Surface Water Hydrology

The purpose of this training module is to teach users how to use XP's tools to create a hydrologic model from GIS files. You will learn how to use the Soil Conservation Service (SCS) and the SWMM Runoff methods for generating runoff from rainfall. Finally, hydrologic model results will be reviewed graphically and in tabular form.

In the Runoff mode, rainfall, infiltration, evaporation and depression storage for each subcatchment is simulated and the runoff is assigned to a collection node. Up to 5 subcatchments are allowed for each node. A variety of hydrologic methods are available to generate runoff hydrographs. Methods details are described in additional workshop modules and in the program documentation.

Objectives

A stormwater collection network can be developed in the graphical interface using a variety of methods. In this example, we will create a collection system network using the direct import of nodes, links and catchment polygons from shape files with GIS background images. Specifically, you will learn how to:

1. Use a template that provides basic Global Database items
2. Add and georeference an Aerial Photo
3. Add a corresponding CAD file to the project and control layer display
4. Create a surface or Digital Terrain Model (DTM)
5. Create and import data for nodes, and catchments from shape files
6. Use graphical tools to calculate subcatchment areas
7. Connect subcatchments to runoff nodes
8. Display and Derive Catchment Parameters from GIS
9. Create and assign SCS design storms in the Global Database
10. Manage Runoff Job Control settings
11. Run the hydrologic analysis
12. Use the global database to manage infiltration data
13. Define the SWMM runoff parameters in a subcatchment using xptables
14. Use graphical tools to obtain data for catchment parameters
15. Review results using XP Tables and the output file

Data files to be used are:

stormwater_template.xpt
TCD06ortho263.jpg
TCD06ortho263.jgw
Stormwater.dwg
spot_elevations.xyz (to create TIN)
Nodes.shp (GIS files for nodes)
Catchments.shp (GIS files for catchments)
stormwater.xls
Landuse_CN.shp
stormwater4a.xp
stormwater_SCS.xp
stormwater_completed.xp

Build a new model using a template

An xpswmm or xpstorm model includes a series of input and output files. The main files are the .xp database file that holds the data and results for the model and references other external files needed, such as background images or DTM surface data; the .mdb file which holds scenario information; and the .json file which contains rainfall data. A very efficient way to build a new model is to use a template file (.xpt). A template file is essentially an xp database that already has important information such as global database records that may be used for the new file.

Create new file from Template

1. Open xpswmm or xpstorm (xp).

2. At the opening dialog, select **Create From Template…**

3. In the Windows Explorer dialog, navigate to the **xps\workshop\M02-Hydrology** folder and name the file **stormwater.xp**. A file with the default extension (.xp) will be created.

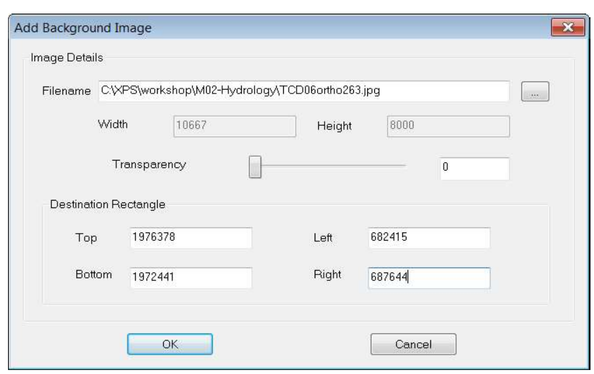
4. In the subsequent Windows Explorer dialog, select the provided template **XPS\workshop\M02-Hydrology\stormwater_template.xpt** and click on **Open**.

5. The template has **File->Properties** set as well as **Configuration->Global Data…->Rainfall** and **XP Tables**.

Add background image and CAD file

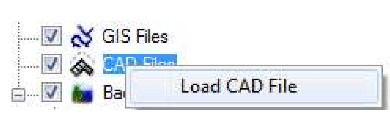
1. Using the menu choose **View->Background Images->Add Background Image** or use the icon on the toolbar for **Add Picture**. 

