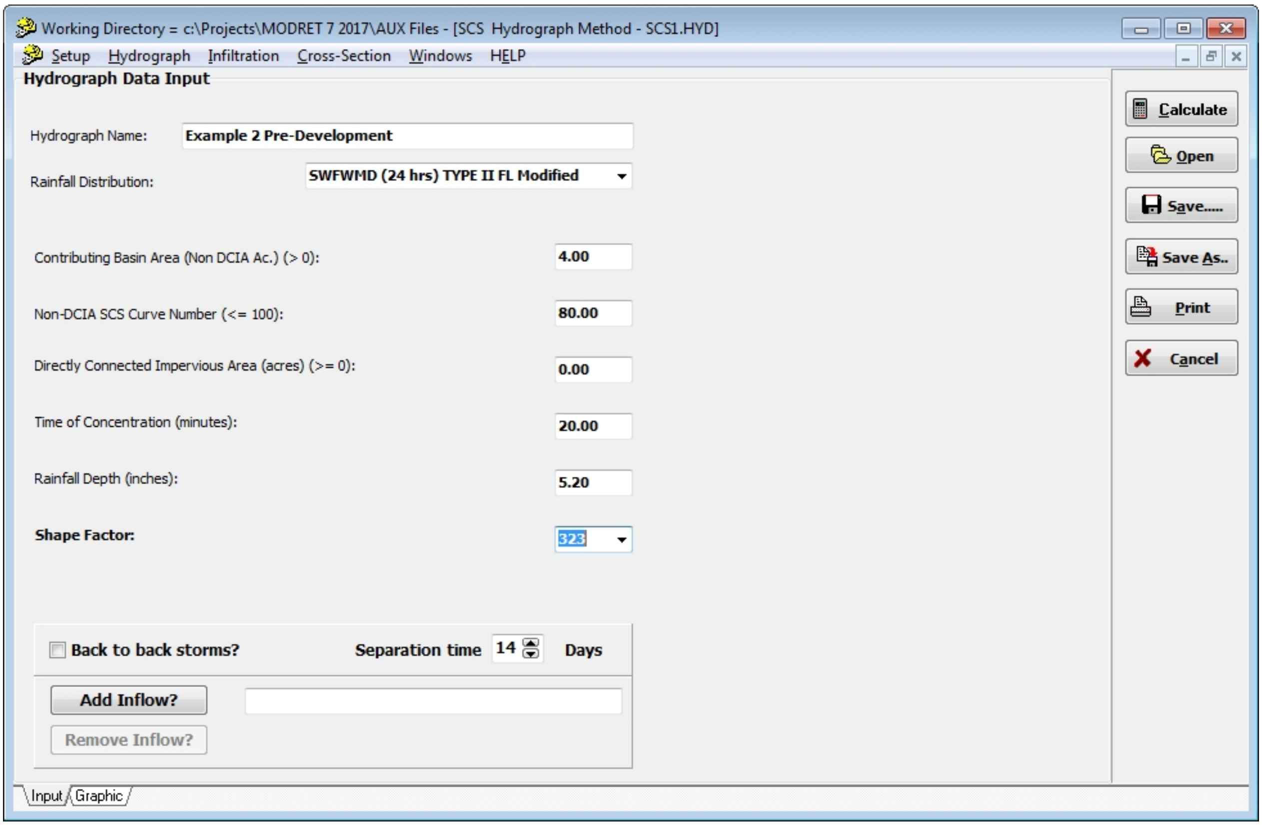


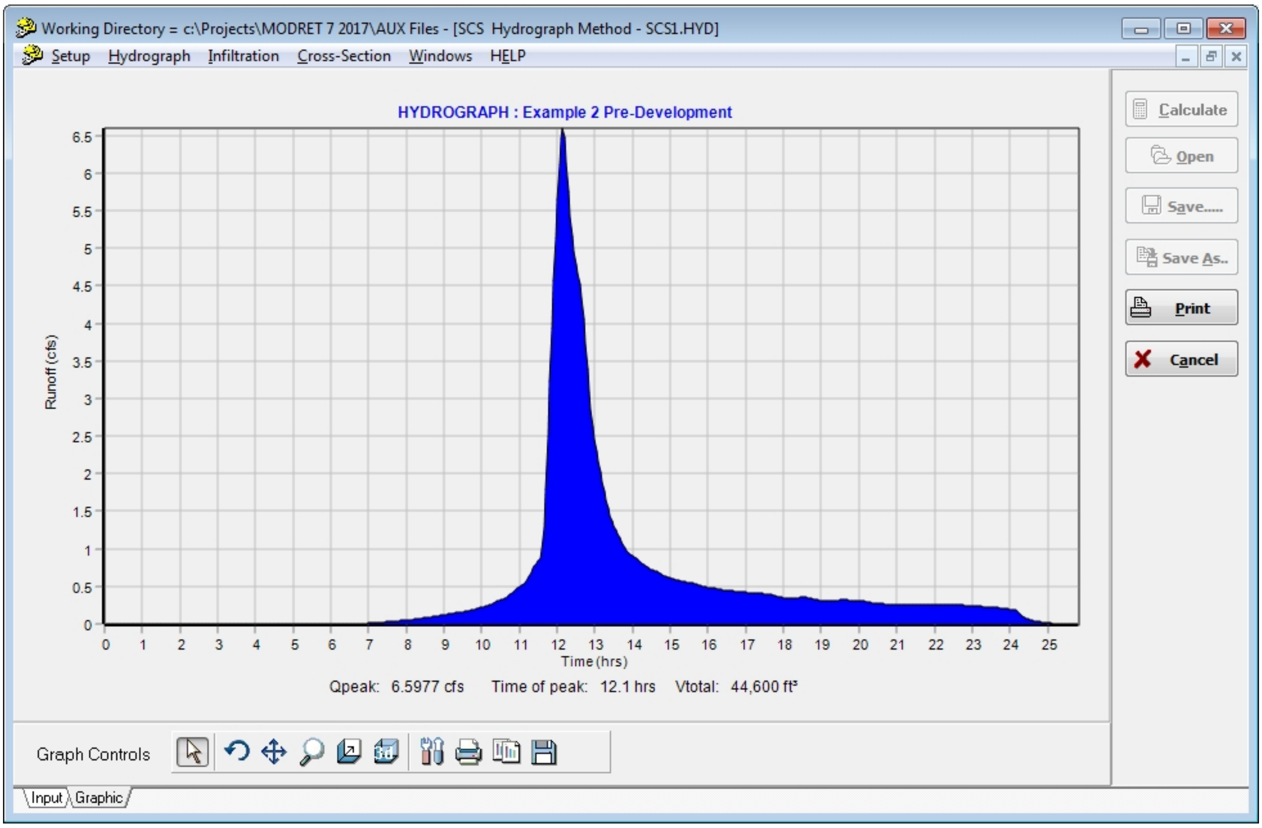
Once the slug load is entered, select **Save As..** and save the input file as **Ex-2PAV.hyd**. The extension *.hyd is convenient because to retrieve the file the model will first look for all files with this extension. Of course, the user can specify any name and any extension as long as during retrieval the user can remember the name and/or extension to find the file. Once saved, click **Calculate** to create the hydrograph. Then click **Graphic** at the bottom left of the screen to display the graphical solution of the created hydrograph, see below:

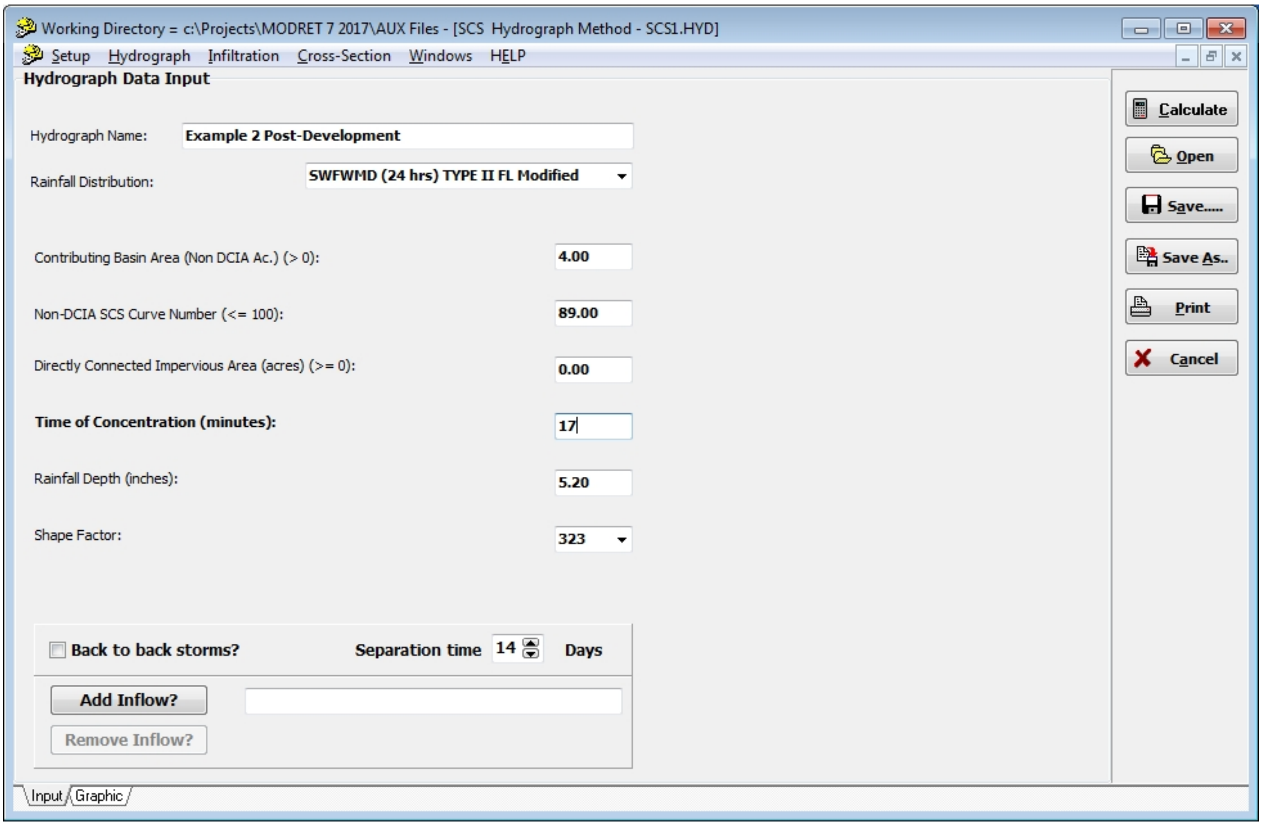


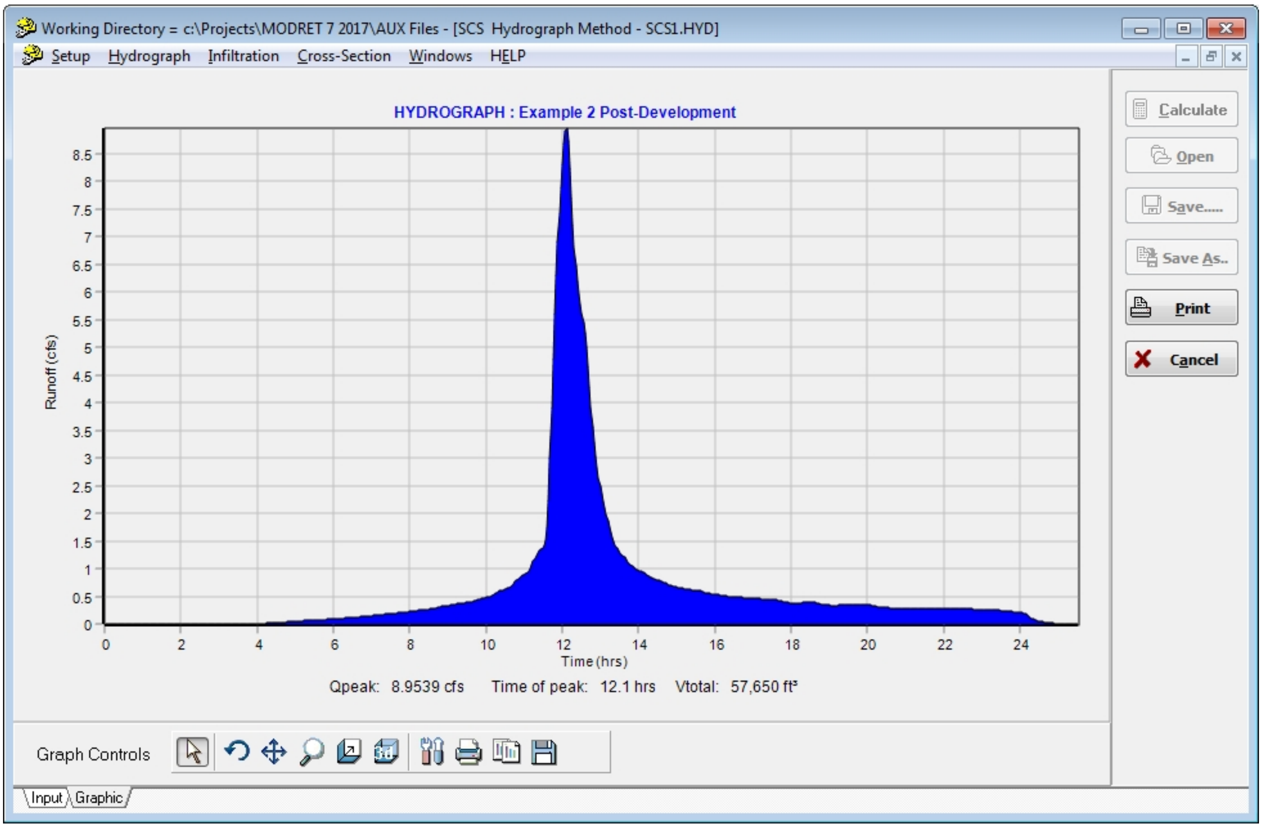
The electronic version of this hydrograph is saved by default using the same file name as the input data file, but the extension for manual runoff hydrograph will be ***.man**. So the hydrograph data is saved as **Ex-2PAV.man**. Click the Cancel button on the right side to exit back to the main screen.

To create the pre & post development runoff hydrographs, again click on the **Hydrograph**, then select **New** and **SCS...** An input data page will appear, prompting to enter the required data. From the runoff data provided above, enter the rainfall distribution, contributing basin area, CN value, time of concentration, rainfall depth and the shape factor. Click on **Save As..** and save the file as **Ex-2Pre.hyd** and **Ex-2Post.hyd**. As indicated in the project data, the SCS unit Hydrograph method was used with Type II Florida modified rainfall distribution. Then click **Calculate** and view the results graphic by clicking the **Graphic** button. The input screens and the graphical results for the two hydrographs follow:


Working Directory = c:\Projects\MODRET 7 2017\AUX Files - [SCS Hydrograph Method - SCS1.HYD]
Setup Hydrograph Infiltration Cross-Section Windows HELP
Hydrograph Data Input
Hydrograph Name: Example 2 Pre-Development
Rainfall Distribution: SWFWMD (24 hrs) TYPE II FL Modified
Contributing Basin Area (Non DCIA Ac.) (> 0): 4.00
Non-DCIA SCS Curve Number (<= 100): 80.00
Directly Connected Impervious Area (acres) (>= 0): 0.00
Time of Concentration (minutes): 20.00
Rainfall Depth (inches): 5.20
Shape Factor: 323
Back to back storms? Separation time 14 Days
Add Inflow?
Remove Inflow?
Calculate
Open
Save.....
Save As..
Print
Cancel
Input Graphic


Working Directory = c:\Projects\MODRET 7 2017\AUX Files - [SCS Hydrograph Method - SCS1.HYD]
Setup Hydrograph Infiltration Cross-Section Windows HELP
HYDROGRAPH : Example 2 Pre-Development
Runoff (cfs)
Time (hrs)
Qpeak: 6.5977 cfs Time of peak: 12.1 hrs Vtotal: 44,600 ft³
Graph Controls
Calculate
Open
Save.....
Save As..
Print
Cancel
Input Graphic





The results indicate a total runoff volume of 44,600 ft^3 for pre-development and 57,650 ft^3 for post-development, resulting in a difference of 13,050 ft^3. The corresponding peak runoff rates are 6.59 cfs and 8.95 cfs, respectively.

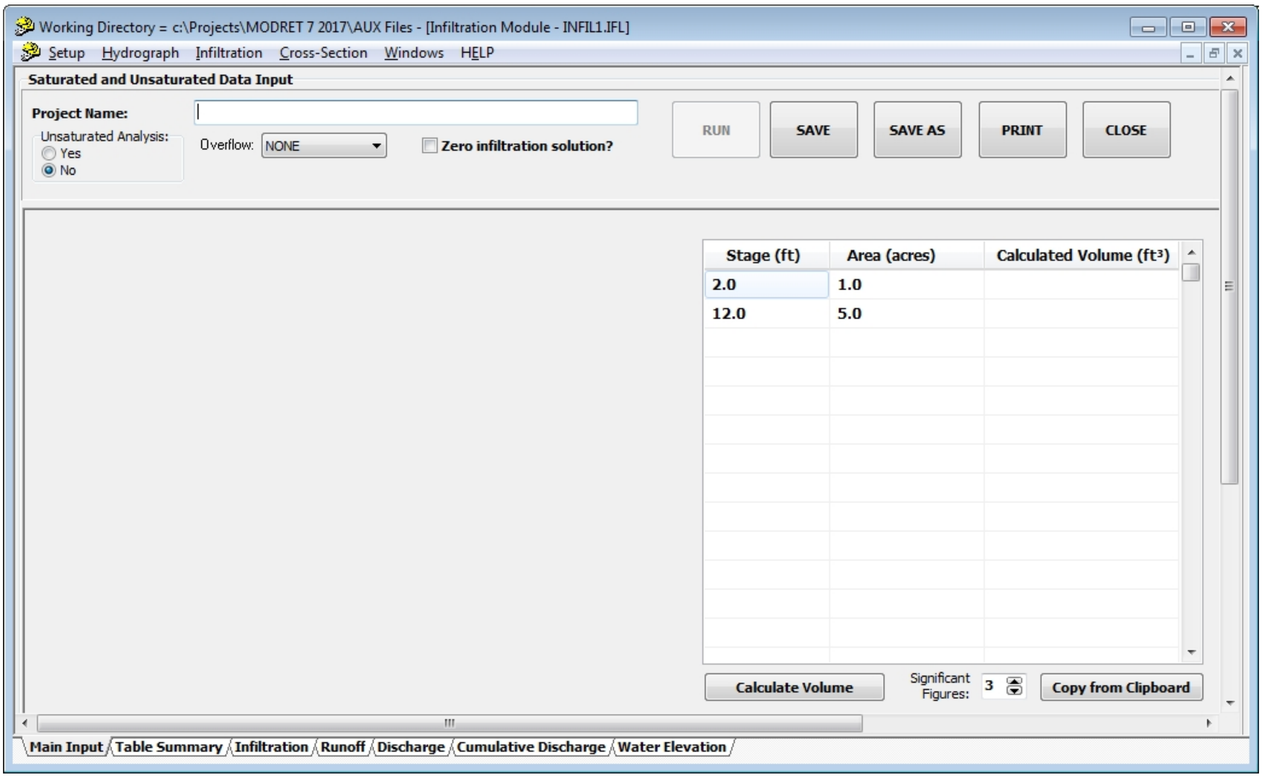
Selection of Pond Geometry and Characteristics: To design the most efficient geometry of the pond (hydraulically), the following general guidelines can be followed:

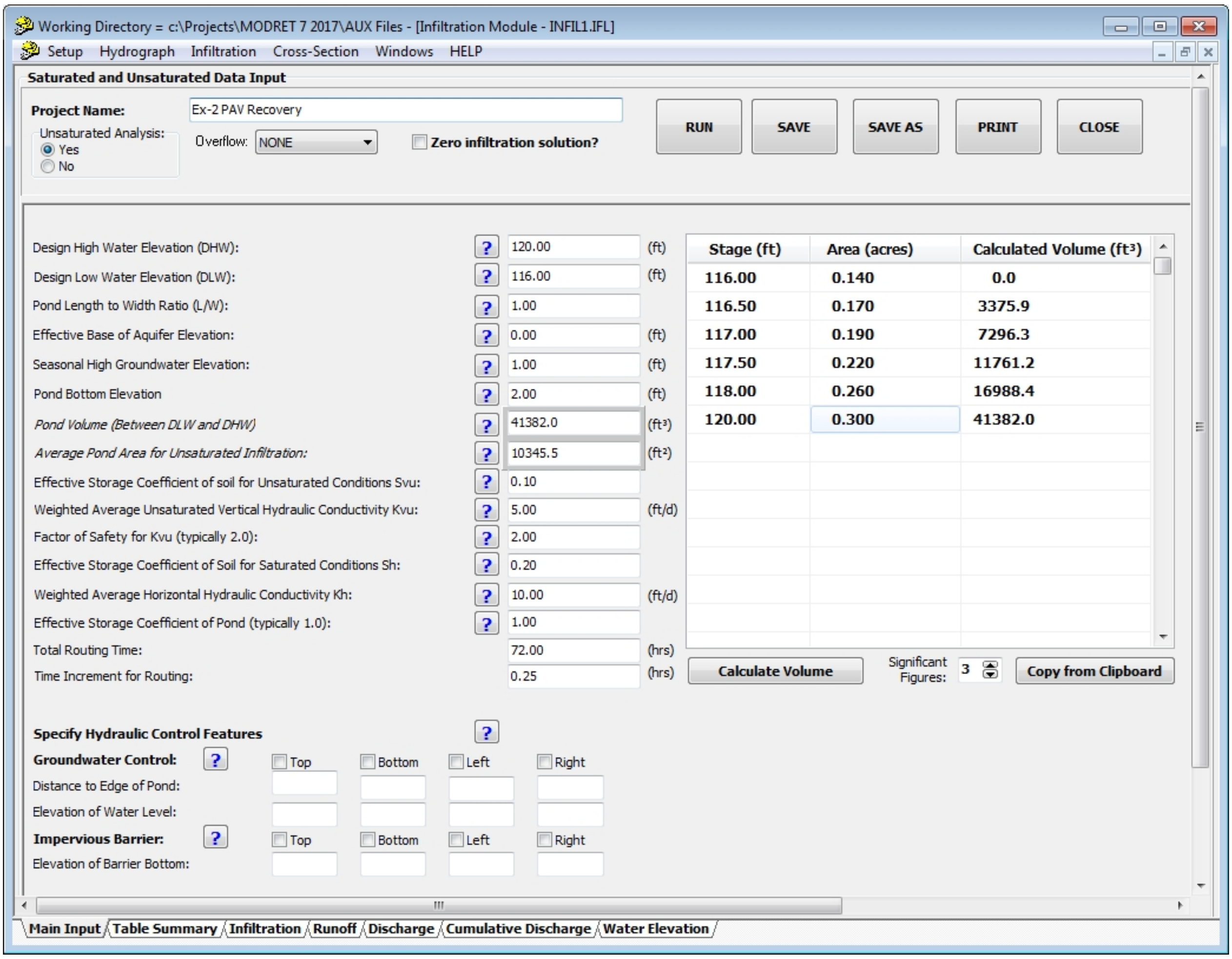
1. Design the pond as long and as narrow as possible.
2. Design the pond bottom elevation as high above the groundwater table as possible.
3. Provide for maximum separation distance from other ponds that may affect negatively the performance of the pond.
4. Design the pond with the minimum water depth possible.

For the purposes of initial design, the criteria of minimum pond size based on the requirements of 100% retention of the pollution abatement volume (7,260 ft^3 between pond bottom and weir overflow level) will be used. First, the pond will be modeled for pollution abatement volume recovery and then, the pre/post development runoff will be modeled. From soil boring data, the surface elevation at the pond area is estimated at about 118.0 feet. Initially, the pond bottom elevation will be selected at 116 feet and the overflow elevations (weir crest) will be selected at 117.0 feet, which can be adjusted later, if necessary. In MODRET 7.0 the stage-area of the pond must be first specified and then the design high water level (DHW) and design low water level (DLW) can be specified. The model will then interpolate from these data the average pond area and the volume of pond between DWH and DLW for modeling. Based on preliminary information create a sample stage-area table as follows:11

Elevation (ft)	Area (acres)
116.0	0.14
116.5	0.17
117.0	0.19
117.5	0.22
118.0	0.26
120.0	0.30

This data can be entered manually or copied and pasted by using the **Copy from Clipboard** option in the initial screen of the **Infiltration** module. Below is the initial **Infiltration** module screen when **New** is selected. The second graphic shows the entered data and the screen after clicking the **Calculate Volume** button on the bottom.





The pond and aquifer parameters after the initial entry of stage-area are default (dummy) numbers. The user must now enter the correct data, starting with name, selection of **Unsaturated Analysis (Yes or No)** and all the parameters on the left side of the screen. Based on PAV volume of 7,260 ft^3, the DHW for PAV modeling would occur at about elevation 117.0 feet and the DLW is 116.0 feet. From the site layout and constraints select an estimated length to width (L/W) ratio of **1.5**.

For pre/post modeling assume an **Overflow Device** to be a sharp crested weir with the following initial parameters:

Crest Elevation	117.0 feet (at top of PAV)
Crest Length	3.5 feet
Coefficient of Discharge	3.33
Weir Coefficient	1.5
Number of End Contractions	0

Select Aquifer Parameters: From Figure EX2-2, the soil profile indicates that sandy soils extend to the terminated depth of the boring, elevation 108 feet. It is assumed that additional information is not available. Therefore, the **Effective Base of Aquifer Elevation** must be selected at 108 feet. The **Seasonal High Groundwater Table** (SHGWT) is estimated at elevation 113.5 feet. One **Vertical Permeability**, $\mathbf{K}_V$, measured at a depth of 2 feet, indicates a value of 11 ft/day. Since reported permeability values are typically saturated values, it is necessary to multiply this value by a factor of 2/3 to obtain a value of unsaturated permeability, $\mathbf{K}_{vu}$, refer to Chapter 3 of the original design manual (Andreyev, Wiseman, 1989), which can be found in the downloaded folder “Andreyev-Wiseman 1989”.

$$\mathbf{K}_{vu} = 2/3\ \mathbf{K}_v = 2/3 \times 11 \text{ ft/day} = 7.33 \text{ ft/day}$$

Use, $\mathbf{K}_{vu} = 7$ ft/day

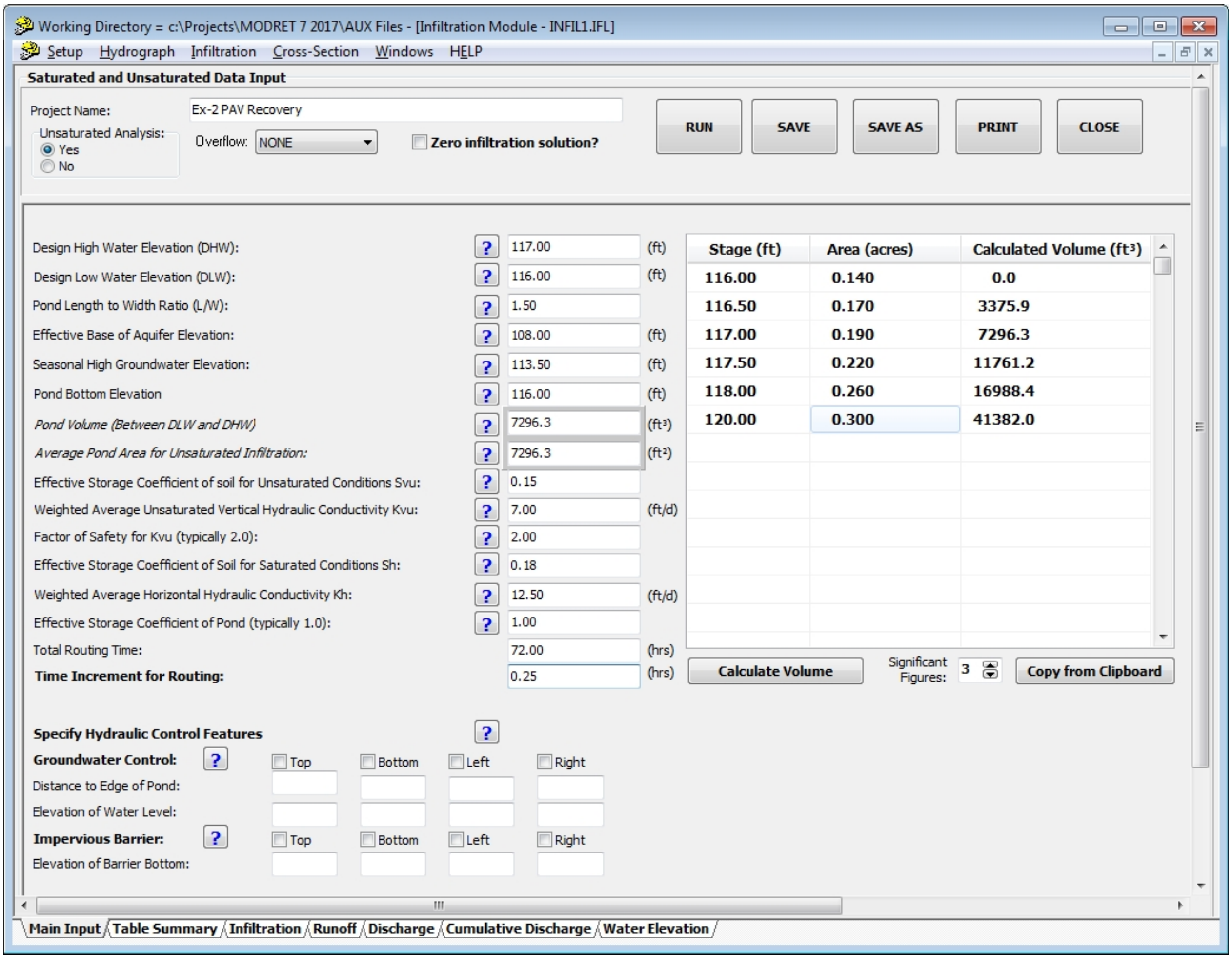
One **Horizontal Permeability**, $\mathbf{K}_H$, measured at a depth of 5 feet (within the top effective layer), indicates a value of 21 ft/day. Since $\mathbf{K}_H$ was not measured in the bottom effective soil layer, a value of 2 ft/day was estimated from Table A-2. From Figure EX2-2, the thicknesses of the effective soil layers were estimated at 5 feet for stratum 2 and at 4 feet for stratum 3, for the purposes of calculating the weighted average horizontal permeability.

$$\mathbf{K}_{Havg} = \frac{5 \text{ ft} \times 21 \text{ fpd} + 4 \text{ ft} \times 2 \text{ fpd}}{9 \text{ ft}} = 12.56 \text{ ft/day}$$

Use, $\mathbf{K}_{Havg} = 12.5$ ft/day

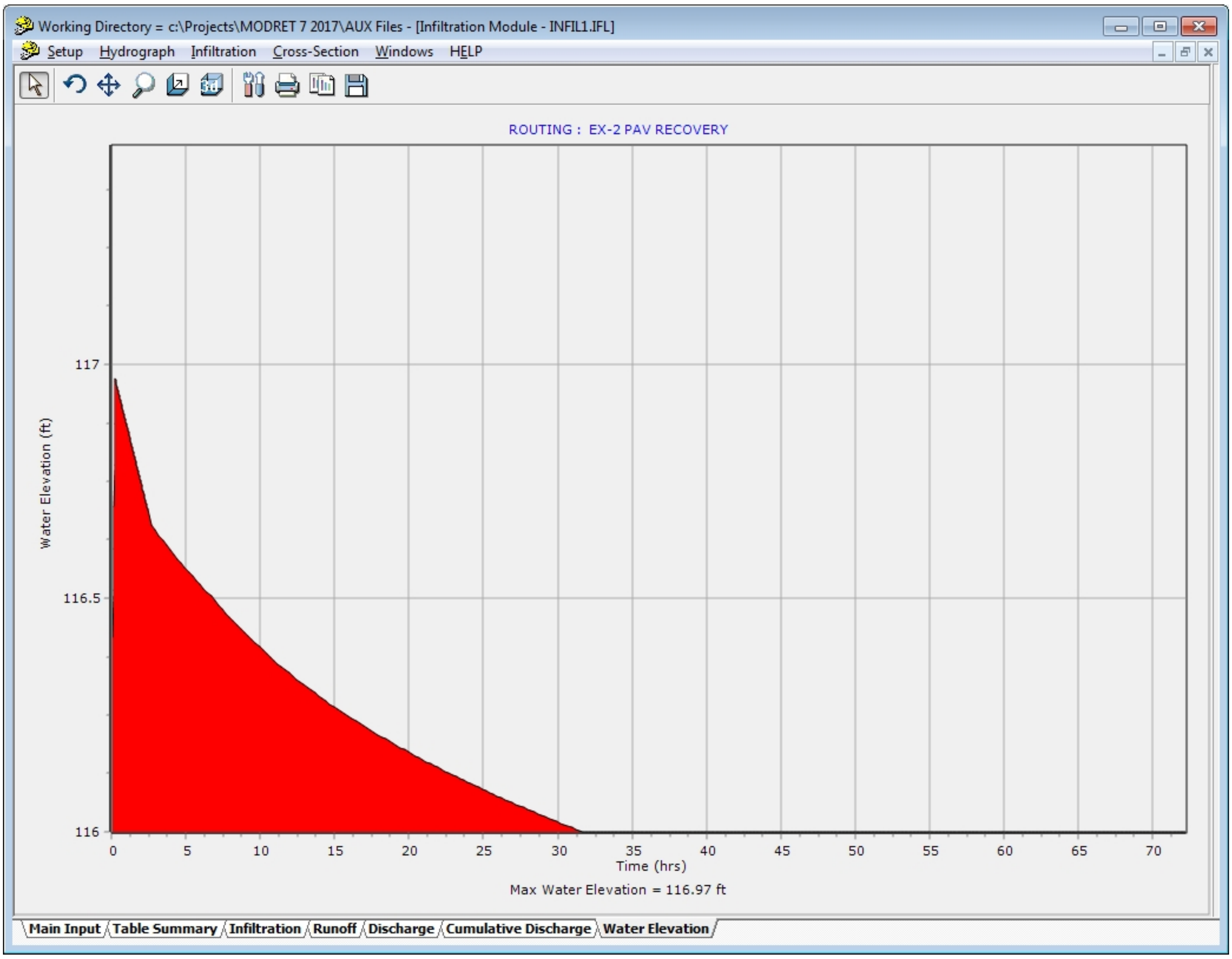
The **Average Effective Storage Coefficient** for the unsaturated infiltration can be obtained from Table A-1, MODRET calculates the appropriate f values automatically from Table A-1 and presents it as default. The user can accept or override this value. The **Total Time** is intended to create the total time of model run plus all the time needed to assess the recovery time, in this case a total of 72 hours was specified. The **Time Increment** is to allow the user to select the routing time increment. After the model is executed MODRET routes the inflow of water, the infiltration losses and the outflow of water using this time increment.

Assume that there are no canals or lakes that could affect the pond performance, and therefore, Groundwater **Control** features were not specified. Perimeter impervious barriers were not present and therefore, **Impervious Barrier** features were not specified. The following pond and aquifer input parameters were entered for PAV modeling option:

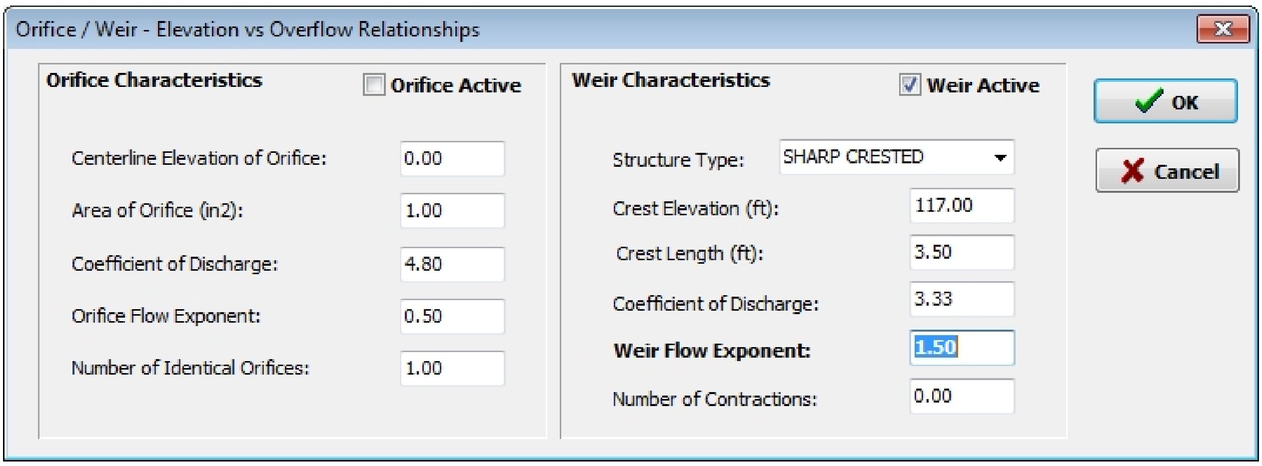


Once all the data is entered and the input data is saved with the default extension, if selected (**Ex-2PAV.ifl**), click on the **RUN** button to model the infiltration loses from the pond and routing of water levels in the pond. The model will prompt to specify the runoff hydrograph. For the PAV model run select the **Ex-2PAV.man** file that was previously created as a slug load of PAV. After model execution the same screen, see above, will reappear with a series of buttons on the bottom that allow review of the results and/or print the graphs.

Click on the **Water Elevation** button to view the graph and determine if the recovery has occurred within the required time period, in this case 72 hours. Based on the results, see graph below, the pond recovers in about 31.5 hours < 72 hours. The **Groundwater Elevation** graph and the input data in **Main Input** are the only two printed pages needed to demonstrate pond recovery for this project.

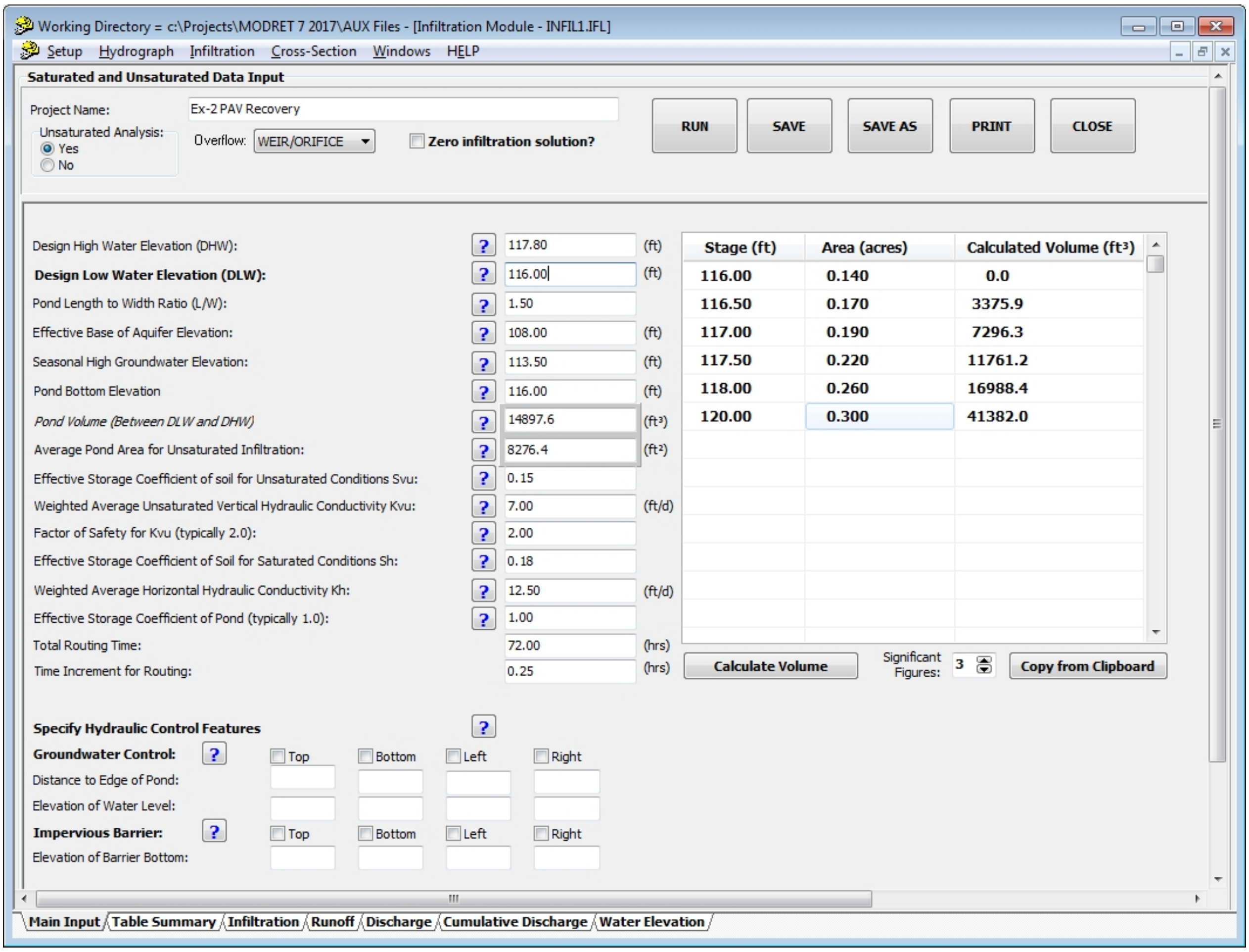


For the pre/post development retention and infiltration analysis, the same pond and aquifer parameters were used and the overflow parameters were added for the selected weir structure. To enter the overflow structure details, click on the down-arrow of the **Overflow** box and select **WEIR/ORIFICE**, which will prompt a window of data input for the weir and orifice characteristics. Check the **Weir Active** box and specify the required data of Sharp Crested Weir, Crest Elevation of 117.0 feet, Crest Length of 3.5 feet, Coefficient of Discharge of 3.33, Weir Overflow Exponent of 1.50 and Number of Contractions of 0.0.