2. Select the file **XPS\workshop\M02-Hydrology\TCD06ortho263.jpg.** The coordinates **1976378**, **682415**, **1972441** and **687664** for the Top, Left, Bottom and right respectively are read automatically from a world file if present. These coordinates can also be directly entered.



3. Locate the **CAD Files** row on the Layer Control Panel.

4. Right click on the **CAD Files** layer and select **Load CAD File** from the popup menu as shown to the right.

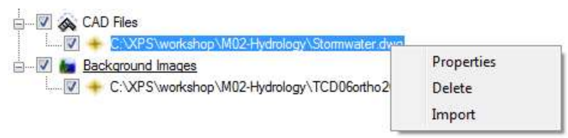


5. In the dialog, select the file **Stormwater.dwg**.

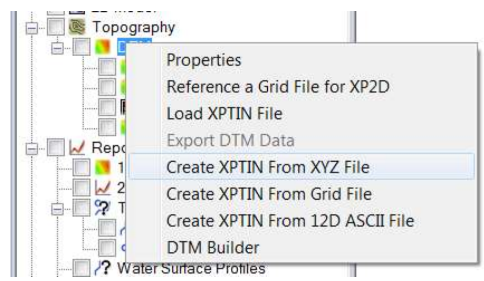
6. Click on **Open** to display the file on the network view. This file is georeferenced so that its x and y coordinates are coincident with the photo and proposed drainage network.

7. Pan the project site by depressing and holding the mouse wheel or right mouse button and then dragging the cursor. A hand appears next to the cursor to pan around the image. Use the mouse wheel to zoom in and out by rolling the wheel forward and backwards, respectively. A second option is to use the pan icon in the navigation panel.

8. To adjust the CAD layer display, right click on the **Stormwater.dwg** layer. Choose **Properties** from the popup menu. You can modify the display of layers in the CAD file at your discretion. Then click **OK** to view the drawing. For example, choose **Properties** again, **uncheck** the **UNITS** layer and view the drawing. You will now see the drawing without these layers of text.



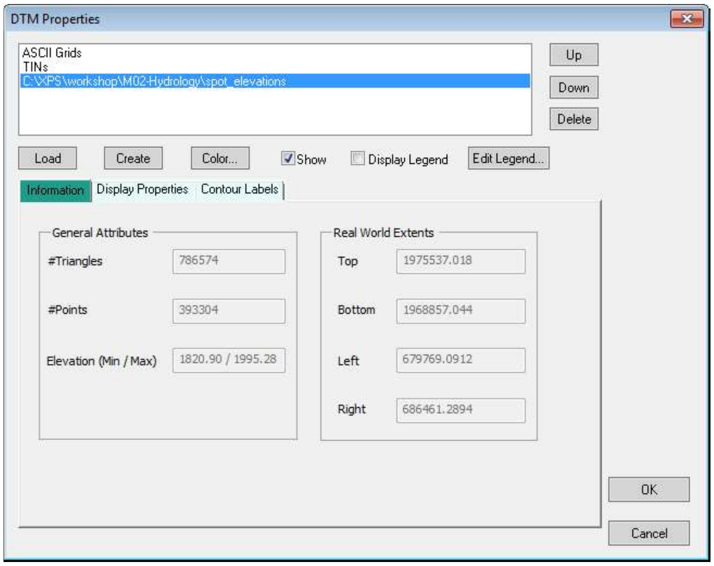
Build DTM



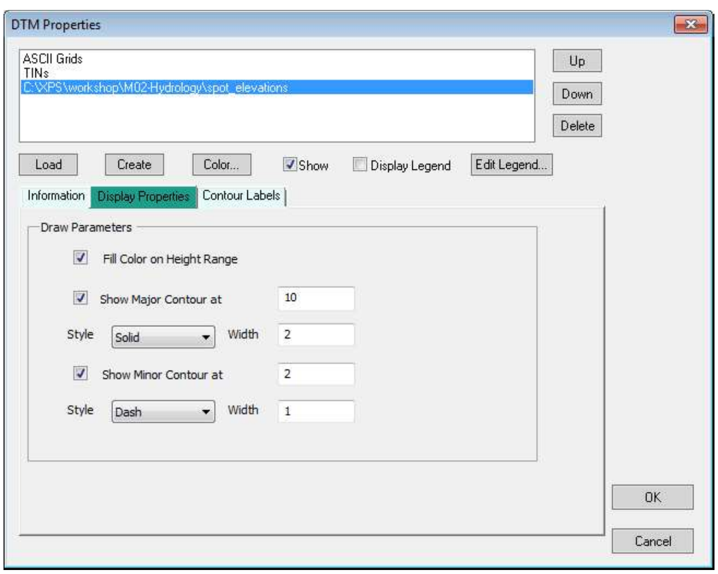
1. To build a digital terrain model (DTM) right-click the **DTM** layer in the Topography section of the Layer Control Panel. From the popup menu, select **Create XPTIN From XYZ File** and **Open** the file **spot_elevations.xyz**.

   Notes: The status bar will display the progress of the triangulation process. Also the S column in a XYZS is used for break lines. When consecutive values have the same S value those points are treated as a break line in the triangulation process.

2. **Right-click** on the line corresponding to the newly created layer. Select **Properties** from the popup menu. Click on **Color** to open the Gradient Colors dialog and set the transparency to about **0.4** using the Transparent slide bar or by directly entering the value. Click on **OK**.

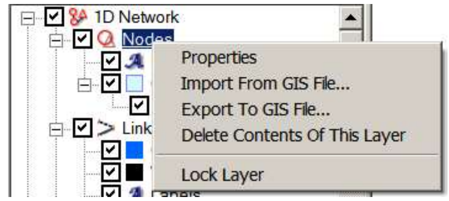


3. Select the **Display Properties** tab and then select the **Show Major Contour at** and **Show Minor Contour at** boxes. Adjust the display properties to show major contours at **10** and minor contours at **2** ft intervals as indicated in the figure above. If the **Fill Color on Height Range** box is unchecked, check this box. Click on **OK**.

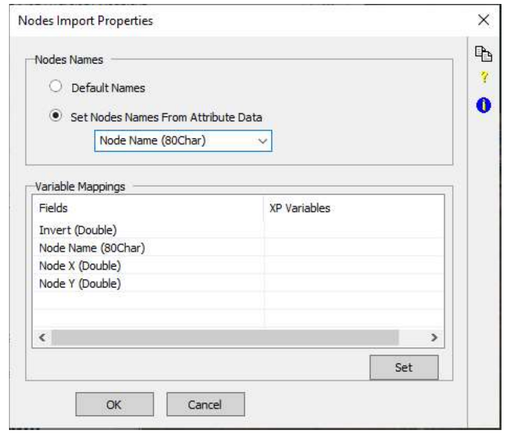


Importing Nodes, and Catchments from GIS (.shp) File

1. We are now ready to import nodes from GIS and overlay them over the optional supporting topographic and background layers. Ensure the Nodes layer is visible and unlocked. Right–click on the **Nodes** layer and choose **Import From GIS File…** Find and **Open** the file **Nodes.shp** and click on **Import**.



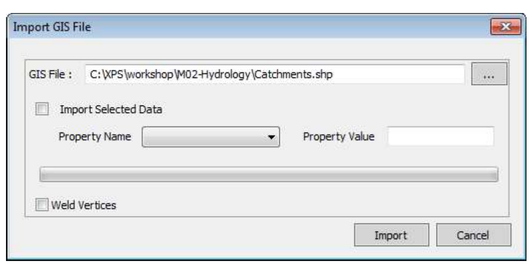
2. Click on the **Set Node Names From Attribute Data** radio button. Select **Node Name** field from the drop list. Other fields of data could be mapped if available in the Variable Mappings. Click on **OK**. A Data Import Information dialog box will report the results of the import and show that 10 objects were read. Click **OK** to close the message window.