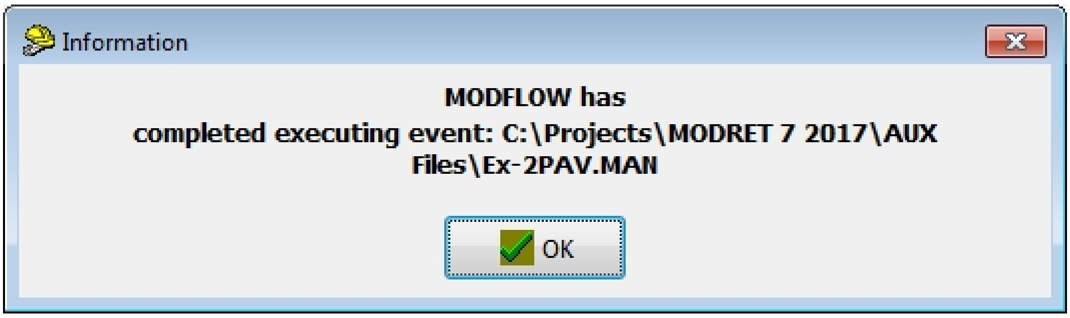


After the appropriate input data was entered, click OK and return to the main input screen.

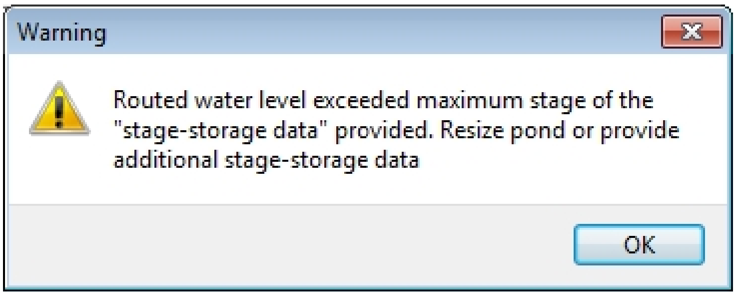
For the 24 hours storm event the previously created post development runoff hydrograph will be used to assess the infiltration of the pond and routing the pond stages during and after the storm. Since the runoff volume is greater than the PAV, the DHW needs to be raised to an approximate high water elevation expected during the simulation. Allowing for significant overflow with the weir set at 117.0 feet, a DHW will initially be set to 117.8 feet. This can be adjusted by trial and error model runs to fit the selected DHW to the simulated high water elevation. The following is the final screen view of the input data for the post development simulation:



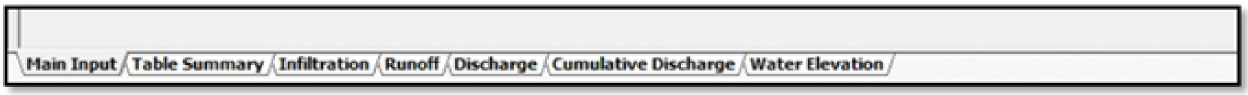
Verify that all data has been accurately specified, then click on **SAVE AS** and specify file name of **Ex-2POST.ifl** then click on the **RUN** button to execute the model. Select the post development runoff hydrograph, **Ex-2Post.SCS**. After model execution the following prompt will appear indicating that the MODFLOW portion of the model has been completed. Click OK to return to the main view screen:



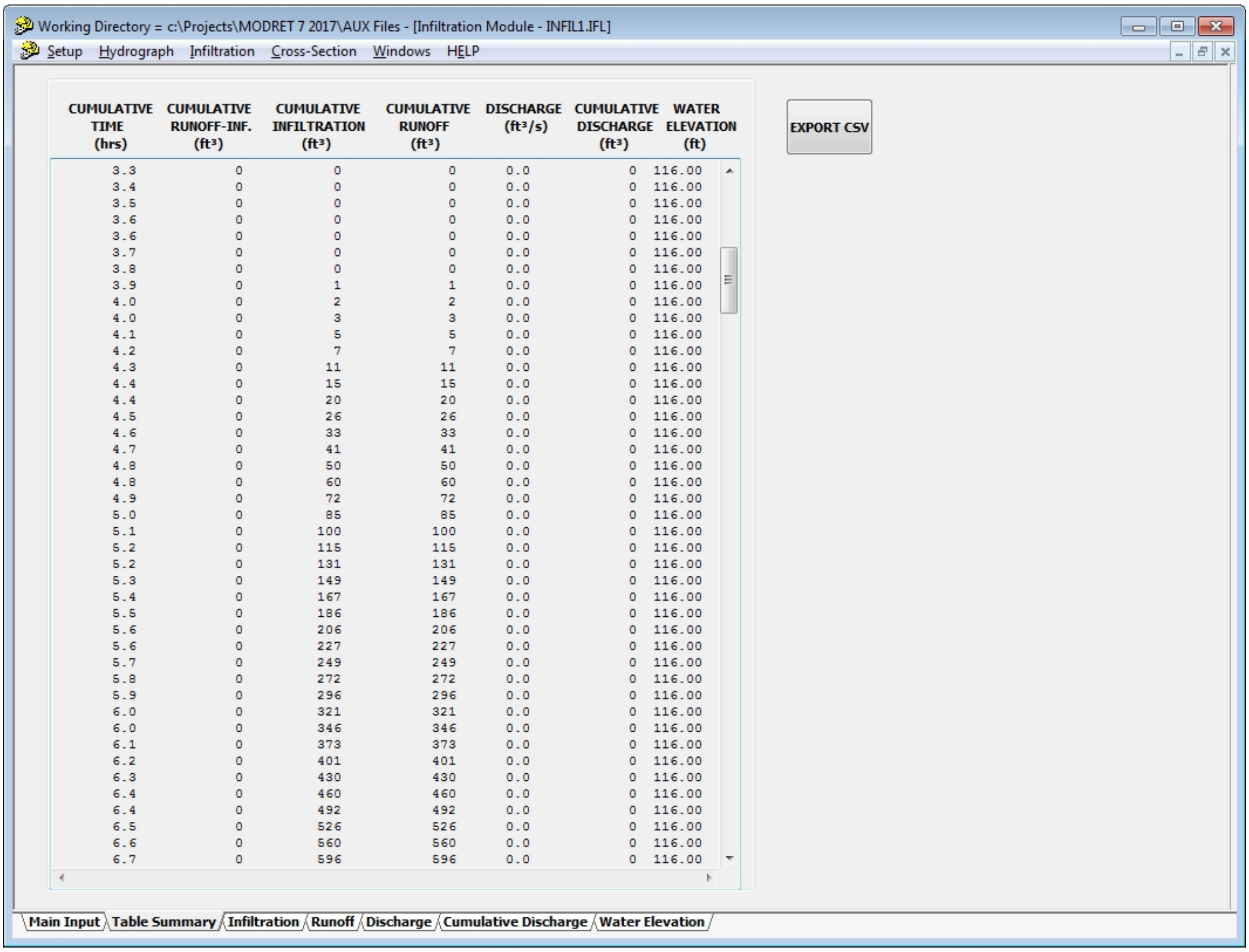
Occasionally, the model simulation can encounter a condition where the simulated water elevations exceed the stage-storage data provided. If this occurs, the model stops and displays the following error message:



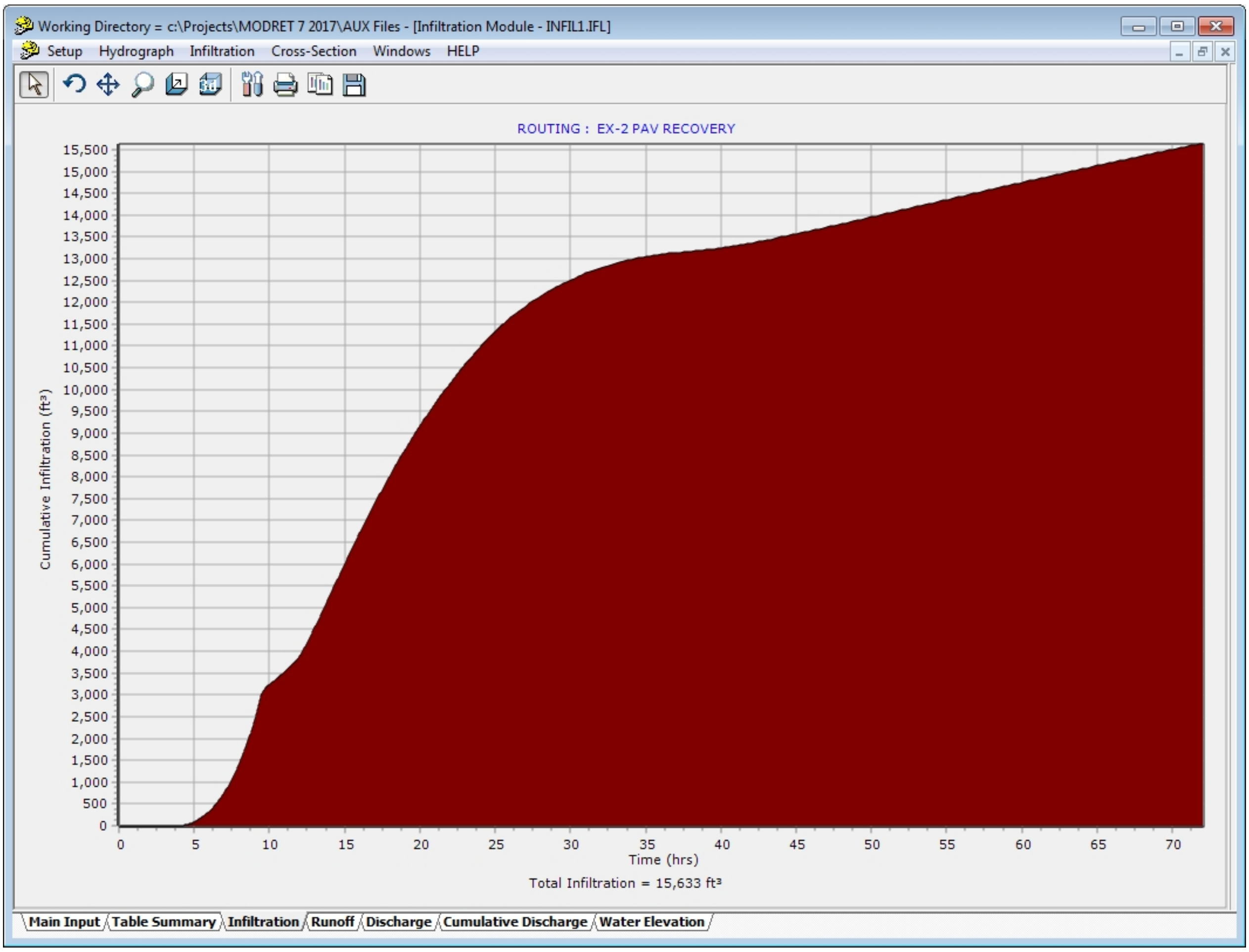
In this case click OK and revise the stage-area input as needed to eliminate this error. Once final execution of the model is complete, the tabs at the bottom of the main screen are activated.

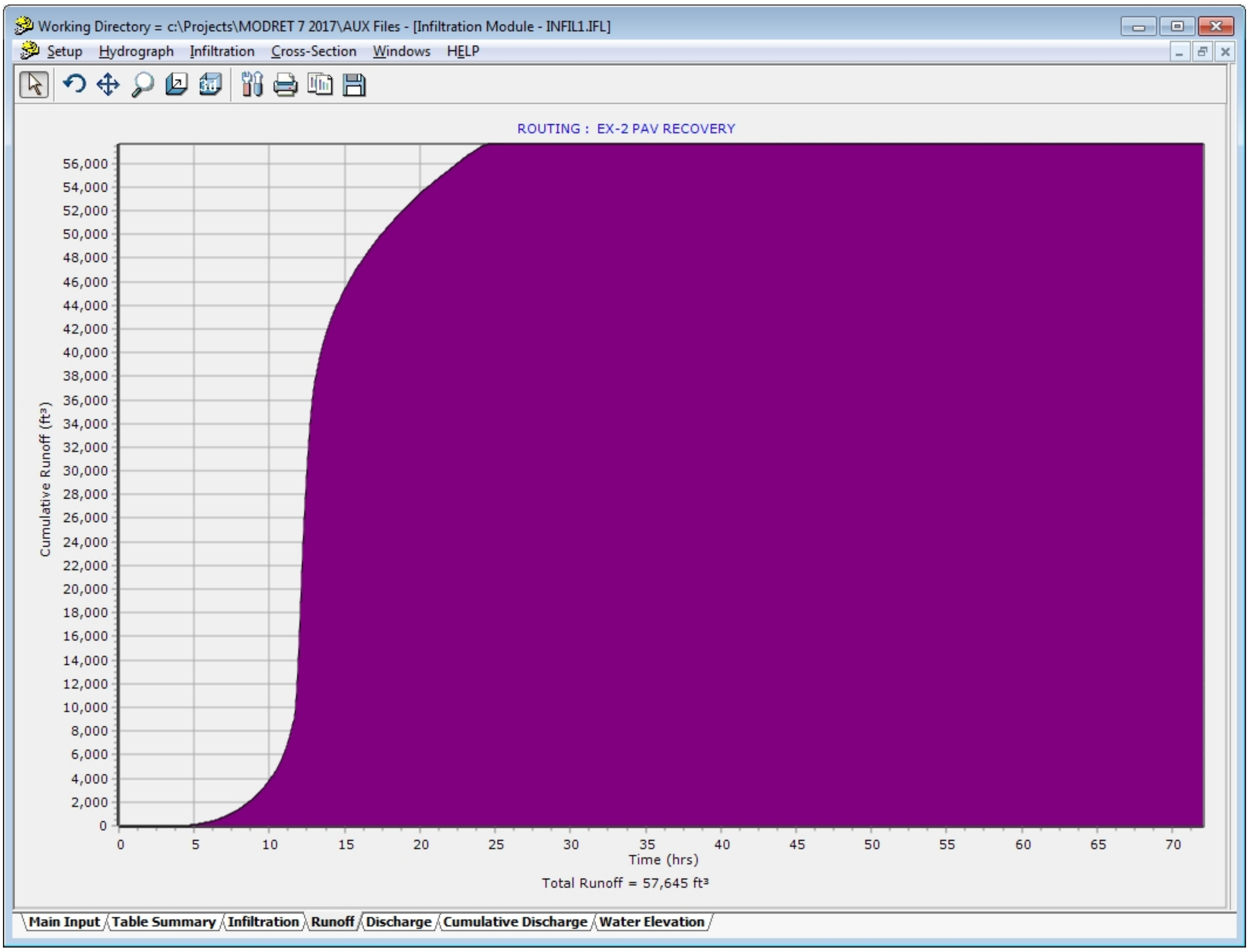


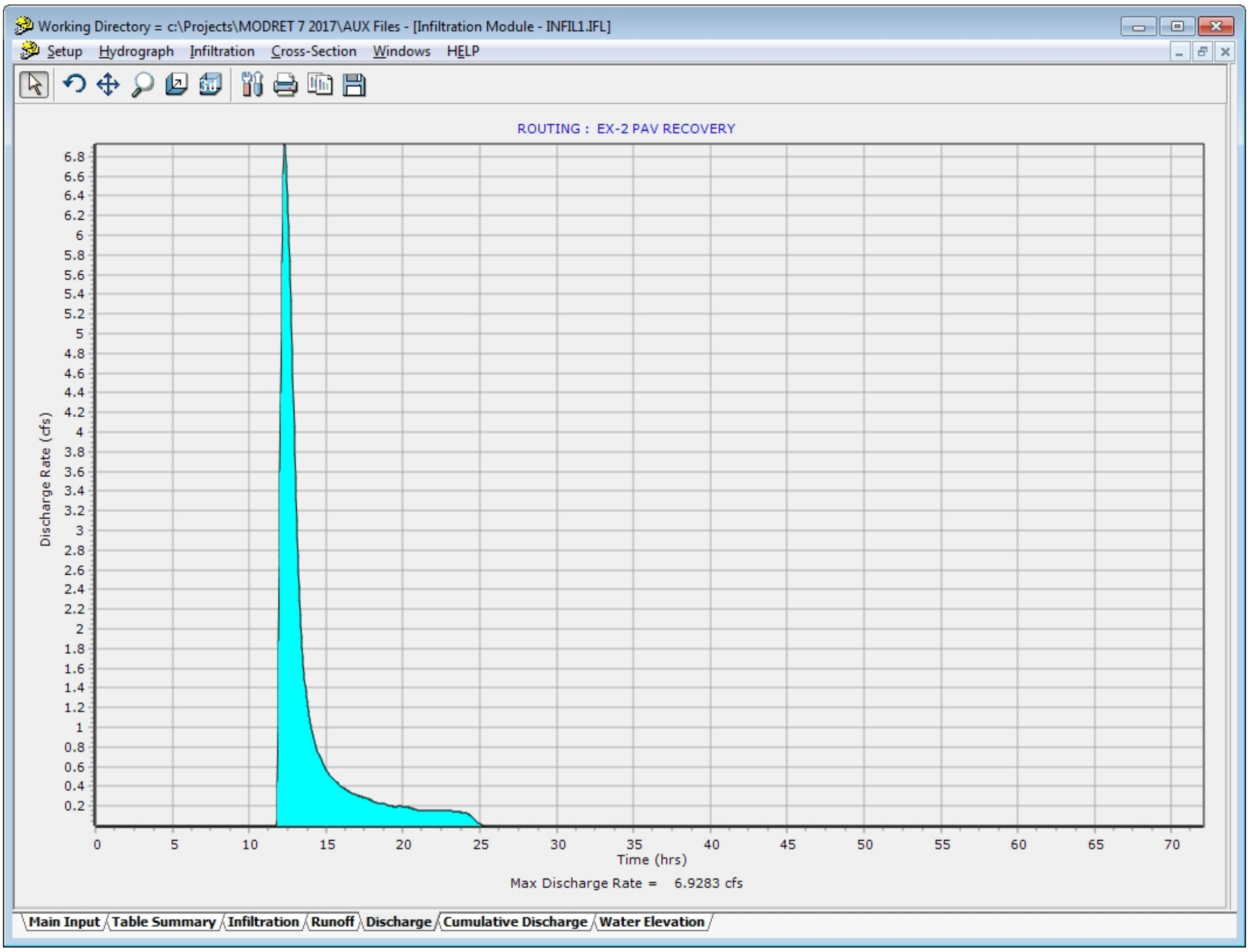
The 6 optional tabs allow viewing, printing and exporting the tabular and graphical results. The results of this simulation, both tabular (partial) and graphical, follow:

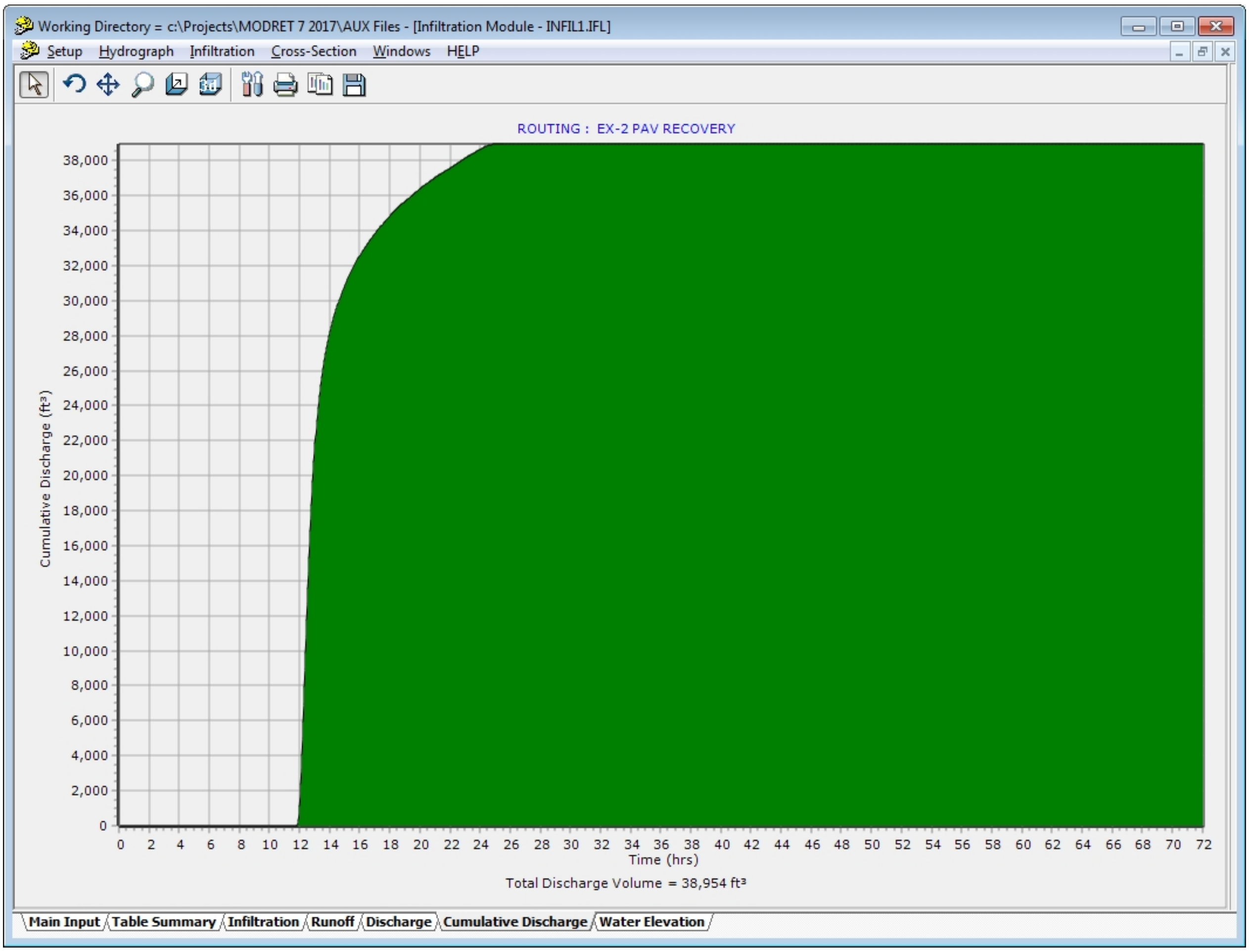


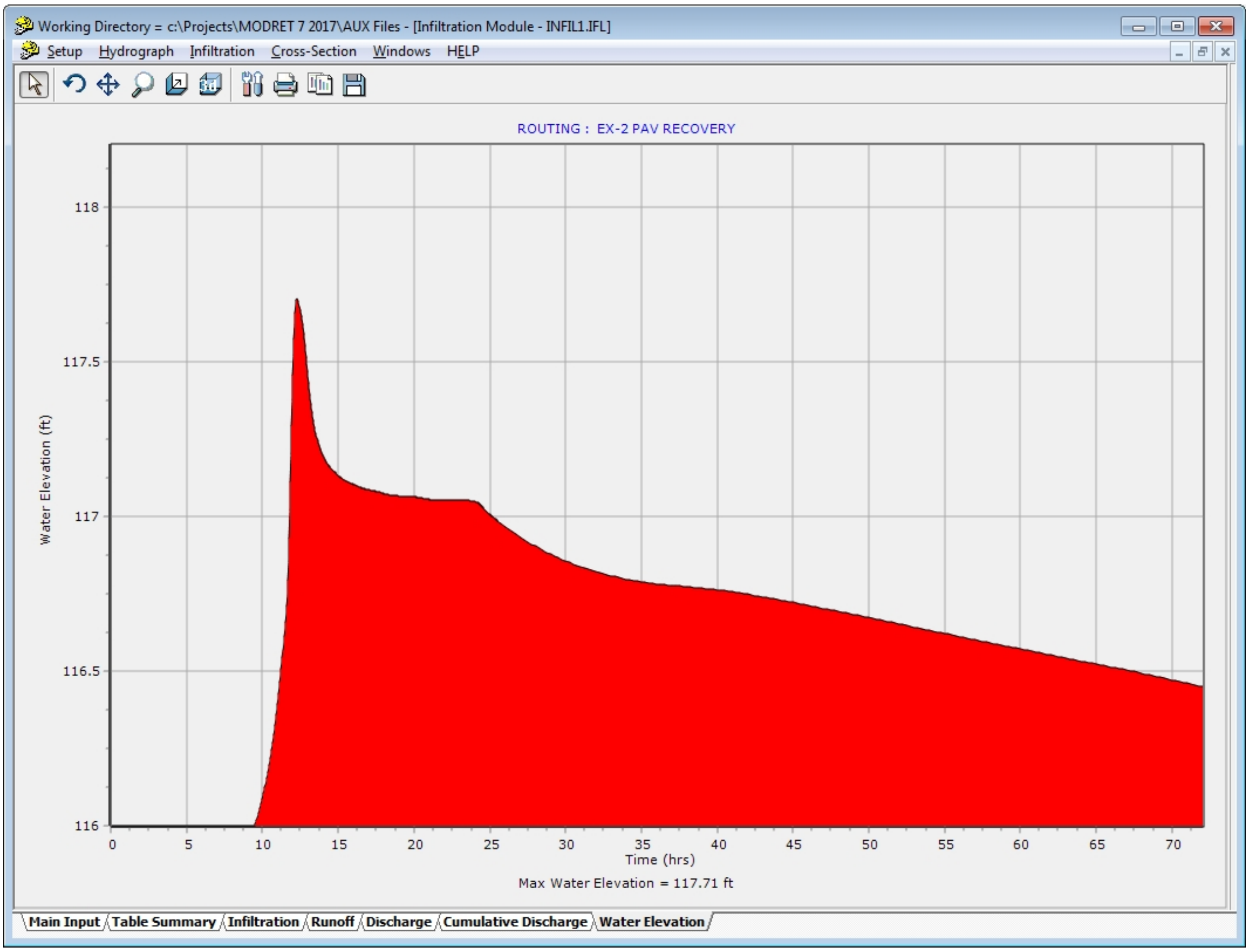
CUMULATIVE TIME (hrs)	CUMULATIVE RUNOFF-INF. (ft³)	CUMULATIVE INFILTRATION (ft³)	CUMULATIVE RUNOFF (ft³)	DISCHARGE (ft³/s)	CUMULATIVE DISCHARGE (ft³)	WATER ELEVATION (ft)
3.3	0	0	0	0.0	0	116.00
3.4	0	0	0	0.0	0	116.00
3.5	0	0	0	0.0	0	116.00
3.6	0	0	0	0.0	0	116.00
3.6	0	0	0	0.0	0	116.00
3.7	0	0	0	0.0	0	116.00
3.8	0	0	0	0.0	0	116.00
3.9	0	1	1	0.0	0	116.00
4.0	0	2	2	0.0	0	116.00
4.0	0	3	3	0.0	0	116.00
4.1	0	5	5	0.0	0	116.00
4.2	0	7	7	0.0	0	116.00
4.3	0	11	11	0.0	0	116.00
4.4	0	15	15	0.0	0	116.00
4.4	0	20	20	0.0	0	116.00
4.5	0	26	26	0.0	0	116.00
4.6	0	33	33	0.0	0	116.00
4.7	0	41	41	0.0	0	116.00
4.8	0	50	50	0.0	0	116.00
4.8	0	60	60	0.0	0	116.00
4.9	0	72	72	0.0	0	116.00
5.0	0	85	85	0.0	0	116.00
5.1	0	100	100	0.0	0	116.00
5.2	0	115	115	0.0	0	116.00
5.2	0	131	131	0.0	0	116.00
5.3	0	149	149	0.0	0	116.00
5.4	0	167	167	0.0	0	116.00
5.5	0	186	186	0.0	0	116.00
5.6	0	206	206	0.0	0	116.00
5.6	0	227	227	0.0	0	116.00
5.7	0	249	249	0.0	0	116.00
5.8	0	272	272	0.0	0	116.00
5.9	0	296	296	0.0	0	116.00
6.0	0	321	321	0.0	0	116.00
6.0	0	346	346	0.0	0	116.00
6.1	0	373	373	0.0	0	116.00
6.2	0	401	401	0.0	0	116.00
6.3	0	430	430	0.0	0	116.00
6.4	0	460	460	0.0	0	116.00
6.4	0	492	492	0.0	0	116.00
6.5	0	526	526	0.0	0	116.00
6.6	0	560	560	0.0	0	116.00
6.7	0	596	596	0.0	0	116.00


Working Directory = c:\Projects\MODRET 7 2017\AUX Files - [Infiltration Module - INFIL1.IFL]
Setup Hydrograph Infiltration Cross-Section Windows HELP
ROUTING : EX-2 PAV RECOVERY
Cumulative Infiltration (ft³)
Time (hrs)
Total Infiltration = 15,633 ft³
Main Input
Table Summary
Infiltration
Runoff
Discharge
Cumulative Discharge
Water Elevation


Working Directory = c:\Projects\MODRET 7 2017\AUX Files - [Infiltration Module - INFIL1.IFL]
Setup Hydrograph Infiltration Cross-Section Windows HELP
ROUTING : EX-2 PAV RECOVERY
Cumulative Runoff (ft³)
56,000
54,000
52,000
50,000
48,000
46,000
44,000
42,000
40,000
38,000
36,000
34,000
32,000
30,000
28,000
26,000
24,000
22,000
20,000
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70
Time (hrs)
Total Runoff = 57,645 ft³
Main Input
Table Summary
Infiltration
Runoff
Discharge
Cumulative Discharge
Water Elevation


Working Directory = c:\Projects\MODRET 7 2017\AUX Files - [Infiltration Module - INFIL1.IFL]
Setup Hydrograph Infiltration Cross-Section Windows HELP
ROUTING : EX-2 PAV RECOVERY
Discharge Rate (cfs)
Time (hrs)
Max Discharge Rate = 6.9283 cfs
Main Input Table Summary Infiltration Runoff Discharge Cumulative Discharge Water Elevation


Working Directory = c:\Projects\MODRET 7 2017\AUX Files - [Infiltration Module - INFIL1.IFL]
Setup Hydrograph Infiltration Cross-Section Windows HELP
ROUTING : EX-2 PAV RECOVERY
Cumulative Discharge (ft³)
Time (hrs)
Total Discharge Volume = 38,954 ft³
Main Input
Table Summary
Infiltration
Runoff
Discharge
Cumulative Discharge
Water Elevation



MODEL RESULTS AND EVALUATION

The results can be evaluated from the graphic data included above. The following is a summary of evaluation of model results and conclusions:

Pre/Post Model: The **Water Elevation** graph presents the time vs water levels, which have been automatically routed at the specified time increment and for the specified duration. The maximum stage in the pond rises to an elevation of **117.71** feet, slightly below the selected elevation of **117.8** feet. Further refinement of the DHW can be obtained by running the model multiple times and adjusting the DHW until the specified and the simulated values match. However, the difference in infiltration due to this adjustment is minimal and an exact value of DHW is not critical (0.3+/- ft). For example, running this model to a more accurate elevation of 117.71 feet produces the match but the simulated high water elevation does not change and the remaining summary graphs indicate very minor differences.

To assess the pre/post effects of runoff for this example problem, the total discharge volume of **38,659 ft^3** can be obtained from the **Cumulative Discharge** graph above. To retain the difference between pre-development and post-development runoff volume, the routed of post-development runoff hydrograph should not produce a discharge volume that exceeds the pre-development runoff volume. Using the runoff hydrographs previously created by MODRET 7.0, the pre-development hydrograph produced a total runoff volume of **44,600 ft^3**. Comparing the **Discharge Volume** from the pond with the pre-development **Runoff Volume** indicates that the pond will retain more than the required amount of volume and meets the design criteria (44,600 – 38,659 = 5,941 ft^3 of excess retention).

Now check if the recovery criteria have been met. The volume of pond at overflow is **7,296.3** ft^3 The 50% of volume will be **3,648.1** ft^3 and corresponds to about elevation **116.59** feet. The simplest way to evaluate this is to look at the **Water Elevation** graph at the required time period of 36 hours after the storm event. In this case the storm duration was 24 hours and adding the 36 hours results in a total time of 60 hours. From the **Water Elevation** graph above, the elevation at 60 hours occurs at the pond bottom of **116.530** <116.59 ft. Therefore, the recovery criteria have been met.

Conclusions: At this point, the pond meets the minimum size required by the project criteria. Although, it retains more than the required pre/post runoff volume (by about 13%), it cannot be downsized because the project criteria specifies a minimum required volume of pond of 7,260 ft^3 between the pond bottom and the overflow elevation to retain the PAV volume. As presented by the **Water Elevation** graph, the peak stage (maximum water level) rises to 117.71 feet, therefore, for final pond design the DHW should be set at **117.71 feet** and the top of pond berms should be set at least 0.5 feet above the DHW or about elevation **118.25 feet**.

Wet Retention Pond with Weir and Orifices

EXAMPLE 3

Wet Retention Pond with Weir and Bleed-down Orifices

This example will demonstrate the use of MODRET to analyze wet retention pond systems with weir overflow structure and bleed-down orifices to attenuate pollution abatement volume. This example is intended to demonstrate a typical wet retention and attenuation system design, for retention ponds in high groundwater table condition areas. The most important aspect of this example is the demonstration of MODRET model's capability to simulate a combination of water losses due to infiltration and overflow devices. Also, the use and effect of adjacent ditch and impervious barrier will be demonstrated.

RETENTION SYSTEM DESIGN DATA

Assume the following storm, runoff characteristics, and catchment area to generate the runoff hydrograph for this example:

Non-DCIA Basin Area: 3.37 Acres
Weighted average CN value for non-DCIA: 81.0
DCIA Area: 0.93 Acres
Rainfall Event to be Modeled: 25 yr - 24 hour
Rainfall Distribution: SFWMD 24 hour
Rainfall depth: 8.4 Inches
Time of concentration: 25 minutes
Shape Factor: 323

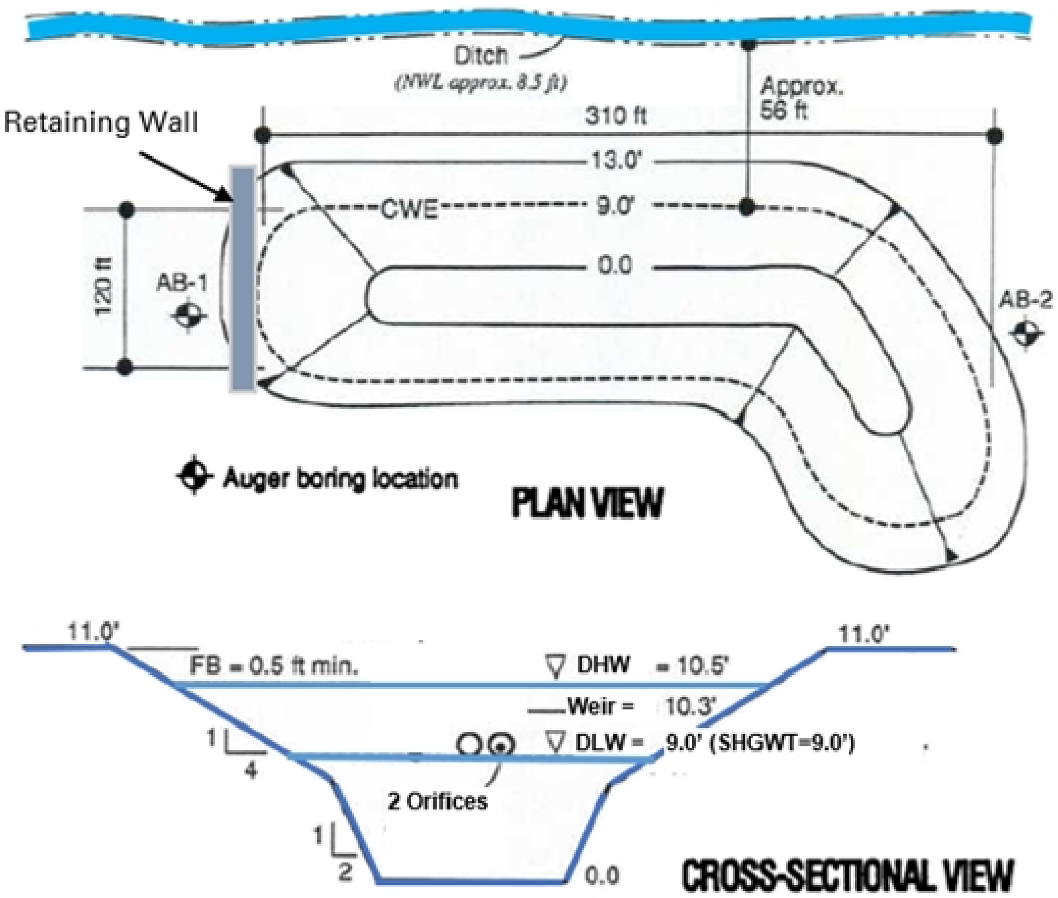
The overflow structures includes a sharp crested weir and two bleed-down orifices, with the following characteristics:

Retention pond:

Design Low Water Elevation (DLW): 9.0 feet
Sharp crested weir:
- Crest Elevation: 10.3 feet
- Crest length: 4.6 feet
- Weir coefficient: 3.12
- Weir exponent: 1.5
- Number of contractions: 2

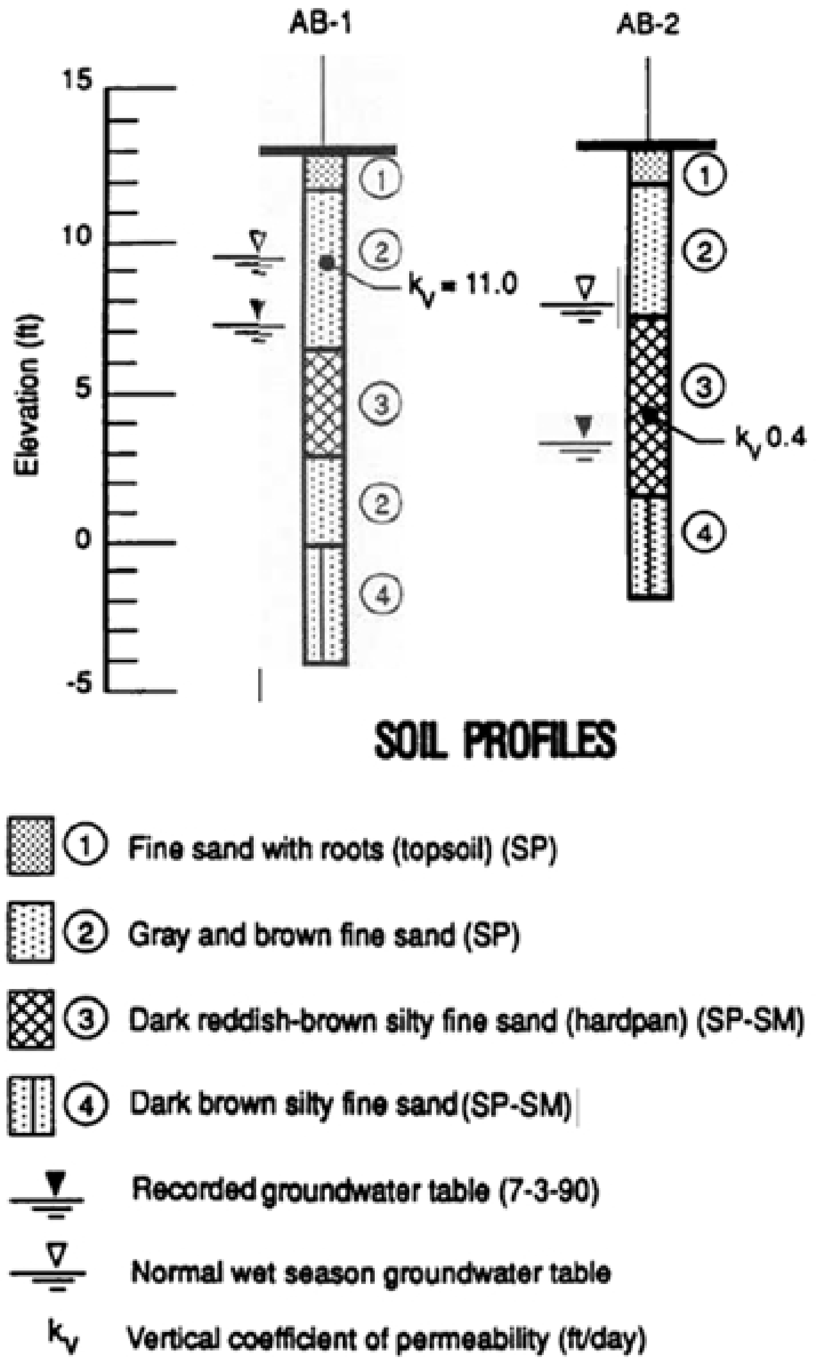
Bleed-down orifices (at DLW):
- Orifice invert elevation: 4.0 inches
- Orifice flow coefficient: C: 4.8 ($C = 0.6*(2g)^{0.5}$
- Orifice exponent: 0.5
- Number of identical orifices: 2

The site soil and groundwater conditions are presented on the following Figures.