3. The network view should show 10 nodes in the upper right-hand corner. **Zoom** to include those 10 objects in the lower left quadrant of the plan view. Note: The nodes may be more visible if the Background Image is turned off.

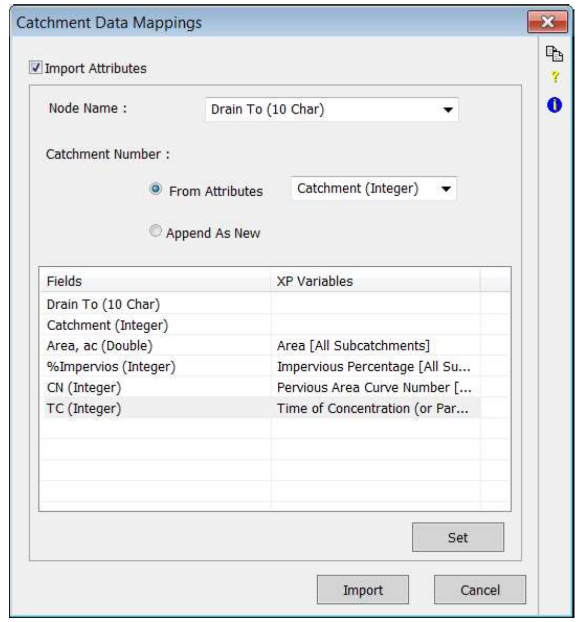
4. Save the View to be able to return to it easily in the future. Use **View->Save View** and enter **Network**. To return to that saved view use **View->Restore Views->Network**.

5. Load catchments from GIS. Make sure the Catchments layer is visible and unlocked. Right-click and choose **Import From GIS File…** from the pop-up menu.



Find and select the file **Catchments.shp**. Click on **Import**.

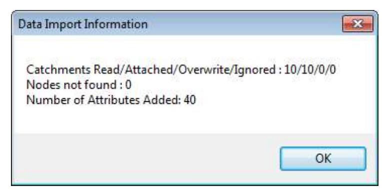
6. Catchments imported from GIS can be assigned to nodes and to a specific catchment position. In addition, hydrologic data can be imported by mapping fields. In the Catchment Data Mappings dialog choose **Drain To (10 Char)** for the **Node Name** field, and **Catchment (Integer)** for the **From Attributes** field. Lastly, in this dialog we will map the hydrologic fields.



7. Map the hydrologic fields. Select the **Area** field and **Set** it to **Node Data and Results->Runoff Node->RNF Node Data->Area** and click **OK**. Repeat this step for the 3 remaining fields. The Impervious Percentage will be found in the list below Area while the CN and TC fields should be mapped to:

CN: **Node Data and Results->Runoff Node->RNF Node Data->Sub Catchment Data->SCS Hydrology->Pervious Area Curve Number**