Stage (feet)	Area (acres)
9.00	0.00
9.52	0.37
9.95	0.69
10.50	1.12
11.00	1.53

Wet Retention Pond



Soil Profiles and Legend

Stage (feet)	Area (acres)
9.00	0.96
9.52	0.98
9.95	1.01
10.50	1.05
11.00	1.75

Using the design storm, the overflow structures and the site soil and groundwater data, estimate the approximate peak overflow rate, and the time of recovery of the pollution abatement volume, which is assumed (in this example) to correspond to the volume between invert elevations of overflow weir and the bleed-down orifices (between 10.3 and 9.0 feet). Assume that a time increment of 0.25 hours (15 minutes) will provide sufficiently accurate results in establishing a representative peak overflow rate.

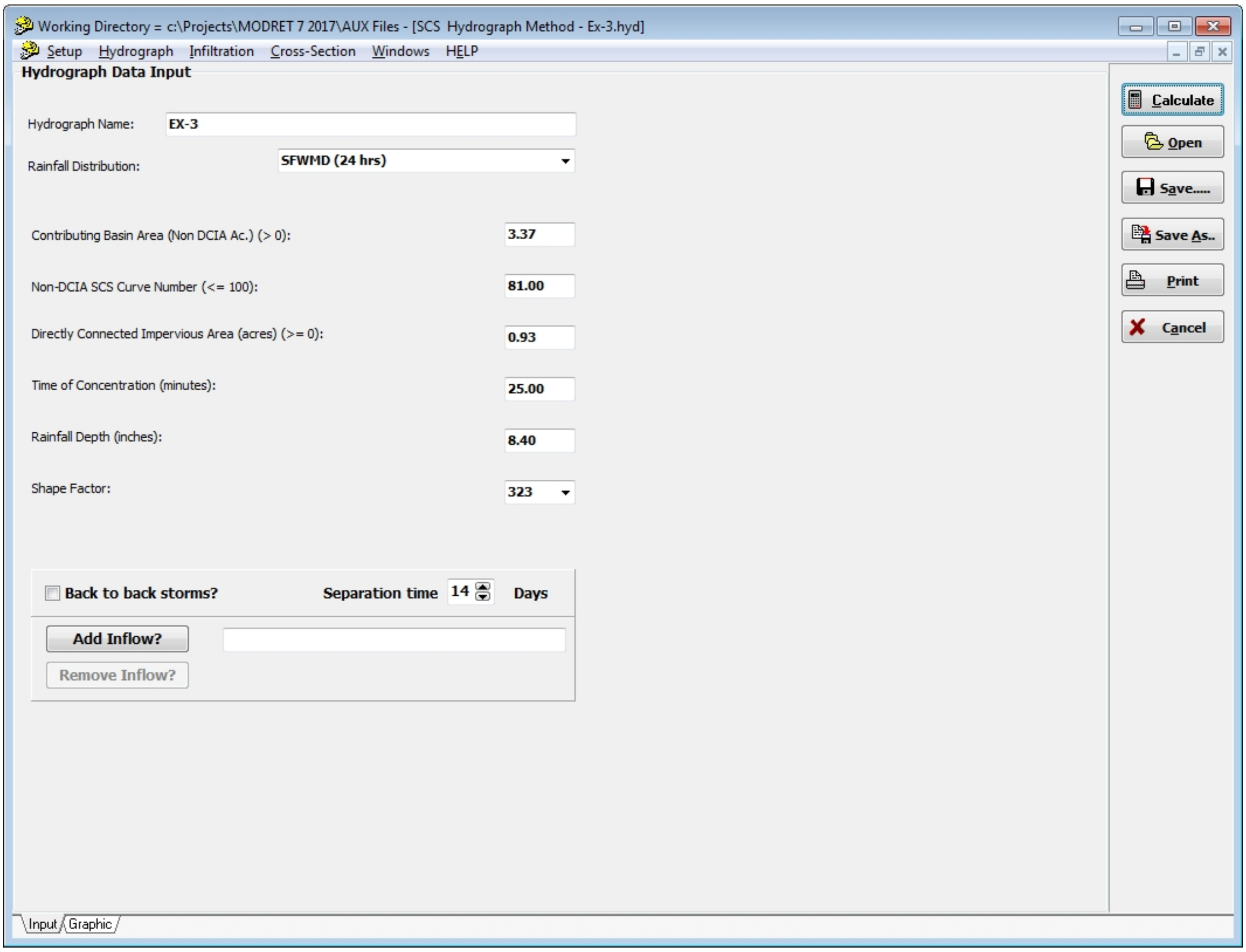
Along the length of the pond (on the **left side**), there is a ditch, located at an average distance of **56 feet** from the edge of pond. The average water level in the ditch is at about elevation **8.5 feet**. Along the width of the pond (on the **bottom side**), there is a retaining wall with the bottom of the footing set at elevation **2.5 feet**, see figure above.

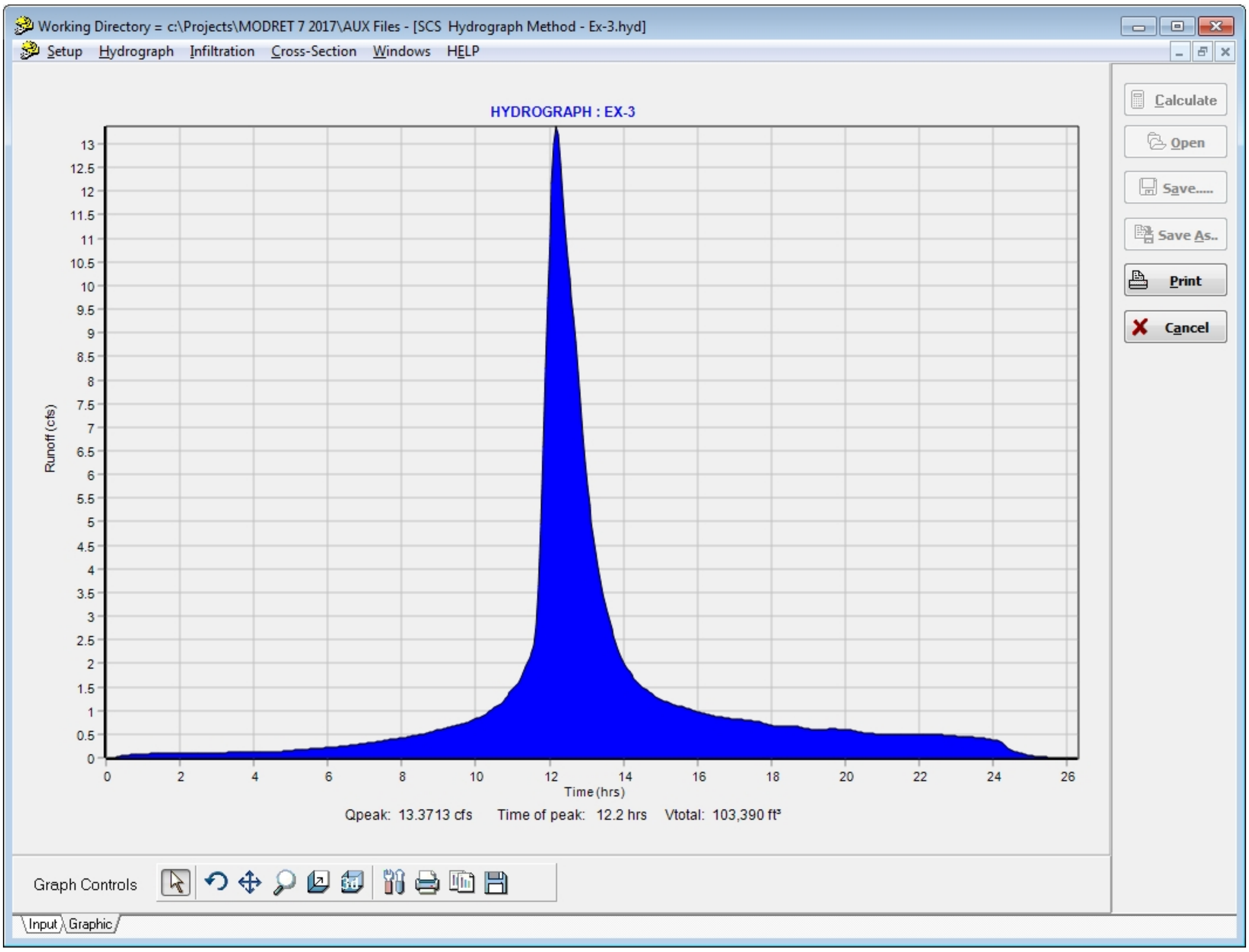
MODEL SETUP AND EXECUTION

Selection of Pond and Aquifer Parameters: A typical wet retention pond system is presented on the figure above. The design normal water level (DLW) is set at elevation 9.0 feet, corresponding to the normal wet season groundwater elevation. Since this is a wet retention pond, unsaturated analysis cannot be included. For the saturated analysis the following pond and aquifer elevations were estimated from the soil boring data above:

Pond design normal water level (DLW)	9.0 feet
Pond bottom elevation	0.0 feet
Design high water level (DHW)	10.5 feet (estimated)
Effective Aquifer Base Elevation	-4.0 feet (bottom of deepest boring)
Normal wet season groundwater elevation	9.0 feet

Hydrograph Generation: To create the runoff hydrographs, click on the **Hydrograph**, then select **New** and **SCS...** An input data page will appear, prompting to enter the required data. From the runoff data provided above, enter the rainfall distribution, contributing basin area, CN value, time of concentration, rainfall depth and the shape factor. Click on **Save As..** and save the file as **Ex-3.hyd**. As **indicated** in the project data, the SCS unit Hydrograph method was used with SFWMD (24 hours) rainfall distribution. Then click **Calculate** and view the results graphic by clicking the **Graphic** button. The input screen and the graphic for the runoff hydrograph is presented below:


Working Directory = c:\Projects\MODRET 7 2017\AUX Files - [SCS Hydrograph Method - Ex-3.hyd]
Setup Hydrograph Infiltration Cross-Section Windows HELP
Hydrograph Data Input
Hydrograph Name: EX-3
Rainfall Distribution: SFWMD (24 hrs)
Contributing Basin Area (Non DCIA Ac.) (> 0): 3.37
Non-DCIA SCS Curve Number (<= 100): 81.00
Directly Connected Impervious Area (acres) (>= 0): 0.93
Time of Concentration (minutes): 25.00
Rainfall Depth (inches): 8.40
Shape Factor: 323
Back to back storms? Separation time 14 Days
Add Inflow?
Remove Inflow?
Calculate
Open
Save.....
Save As..
Print
Cancel
Input Graphic

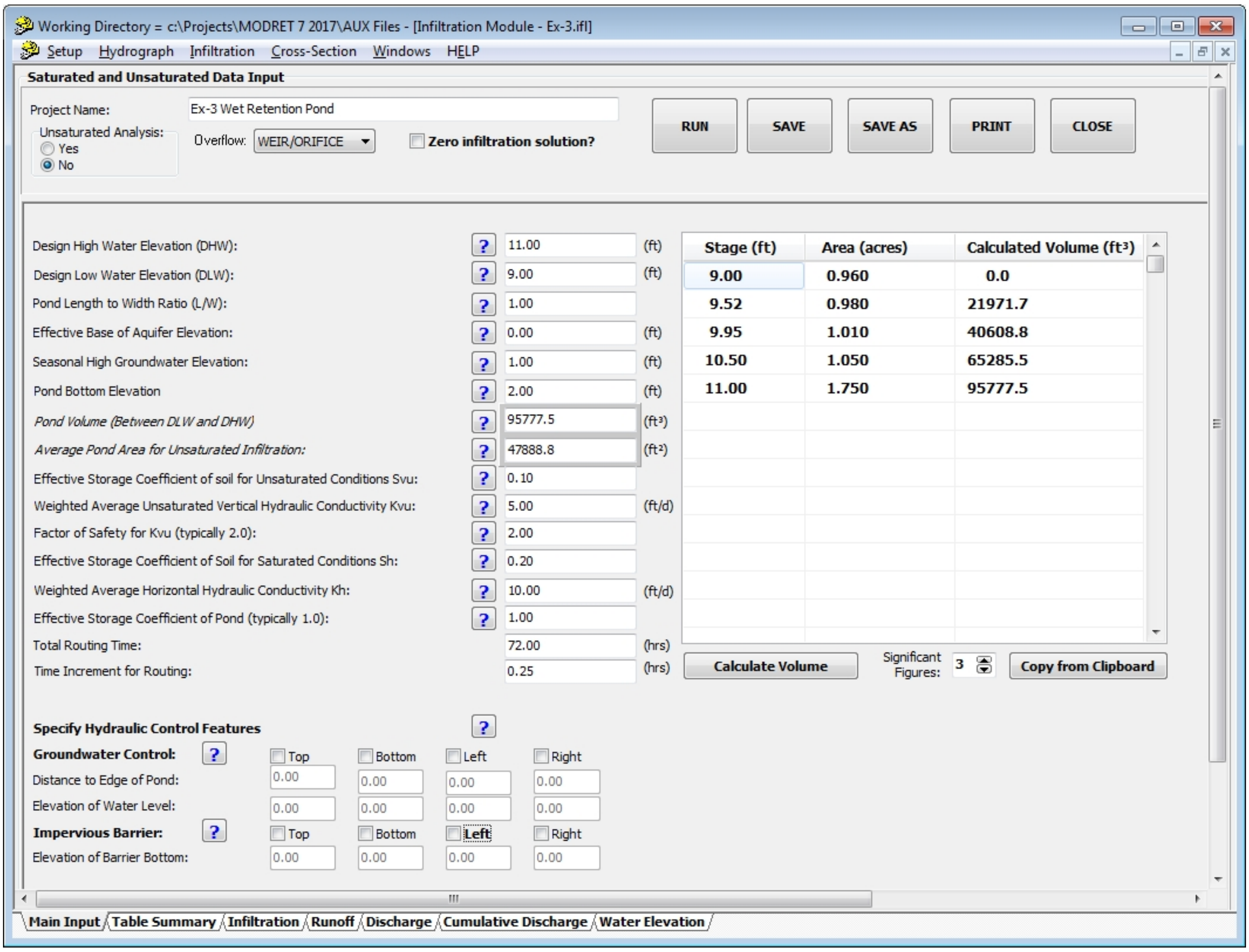


The results indicate that the total volume of runoff from the catchment area is 103,390 ft3 and the peak runoff rate is 13.37 cfs, occurring at 12.2 hours. These results are summarized at the bottom of the hydrograph graphic.

Infiltration and Routing Analyses: In MODRET 7.0 the stage-area of the pond must be first specified and then the design high water level (DHW) and design low water level (DLW) can be specified. The model will then interpolate from these data the average pond area and the volume of pond between DWH and DLW. Based on the data provided for this project, the following stage-area table depicts the wet retention pond system:

Stage (feet)	Area (acres)
9.00	0.96
9.52	0.98
9.95	1.01
10.50	1.05
11.00	1.75

To start the infiltration simulation in MODRET 7.0, click on **Infiltration**, then **New** and enter the project name, select **NO** for **Unsaturated Analysis** and fill in the stage-area table, then click **Calculate Volume**. The following partially filled in screen will appear:



At this point the remaining pond and aquifer data needs to be entered. However, the various pond and aquifer parameters need to be extracted from the available data or calculated. The measured vertical permeability (hydraulic conductivity) of soil strata 2 and 3 is 11 ft/day and 0.4 ft/day, respectively as shown on the soil profiles. Based on a conservative correction factor of 1.5 for fine sand layers in Florida, an approximate value of horizontal permeability will be calculated. Stratum 4 consists of dark brown silty fine sand material, and permeability tests were not conducted in this stratum. A conservative value of 1.0 ft/day was estimated from the table below, based on the 0.5 to 5.0 ft/day range of the SP-SM soil classification:

Typical Values of Permeability for Various Soil Types in Unconfined Sand Aquifers in Florida	
Type of Soil and USCS Classification	**Soil Permeability (feet/day)**
Clayey fine sands and silty fine sands (SM-SC)	0.01 to 0.50
Slightly silty fine sands (SP-SM)	0.50 to 5.0
Clean fine sands (SP)	5.0 to 50.0
Fine to medium Sands (SP)	20.0 to 100.0
Source: Andreyev & Wiseman, 1989	
Note: The range of permeability (hydraulic conductivity) values in this table generally reflect the variation of percent of fines and soil density. Soil cementation also affects the K values	

The average horizontal permeability for this aquifer system can be calculated as follows:

Stratum	**K_H (ft/day)**
2	16.5 (1.5 x K_V)
3	0.6 (1.5 x K_V)
4	1.0 (from Table A-2)

At AB-1,

$$K_{Havg} = \frac{4ft \times 16.5fpd + 3.5ft \times 0.6fpd + 3ft \times 16.5fpd + 4ft \times 1fpd}{14.5ft} = 8.3 \text{ ft/day}$$

At AB-2,

$$K_{Havg} = \frac{3\text{ ft} \times 16.5\text{ fpd} + 5.5\text{ ft} \times 0.6\text{ fpd} + 6\text{ ft} \times 1\text{ fpd}}{14.5ft} = 4.05 \text{ ft/day}$$

And the overall average is, K_{Havg} = (8.38 + 4.05) / 2 = 6.2 ft/day, **Use 6.0 ft/day**

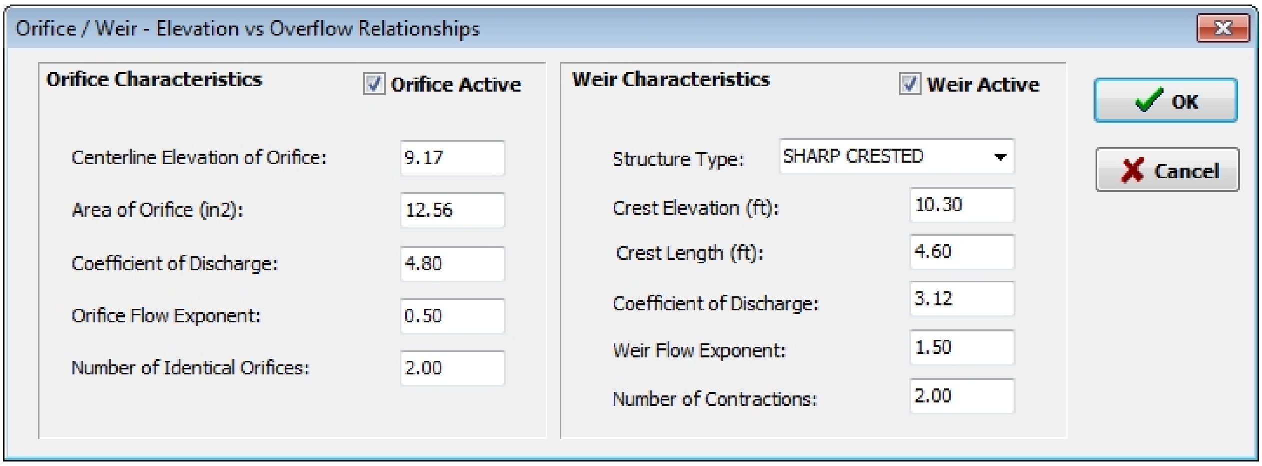
It should be noted that a reduced thickness of stratum 2 (top part) was utilized, since the effective saturated aquifer will only reach elevation 10.5 (DHWL), and the soil above that elevation will not be effective. Also, a thickness of 6 feet was used for stratum 4 in boring AB-2 to account for the base of aquifer extension down to elevation -4.0 feet.