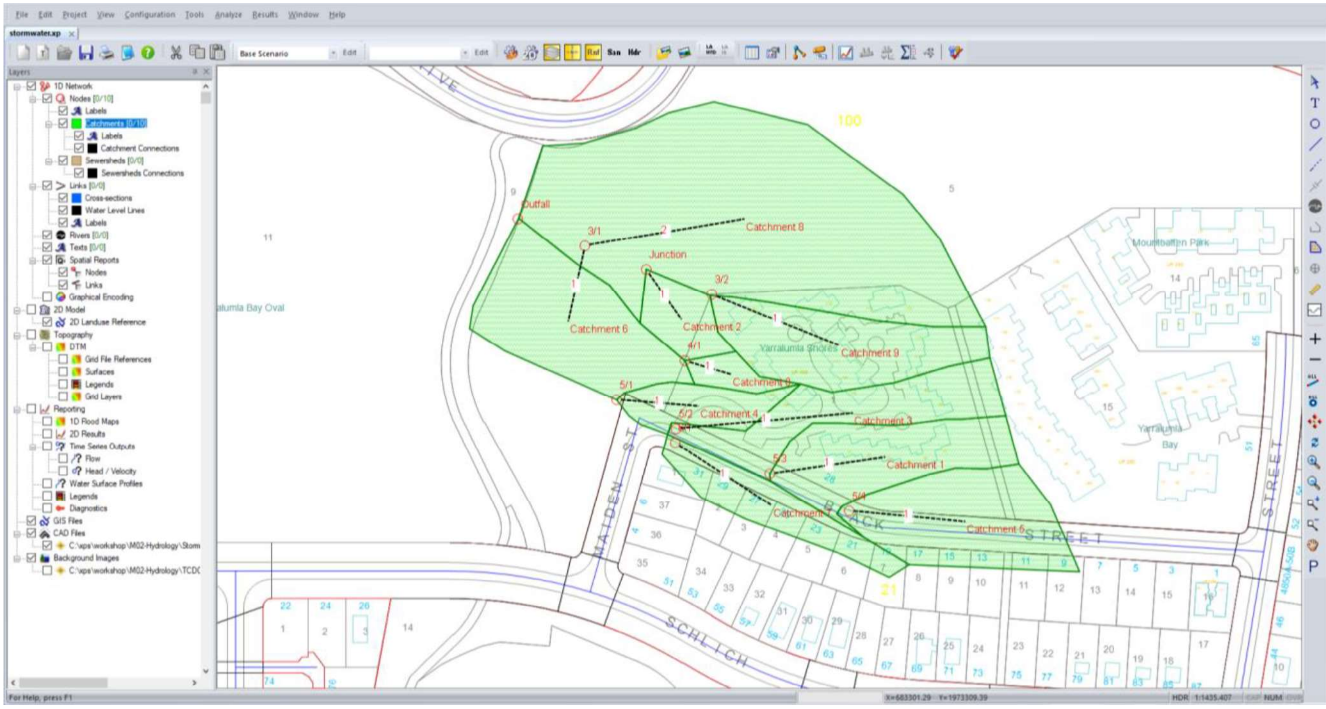
TC: **Node Data and Results->Runoff Node->RNF Node Data->Sub Catchment Data->Time of Concentration (or Parameter 2)**



Click on **Import**. A notification dialog box will report the import.