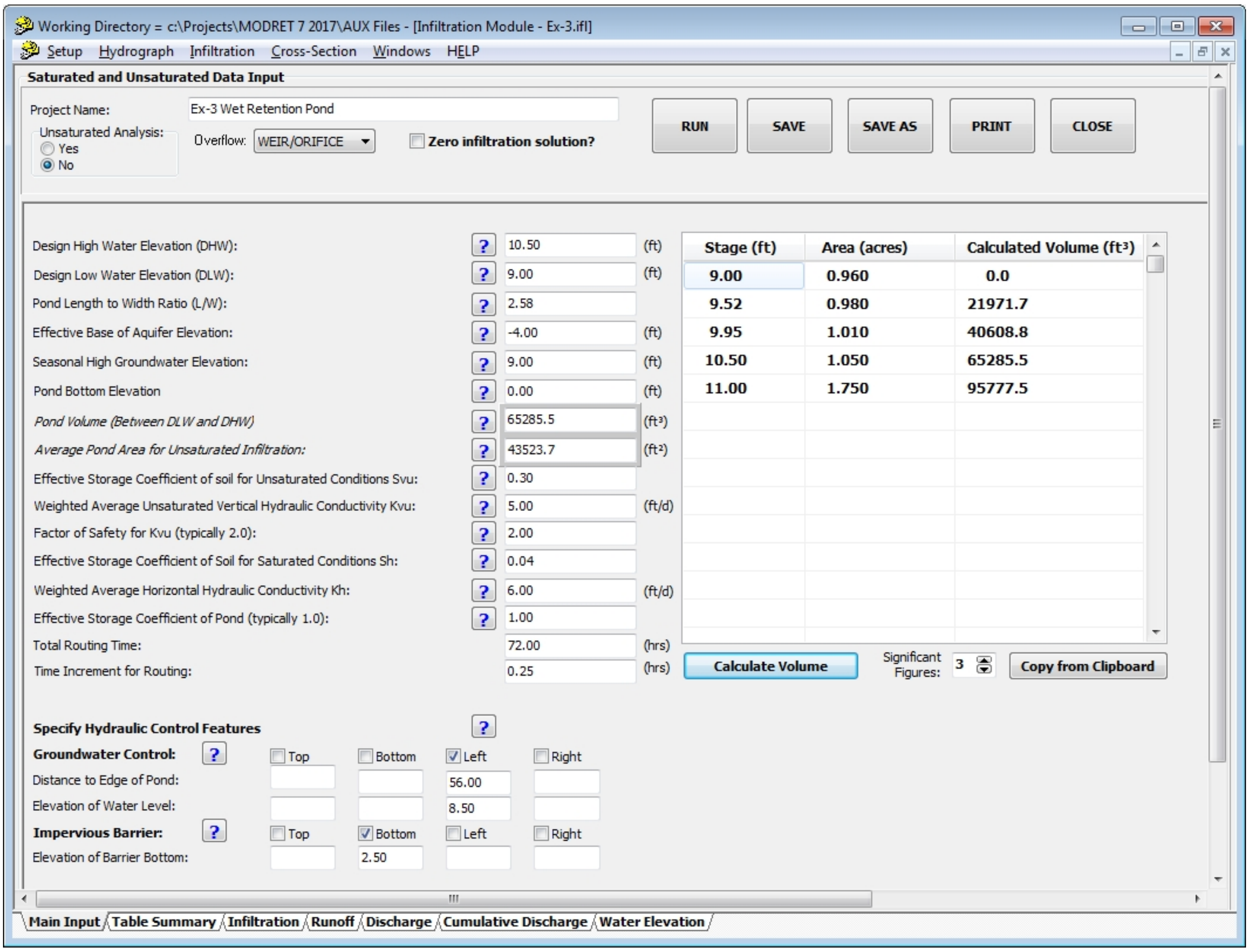
Soil Storage Coefficient (fillable porosity)		
Depth	**Compacted Soil**	**Uncompacted Soil**
0.00	0.00	0.00
1.00	0.04	0.05
2.00	0.08	0.11
3.00	0.14	0.18
4.00	0.17	0.23
5.00	0.20	0.28
>=6.00	0.22	0.30
Source: Adapted from SFWMD Soil Storage Curves		

The effective storage coefficient can be estimated from the table below for h = 0.75 feet (average level between groundwater table of 9.0 feet and DHWL of 10.5) at *f* = 0.04 for uncompacted fine sand soils.

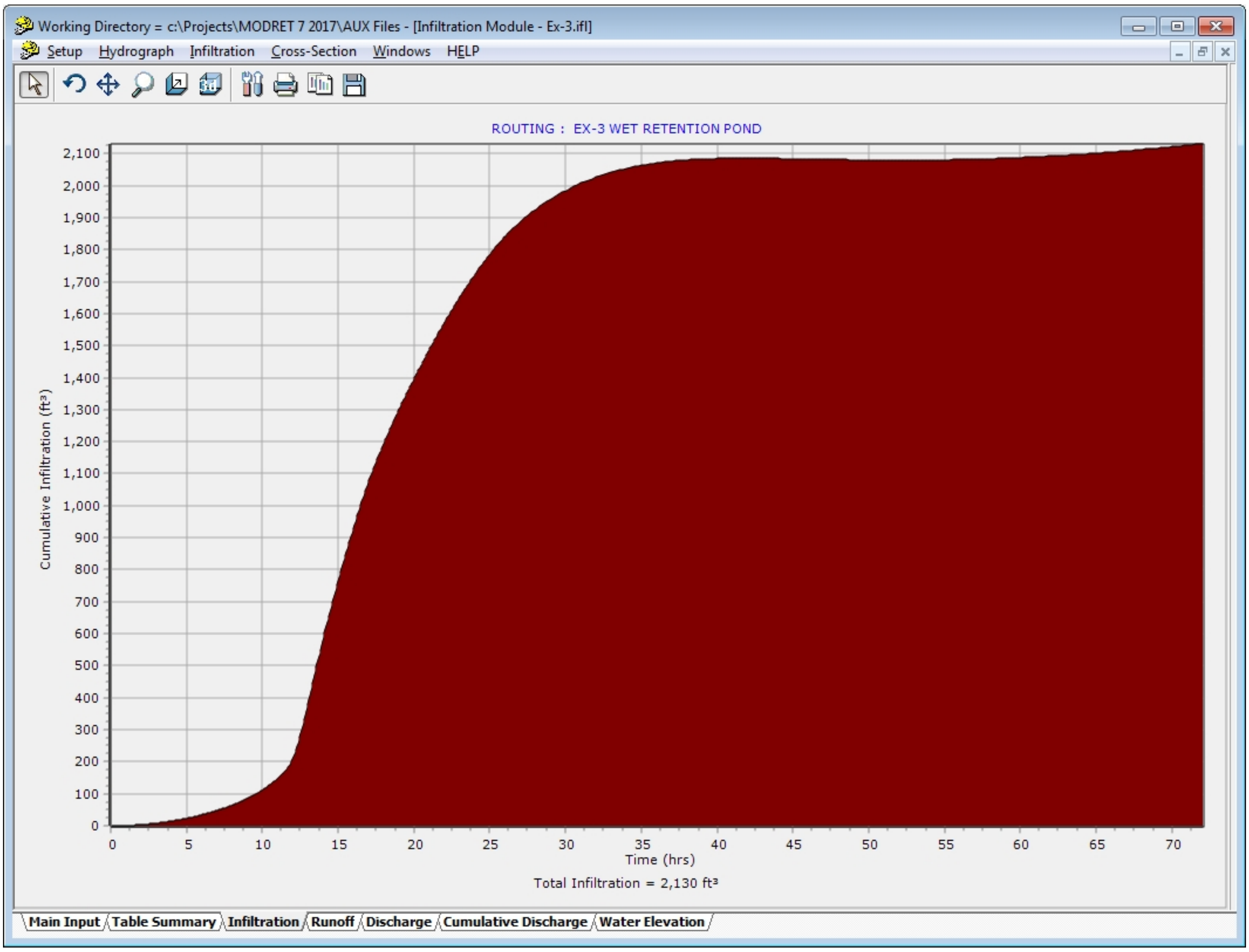
The pond length to width ratio can be estimated from the approximate site plan dimensions at 2.58 (310/120).

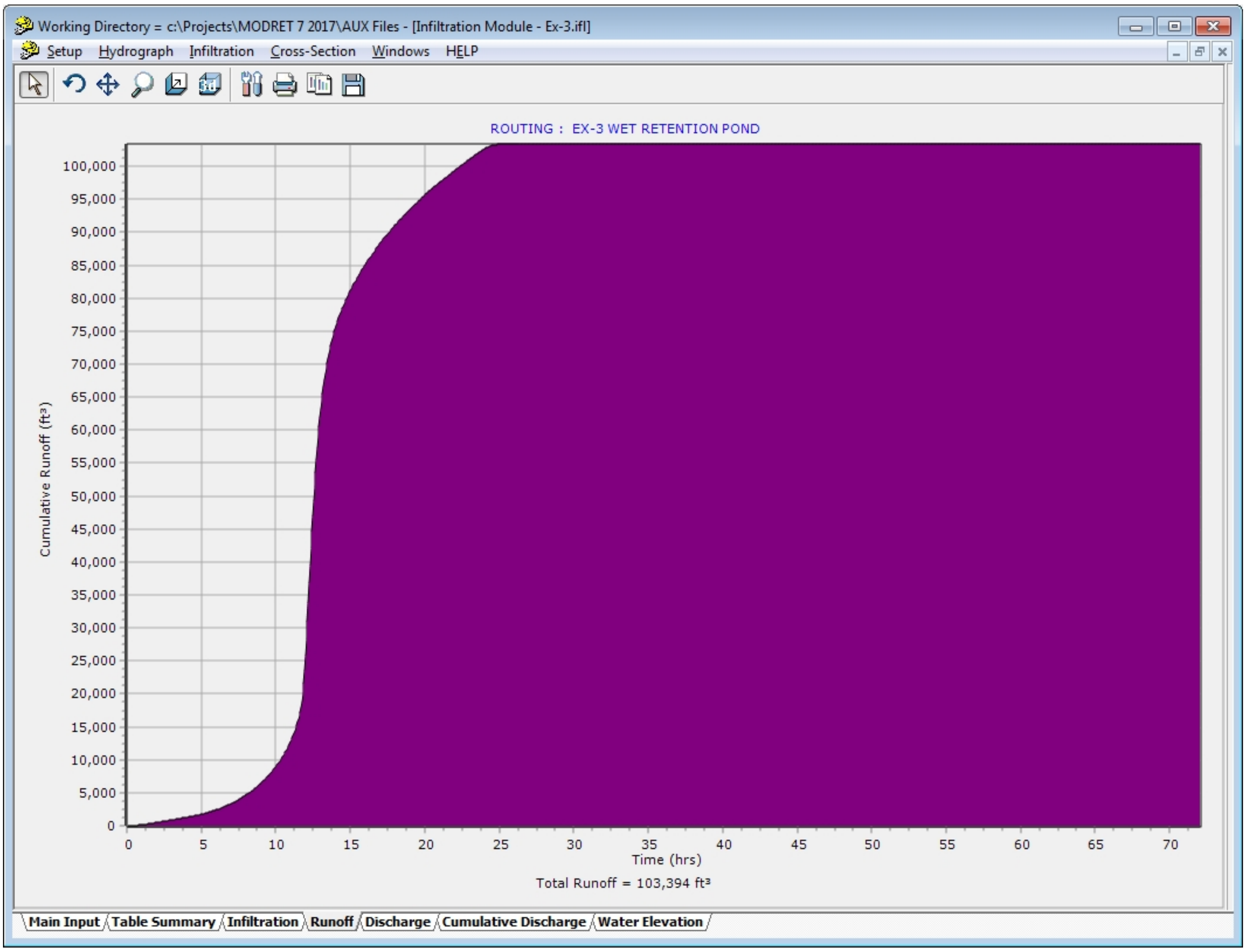
The overflow package of MODRET incorporates direct calculation of combined overflow rate for a weir and orifices. For cases where the overflow occurs through irregular or other structure types (other than weir and/or orifices, then the manual option of input for overflow will be necessary.
Now that all the needed parameters have been established or extracted from the data provided for this example problem, enter the data into the **Infiltration** module. The following screen shows the complete data entry for this example project:

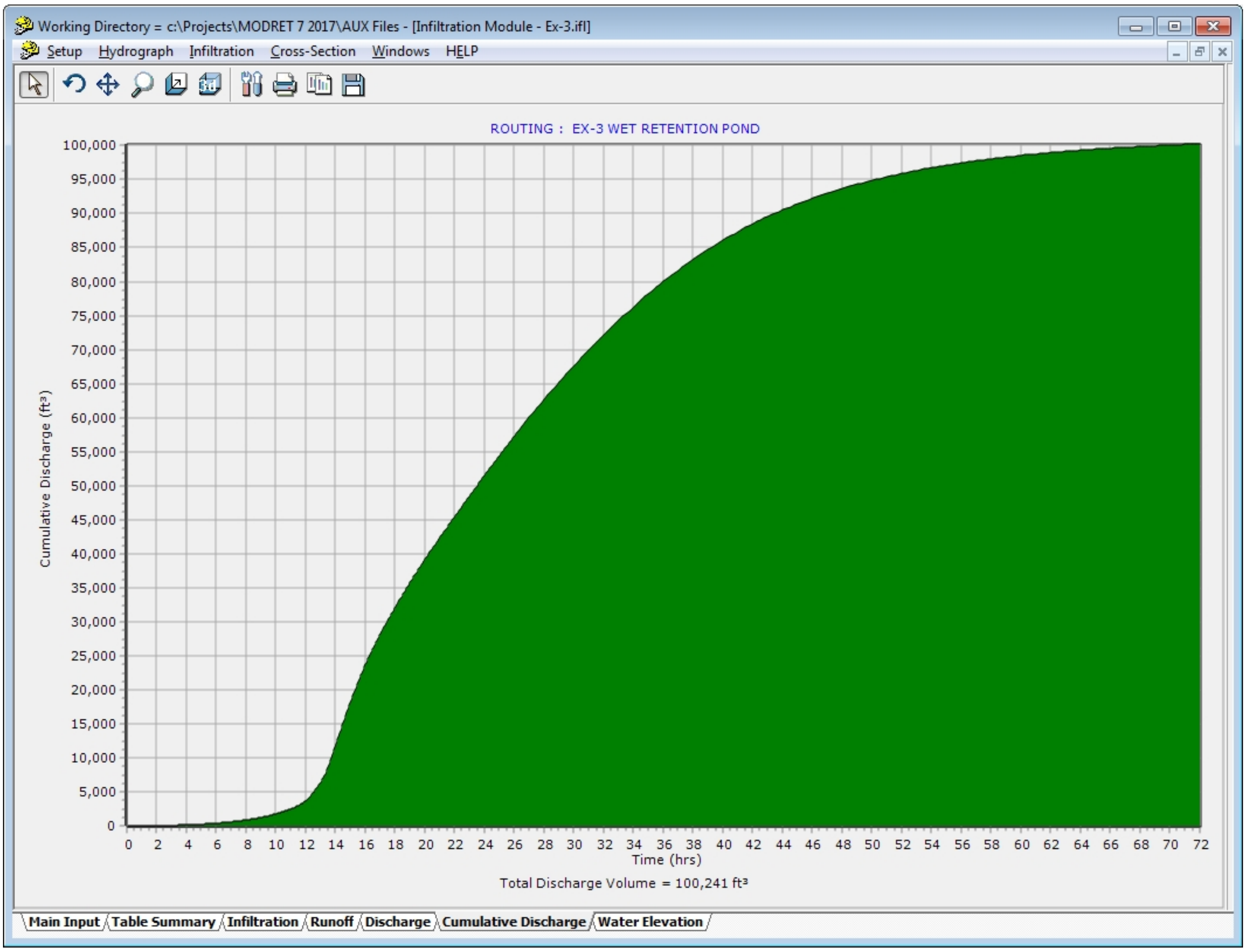


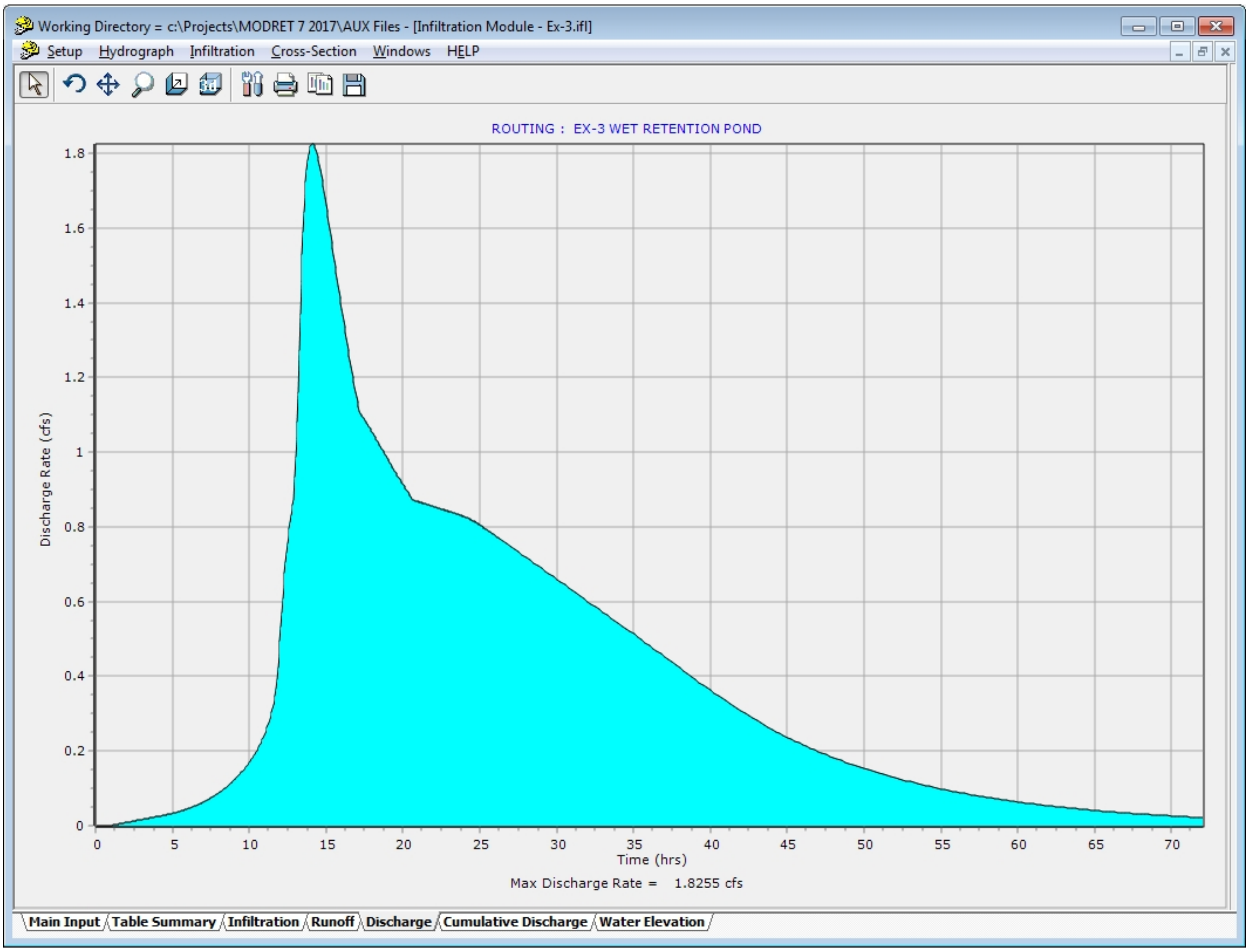


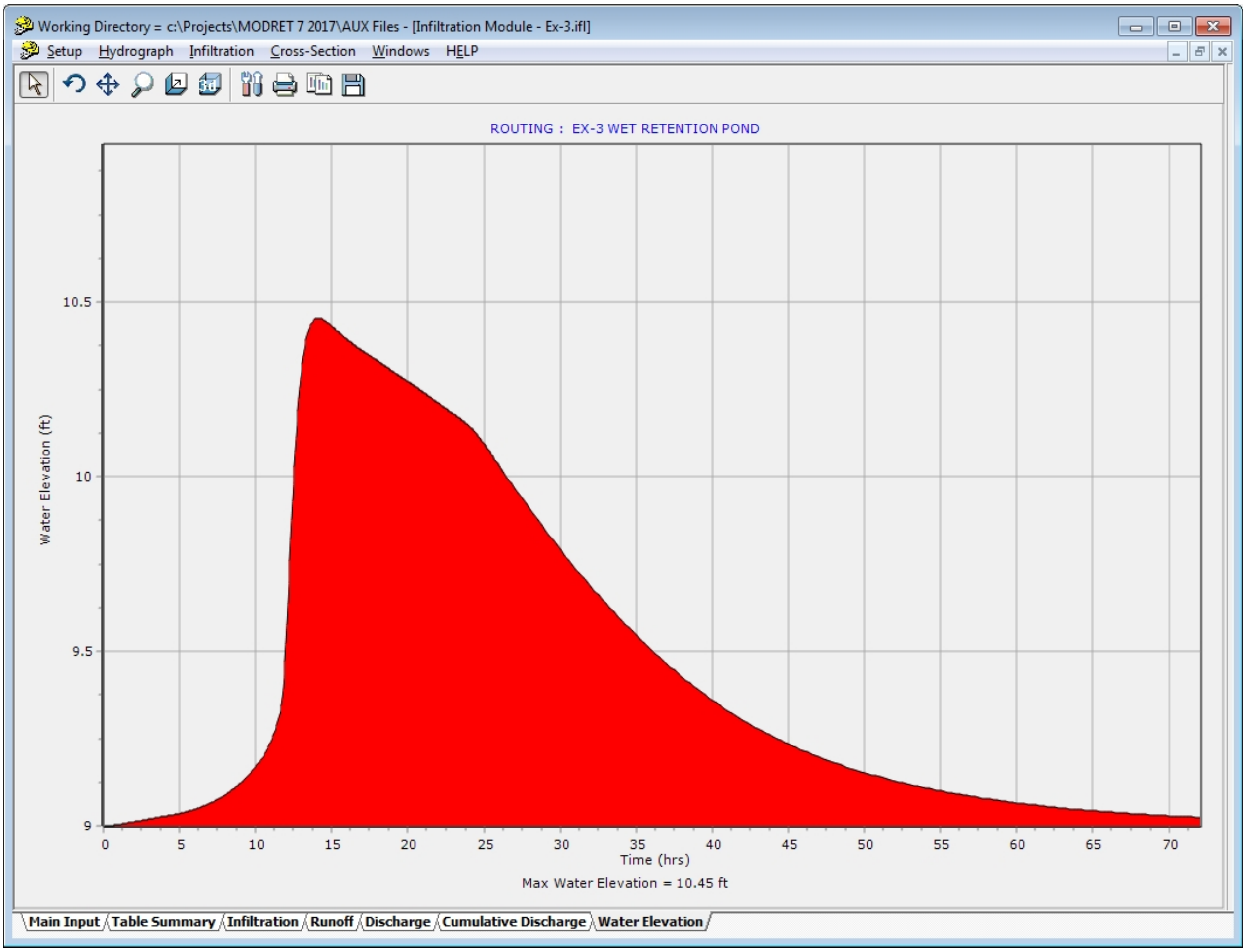
After entering all data and review, save the **Infiltration** data file by clicking **SAVE AS** then specifying a file name of **Ex-3.ifl** or other preferred by the user. After saving the input data, click **RUN** and select the previously created runoff hydrograph **Ex-3.SCS** to calculate infiltration and route the runoff through the pond and overflow structures. The following series of graphs present the results of the model simulation:


Working Directory = c:\Projects\MODRET 7 2017\AUX Files - [Infiltration Module - Ex-3.ifl]
Setup Hydrograph Infiltration Cross-Section Windows HELP
ROUTING : EX-3 WET RETENTION POND
Cumulative Infiltration (ft³)
Time (hrs)
Total Infiltration = 2,130 ft³
Main Input Table Summary Infiltration Runoff Discharge Cumulative Discharge Water Elevation


Working Directory = c:\Projects\MODRET 7 2017\AUX Files - [Infiltration Module - Ex-3.ifl]
Setup
Hydrograph
Infiltration
Cross-Section
Windows
HELP
ROUTING : EX-3 WET RETENTION POND
Cumulative Runoff (ft³)
100,000
95,000
90,000
85,000
80,000
75,000
70,000
65,000
60,000
55,000
50,000
45,000
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
Time (hrs)
Total Runoff = 103,394 ft³
Main Input
Table Summary
Infiltration
Runoff
Discharge
Cumulative Discharge
Water Elevation


Working Directory = c:\Projects\MODRET 7 2017\AUX Files - [Infiltration Module - Ex-3.ifl]
Setup Hydrograph Infiltration Cross-Section Windows HELP
ROUTING : EX-3 WET RETENTION POND
Cumulative Discharge (ft³)
100,000
95,000
90,000
85,000
80,000
75,000
70,000
65,000
60,000
55,000
50,000
45,000
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44 46 48 50 52 54 56 58 60 62 64 66 68 70 72
Time (hrs)
Total Discharge Volume = 100,241 ft³
Main Input
Table Summary
Infiltration
Runoff
Discharge
Cumulative Discharge
Water Elevation

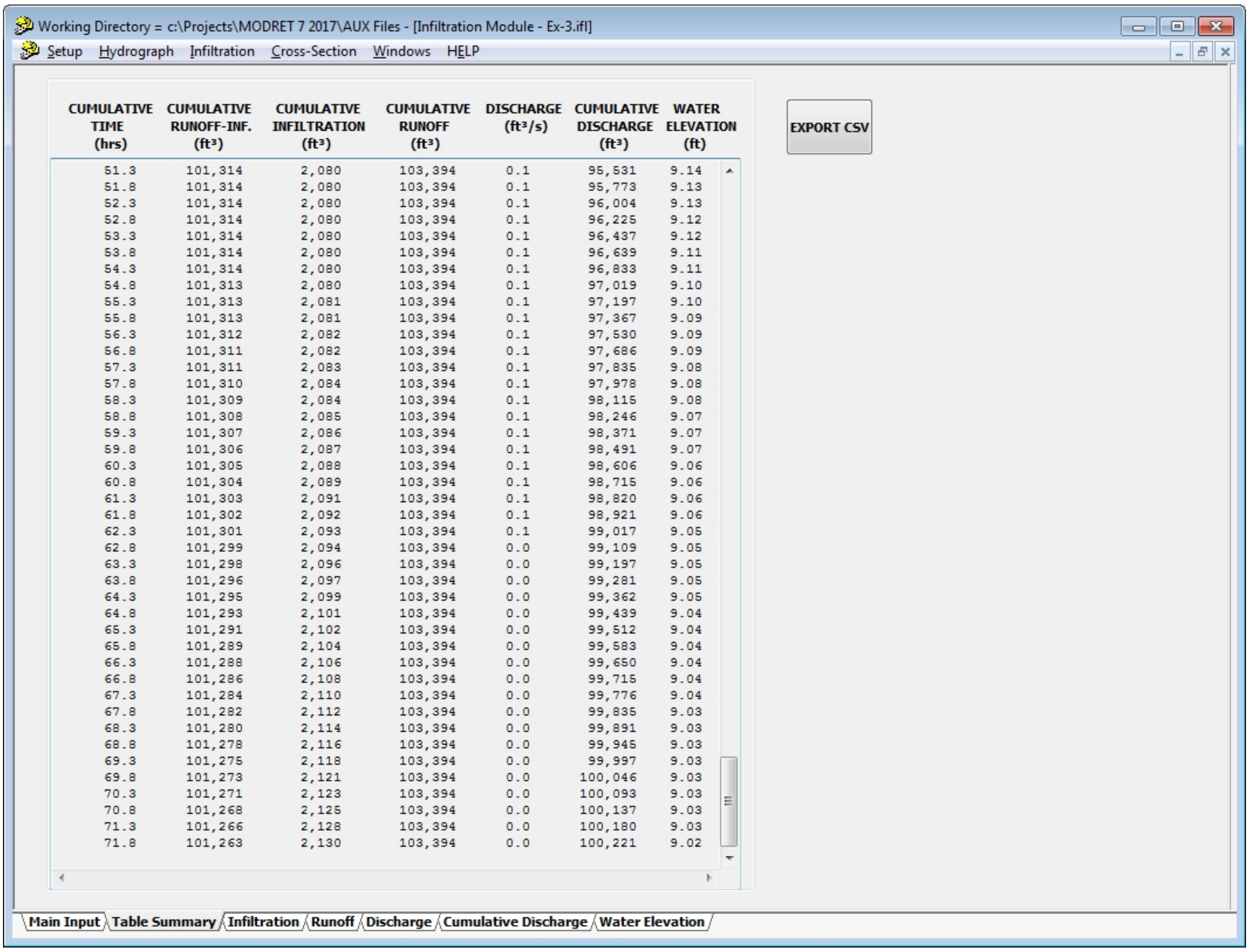

Working Directory = c:\Projects\MODRET 7 2017\AUX Files - [Infiltration Module - Ex-3.ifl]
Setup Hydrograph Infiltration Cross-Section Windows HELP
ROUTING : EX-3 WET RETENTION POND
Discharge Rate (cfs)
Time (hrs)
Max Discharge Rate = 1.8255 cfs
Main Input
Table Summary
Infiltration
Runoff
Discharge
Cumulative Discharge
Water Elevation



MODEL RESULTS AND EVALUATION

The results of the MODRET modeling indicate that the peak discharge rate for this pond is 1.82 cfs, which occurs at the routed maximum stage of 10.45 feet. The discharge occurs through the combined overflow structures, one harp crested weir and 2 orifices.

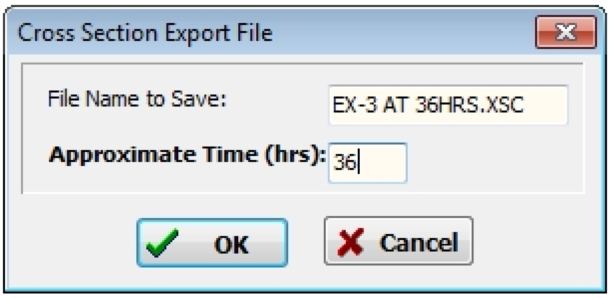
The time of recovery of the pollution abatement volume (PAV) below the weir can be estimated from the graphical interpolation of the **Water Elevation** graph above or direct look up in the **Table Summary**. The direct look up in **Table Summary** when water elevation drops to 9.05 feet shows a total time of 62.3 hours (38.3 hours after the 24-hour storm event).

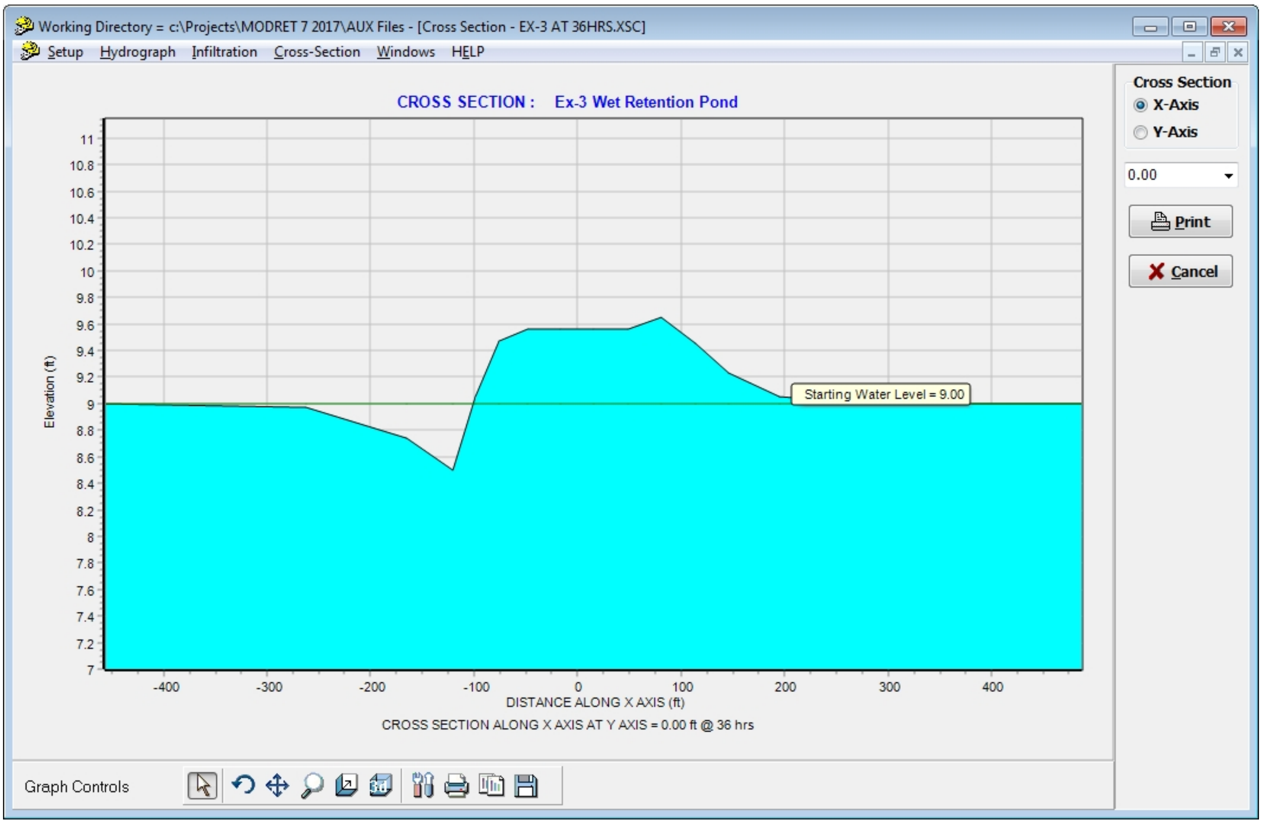


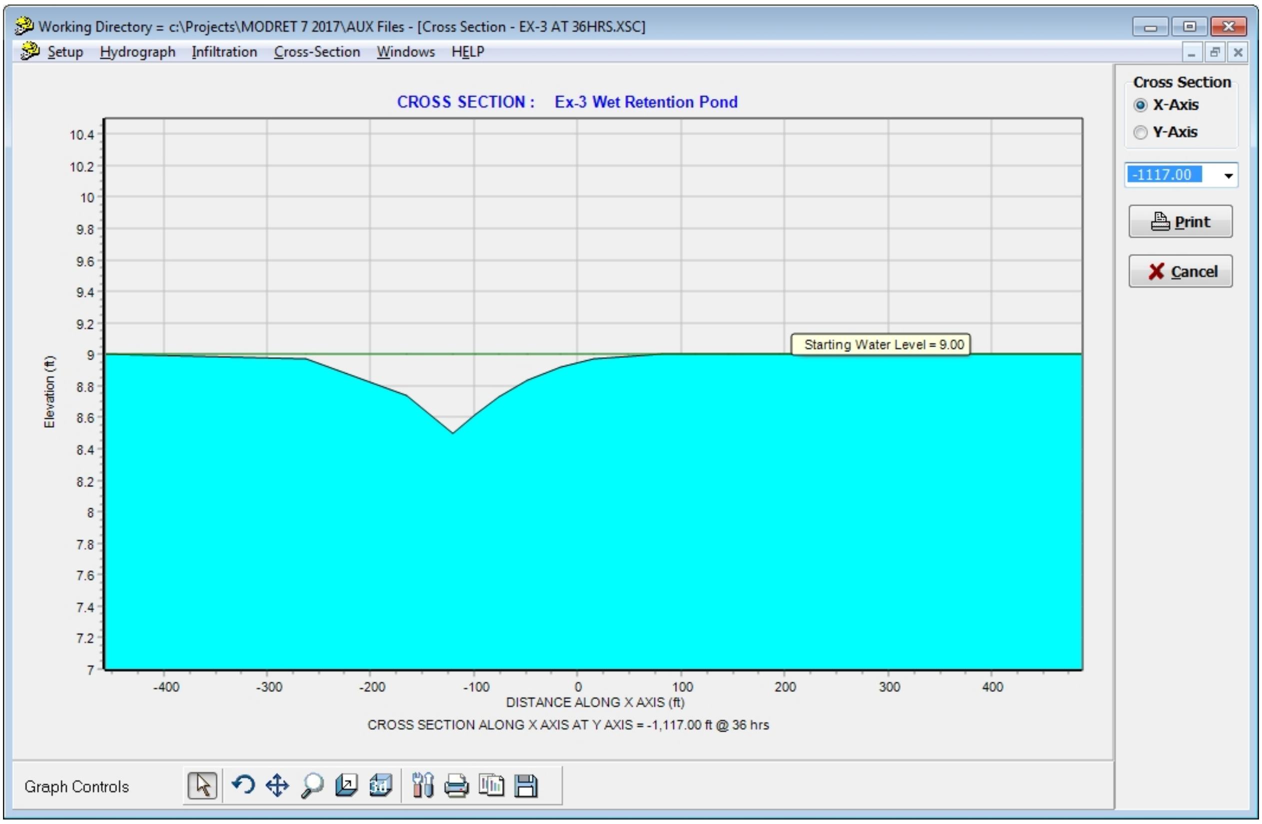
CUMULATIVE TIME (hrs)	CUMULATIVE RUNOFF-INF. (ft³)	CUMULATIVE INFILTRATION (ft³)	CUMULATIVE RUNOFF (ft³)	DISCHARGE (ft³/s)	CUMULATIVE DISCHARGE (ft³)	WATER ELEVATION (ft)
51.3	101,314	2,080	103,394	0.1	95,531	9.14
51.8	101,314	2,080	103,394	0.1	95,773	9.13
52.3	101,314	2,080	103,394	0.1	96,004	9.13
52.8	101,314	2,080	103,394	0.1	96,225	9.12
53.3	101,314	2,080	103,394	0.1	96,437	9.12
53.8	101,314	2,080	103,394	0.1	96,639	9.11
54.3	101,314	2,080	103,394	0.1	96,833	9.11
54.8	101,313	2,080	103,394	0.1	97,019	9.10
55.3	101,313	2,081	103,394	0.1	97,197	9.10
55.8	101,313	2,081	103,394	0.1	97,367	9.09
56.3	101,312	2,082	103,394	0.1	97,530	9.09
56.8	101,311	2,082	103,394	0.1	97,686	9.09
57.3	101,311	2,083	103,394	0.1	97,835	9.08
57.8	101,310	2,084	103,394	0.1	97,978	9.08
58.3	101,309	2,084	103,394	0.1	98,115	9.08
58.8	101,308	2,085	103,394	0.1	98,246	9.07
59.3	101,307	2,086	103,394	0.1	98,371	9.07
59.8	101,306	2,087	103,394	0.1	98,491	9.07
60.3	101,305	2,088	103,394	0.1	98,606	9.06
60.8	101,304	2,089	103,394	0.1	98,715	9.06
61.3	101,303	2,091	103,394	0.1	98,820	9.06
61.8	101,302	2,092	103,394	0.1	98,921	9.06
62.3	101,301	2,093	103,394	0.1	99,017	9.05
62.8	101,299	2,094	103,394	0.0	99,109	9.05
63.3	101,298	2,096	103,394	0.0	99,197	9.05
63.8	101,296	2,097	103,394	0.0	99,281	9.05
64.3	101,295	2,099	103,394	0.0	99,362	9.05
64.8	101,293	2,101	103,394	0.0	99,439	9.04
65.3	101,291	2,102	103,394	0.0	99,512	9.04
65.8	101,289	2,104	103,394	0.0	99,583	9.04
66.3	101,288	2,106	103,394	0.0	99,650	9.04
66.8	101,286	2,108	103,394	0.0	99,715	9.04
67.3	101,284	2,110	103,394	0.0	99,776	9.04
67.8	101,282	2,112	103,394	0.0	99,835	9.03
68.3	101,280	2,114	103,394	0.0	99,891	9.03
68.8	101,278	2,116	103,394	0.0	99,945	9.03
69.3	101,275	2,118	103,394	0.0	99,997	9.03
69.8	101,273	2,121	103,394	0.0	100,046	9.03
70.3	101,271	2,123	103,394	0.0	100,093	9.03
70.8	101,268	2,125	103,394	0.0	100,137	9.03
71.3	101,266	2,128	103,394	0.0	100,180	9.03
71.8	101,263	2,130	103,394	0.0	100,221	9.02