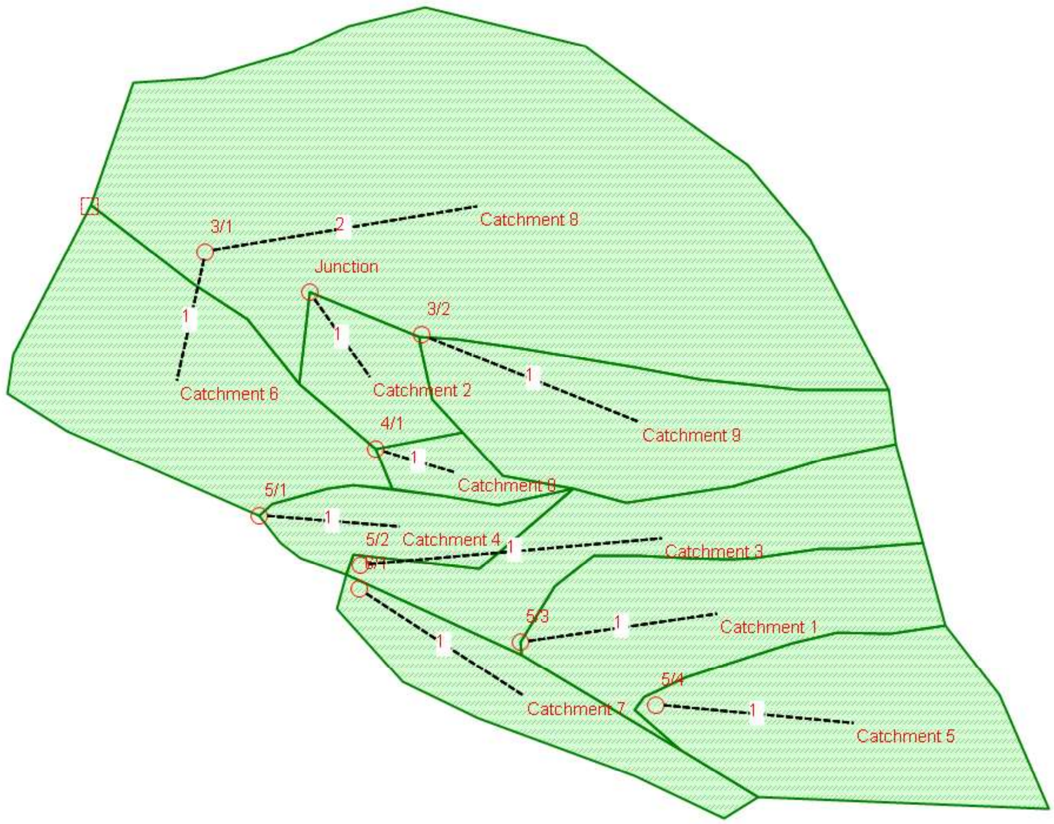
8. Turn off the **Background Image** and **Surface** to visualize the network and catchments.

9. The catchment polygons with the connections are displayed in the network view, as shown below. **Right-click** on the **Catchments** layer in the Layer Control Panel and select **Properties** to adjust the display (color, pattern, line size) of the catchments.

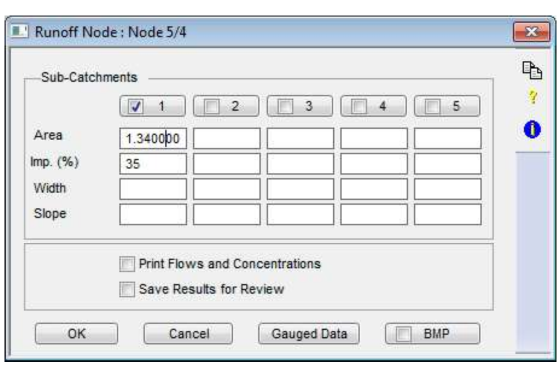


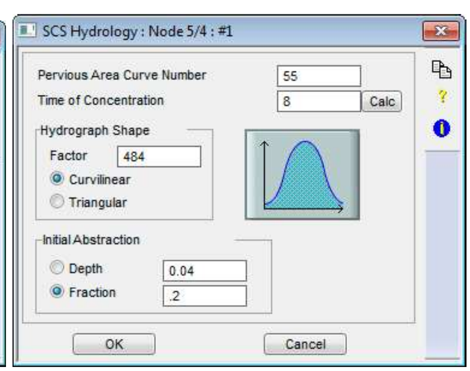
Verify Catchment Data Import and Calculate Areas

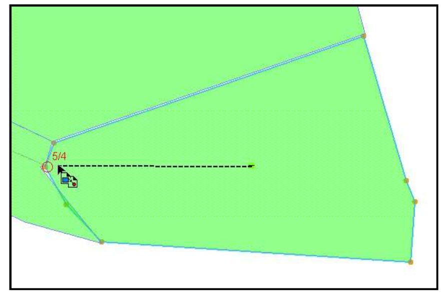
1. Verify Catchment Nodes in Runoff. Navigate to the Runoff mode by clicking on the **Rnf** button in the toolbar if it is not already highlighted. Having imported the nodes to the Runoff Layer they are inactive in the Runoff layer. To make the catchment nodes active, **click** on the **Select All Nodes** tool or <**Ctrl>+A**. Then click on the **"+"** tool or **+** key on the keyboard. This action will make all selected Nodes in the network active in the current mode. Then **click** on white space of the network view to deselect the nodes. Next **click** on the node **Outfall** then click on the **"-"** tool. This will leave only nodes active in the Runoff Mode with catchments. The network should appear as shown on the next page. Note: multiple objects can be selected using the **<Ctrl>** with click.