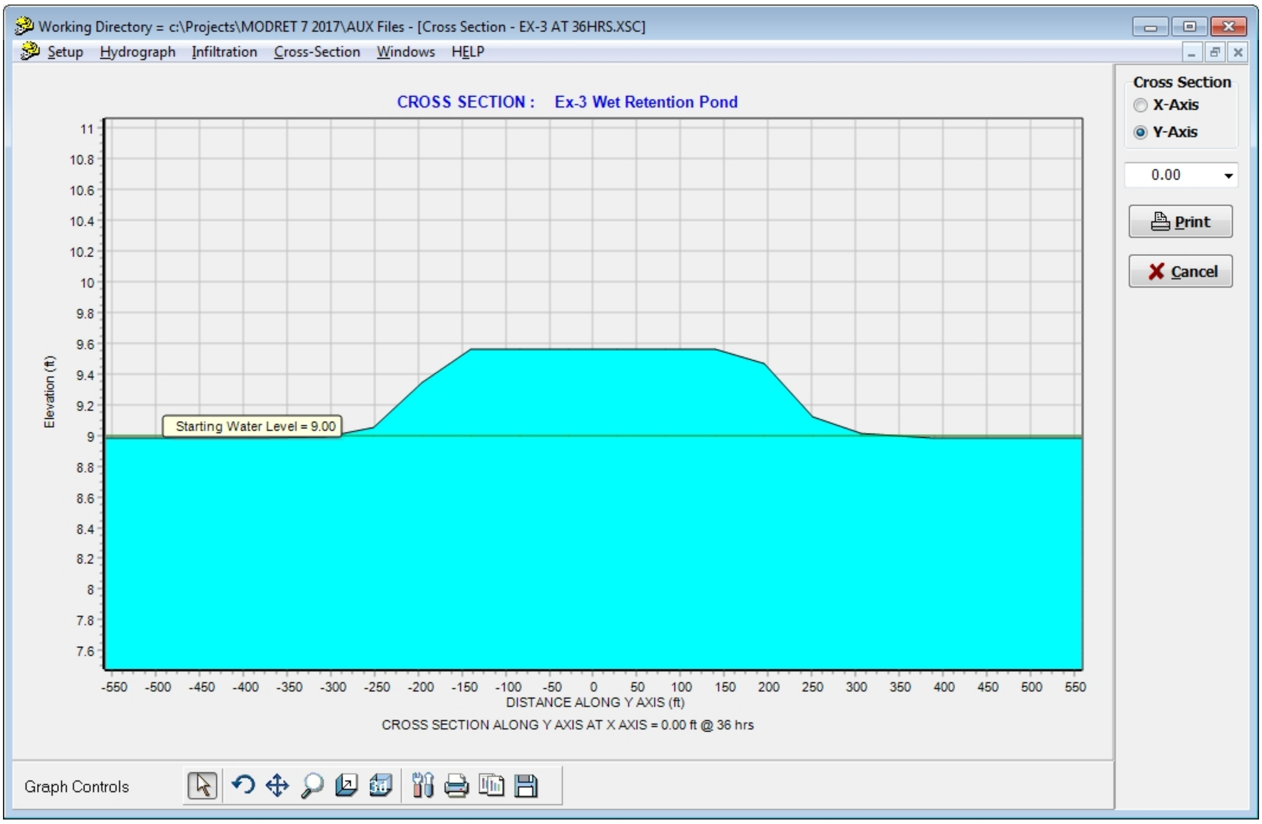
It can be observed on the **Infiltration** graph above that the infiltration losses from this pond are very low (total of 2,130 ft^3 during the entire simulation period of 72 hours). This is primarily due to the high groundwater conditions and low permeability soils.

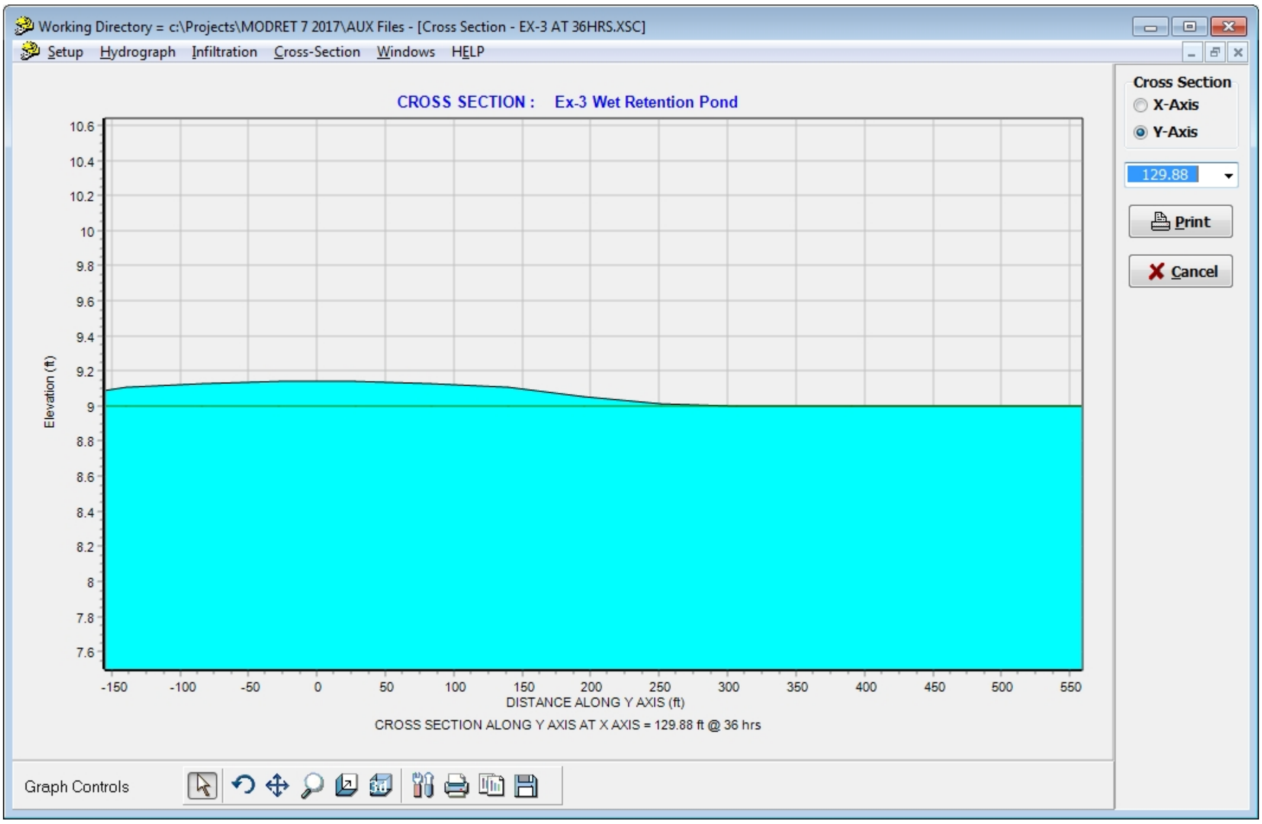
To assess the effects of hydraulic control features, the **Cross-Section** module can be selected to create a series of cross section across the pond and areas outside the pond. For this example, click on **Cross-Section**, then **New** and enter a name (**Ex-3 at 24 hrs**) and time (**24**). This will create a series of cross section for the end of storm event at 24 hours. However, any other time can be selected. The model will find the closest simulation stress period and create the cross sections. After creating the cross section data file, click on **Cross-Section** and **Open**, then select the file just created (**EX-3 AT 36HRS.XSC**) and click on the desired cross section from the optional menu on the top-right side of the screen. The following are several of the cross sections created for the 36-hour time period: as shown below:




Working Directory = c:\Projects\MODRET 7 2017\AUX Files - [Cross Section - EX-3 AT 36HRS.XSC]
Setup Hydrograph Infiltration Cross-Section Windows HELP
CROSS SECTION : Ex-3 Wet Retention Pond
Starting Water Level = 9.00
Elevation (ft)
DISTANCE ALONG X AXIS (ft)
CROSS SECTION ALONG X AXIS AT Y AXIS = 0.00 ft @ 36 hrs
Cross Section
X-Axis
Y-Axis
0.00
Print
Cancel
Graph Controls


Working Directory = c:\Projects\MODRET 7 2017\AUX Files - [Cross Section - EX-3 AT 36HRS.XSC]
Setup Hydrograph Infiltration Cross-Section Windows HELP
CROSS SECTION : Ex-3 Wet Retention Pond
Starting Water Level = 9.00
Elevation (ft)
DISTANCE ALONG X AXIS (ft)
CROSS SECTION ALONG X AXIS AT Y AXIS = -1,117.00 ft @ 36 hrs
Cross Section
X-Axis
Y-Axis
-1117.00
Print
Cancel
Graph Controls





The controlled water level of the ditch can be seen on the first cross sectional graphic above. The minor effects of the impervious barrier are almost unnoticeable on the cross sectional graphics. The cross section along Y-axis passes through the bottom portion of the pond, and the impervious barrier is located at the edge of the pond at a distance of about -155 feet. The range of the X and Y axis can be edited by the user to create a graphic that depicts the levels at a specific distance of interest. For example, the last graphic above was edited where the left axis, Y-axis, starts at the location of the impervious barrier, at -155 feet. The edits can be made using the tools icon on the bottom-left of the screen.

Supporting Technical Information

Effective Storage Coefficients

Typical Permeability Values

Conceptual MODFLOW Grid

Soil Storage Curves

Hydrograph Formats

Effective Storage Coefficients

TABLE A-1

Approximate Effective Storage
Coefficient of Fine Sands

(Source: Adapted from SFWMD Soil Storage Curves)

Effective depth to GWT (Feet)	*f* (fraction)	
	Compacted Soil	Uncompacted Soil
0	0.00	0.00
1	0.04	0.05
2	0.08	0.11
3	0.14	0.18
4	0.17	0.23
5	0.20	0.28
$ 6	0.22	0.30

Typical Permeability Values

TABLE A-2

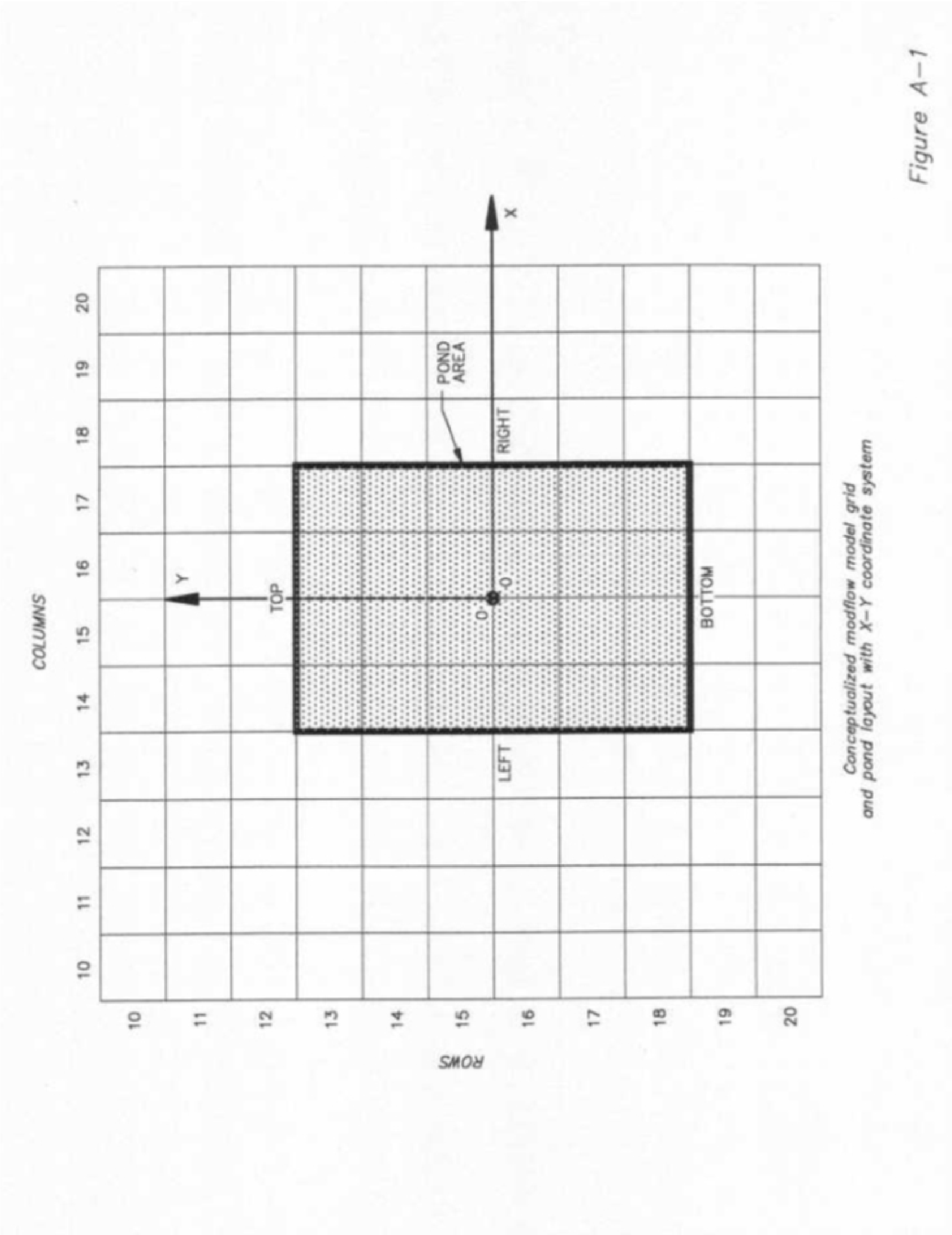
Typical Values of Permeability for Various Soil Types In Unconfined Sand Aquifers in Florida

(Source: Andreyev & Wiseman, 1989)

Type of Soil and USCS Classification	Hydraulic Conductivity (Feet/Day) *
Clayey fine sands and silty fine sands (SM-SC)	0.01 to 0.5
Slightly silty fine sands (SP-SM)	0.5 to 5.0
Clean fine sands (SP)	5.0 to 50.0
Fine to medium sands (SP)	20.0 to 100.0

* The range of permeability (hydraulic conductivity) values presented in this table generally reflect the variation of percent fines and soil density. Soil cementation also affects the permeability values.

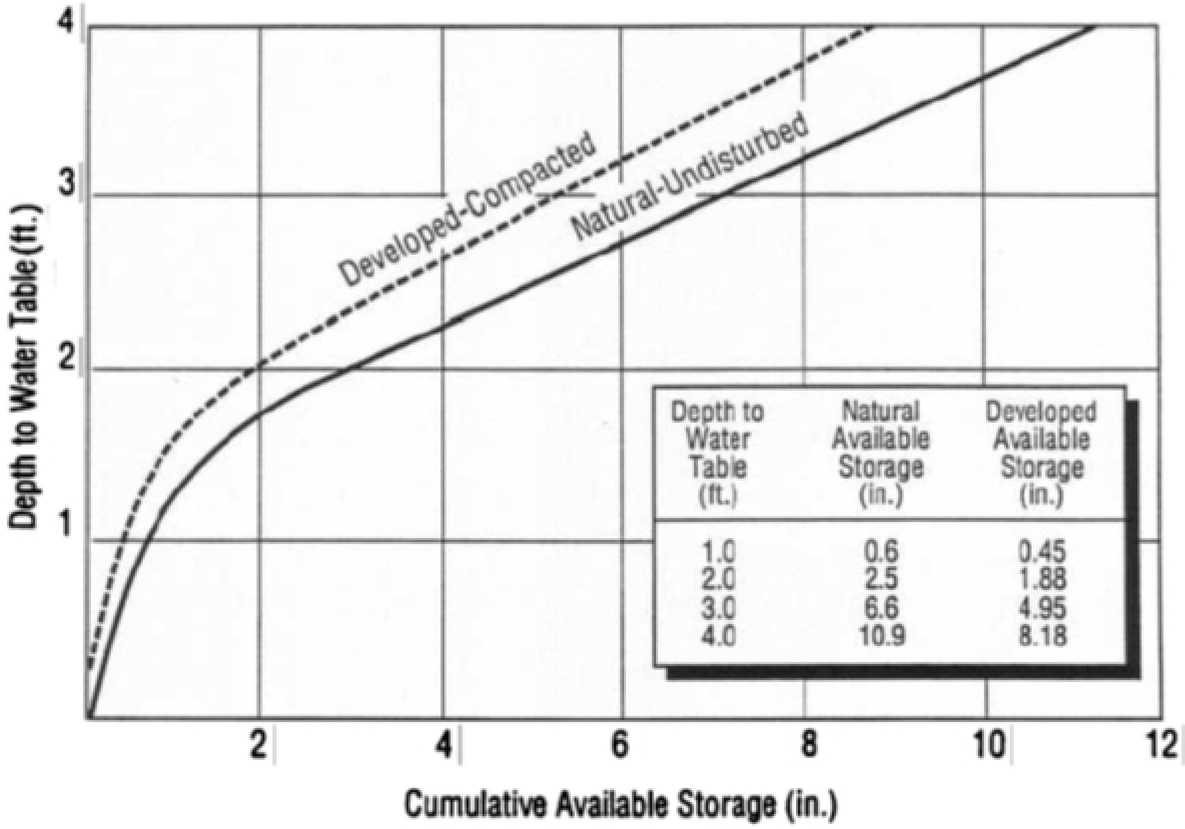
Conceptual MODFLOW Grid



Conceptualized modflow model grid and pond layout with X-Y coordinate system

Figure A-1

Soil Storage Curves



Depth to Water Table (ft.)	Natural Available Storage (in.)	Developed Available Storage (in.)
1.0	0.6	0.45
2.0	2.5	1.88
3.0	6.6	4.95
4.0	10.9	8.18

SFWMD Soil Storage Curves
A-3

Hydrograph Formats

SUMMARY OF HYDROGRAPH FORMATS

The following is a summary of two types of hydrograph formats (in ASCII) which MODRET expects, when read by the **Infiltration-Runoff Data** option, or the **Hydrograph-Open-Graph** option of MODRET:

ALTERNATIVE 1	ALTERNATIVE 2
NN TNI	NN TNI
n1	n1
n2	n2
.	.
.	.
nNN	nNN
t(1) $\mathrm{ROn1}_{(1)}$ $\mathrm{ROn2}_{(1)}$ . . $\mathrm{ROnNN}_{(1)}$	t(1)
t(2) $\mathrm{ROn1}_{(2)}$ $\mathrm{ROn2}_{(2)}$ . . $\mathrm{ROnNN}_{(2)}$	$\mathrm{ROn1}_{(1)}$
.	$\mathrm{ROn2}_{(1)}$
.	.
t(TNI) $\mathrm{ROn1}_{(TNI)}$ $\mathrm{ROn2}_{(TNI)}$ . . $\mathrm{ROnNN}_{(TNI)}$	.
	$\mathrm{ROnNN}_{(1)}$
	t(2)
Where:	$\mathrm{ROn1}_{(2)}$
	$\mathrm{ROn2}_{(2)}$
	.
NN = Total Number of Nodes	.
TNI = Total Number of Time Increments	$\mathrm{ROnNN}_{(2)}$
n1 = Node 1 Identification Name or Number	.
n2 = Node 2 Identification Name of Number, etc.	.
t(1) = First Time (hours) of Hydrograph, typically = 0.0	t(TNI)
t(2) = Second Time (hours) of Hydrograph, etc.	$\mathrm{ROn1}_{(TNI)}$
$t_{(TNI)}$ = Last Time (hours) of Hydrograph	$\mathrm{ROn2}_{(TNI)}$
$\mathrm{ROn1}_{(1)}$ = First Runoff Rate for Node "n1" (cfs)	.
$\mathrm{ROn2}_{(2)}$ = Second Runoff Rate for Node "n2" (cfs), etc.	.
$\mathrm{ROn1}_{(TNI)}$ = Last Runoff Rate for Node 1	$\mathrm{ROnNN}_{(TNI)}$