2. **Double-click** the catchment polygon connected to node **5/4**. The imported data can be seen in the Runoff Node dialog, and in the SCS Dialog found within the Sub-Catchment dialog. In the Runoff Node dialog, **Width** and **Slope** values are required, and an error message will display if they are left blank. Enter a value of **1.0** for both to make the error message go away. The **Width** and **Slope** are not used for the SCS routing method, and we will go over these parameters in more detail when we discuss the **RUNOFF** routing method.



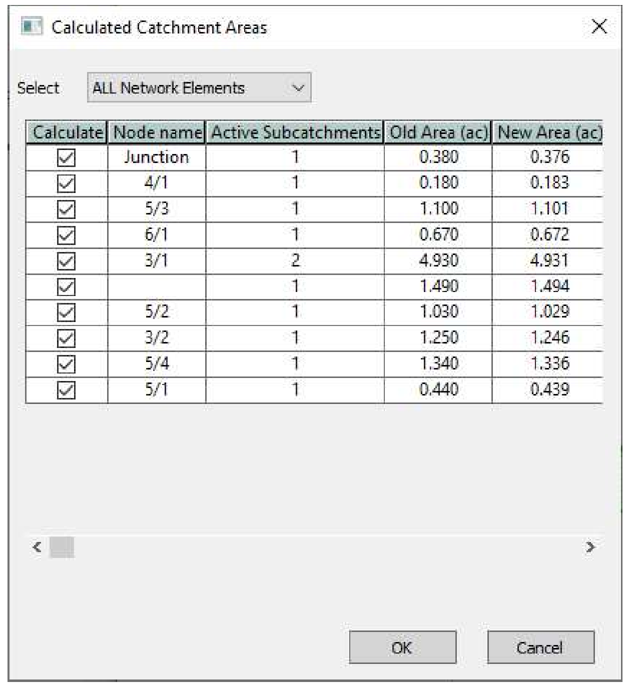




Note: To connect catchment polygons to nodes: Select the polygon. Move the cursor over the centroid, it will appear as shown to the right indicating a catchment to node drawing process. Hold the left button down and draw a line to the node. Once snapped to a node the cursor will appear as a cross. Release the button and a menu will appear. Choose the drain to subcatchment positions.

3. Calculate catchment areas. On the Tools menu select **Calculate Node** and then **Catchment Areas**.

   A dialog will be displayed showing the imported values and new (calculated from the subcatchment polygons) areas. The new areas may be edited to override the calculation. Click on **OK** to accept the new values. This data is added to the model database. A dialog box will show that the calculation was completed successfully. Click **OK**.

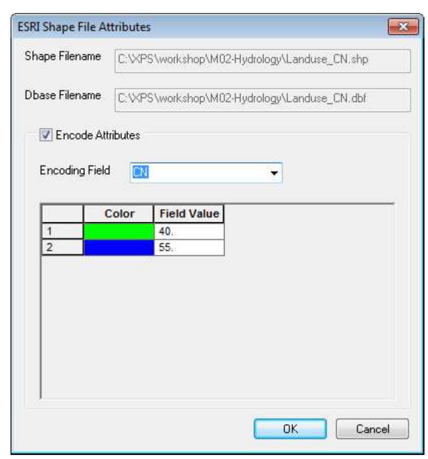


4. Save your file as **stormwater2.xp** by selecting the **File** menu and using the **Save As…** selection in the list.

Display and Derive Catchment Data From GIS Files

1. **Right-click** on the **Background Images** layer in the Layer Control Panel and choose **Add Background Image**. Select the file using the ellipsis **(…) Landuse_CN.shp** and press **Open**.

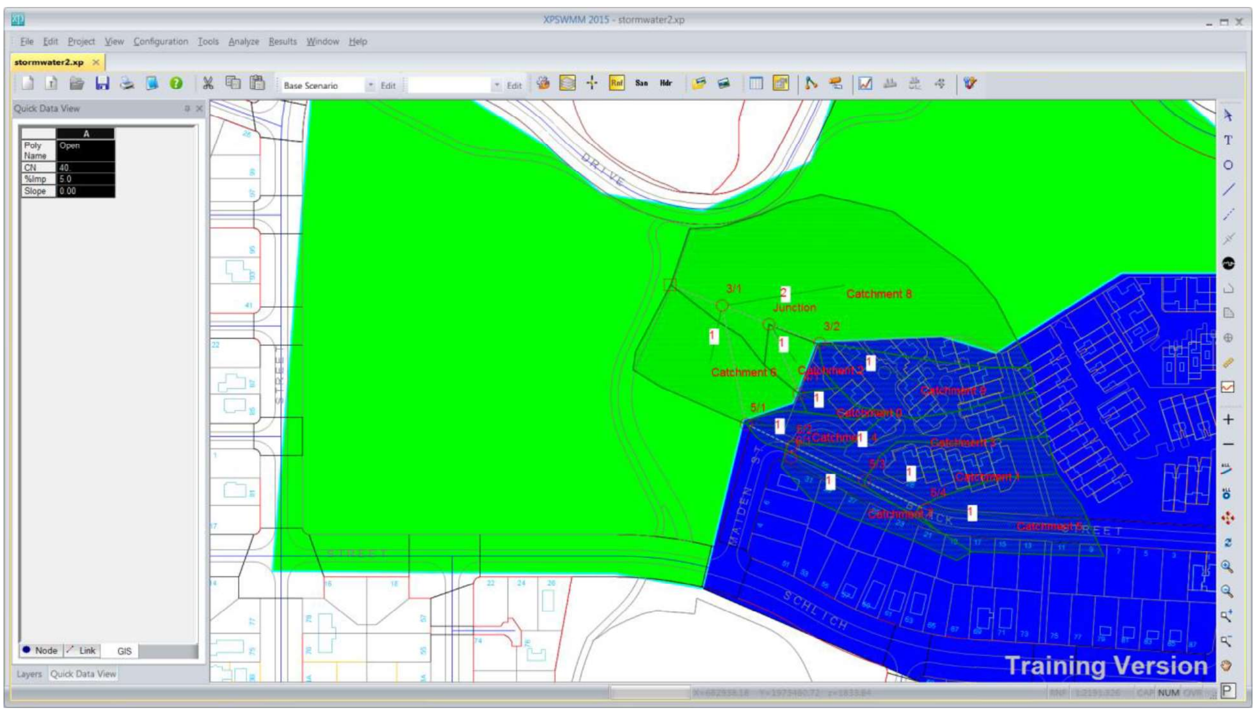
2. In the ESRI Shape File Attributes dialog choose **Encode Attributes** and select **CN** as the Encoding Field. The colors may be altered or accept green for a value of 40 and blue for a value of 55. Click **OK**. This will color the polygons in the plan view based on the CN field. Shapefiles of polylines and points can also be displayed in this manner. **Restore** the **Network** view.



3. Load a GIS File. Data from GIS files can also be displayed in the plan view. **Right-click** on the **GIS Files** layer in the Layer Control Panel and select **Load GIS File**. Select **Landuse_CN.shp** and press **Open**. The polygons are traced with a black line in the Plan View. Color, fill and line color can be specified to the newly added GIS layer, by right-clicking the new layer where the GIS file is loaded, and then selecting **Properties**. All objects will have the same color in this layer.

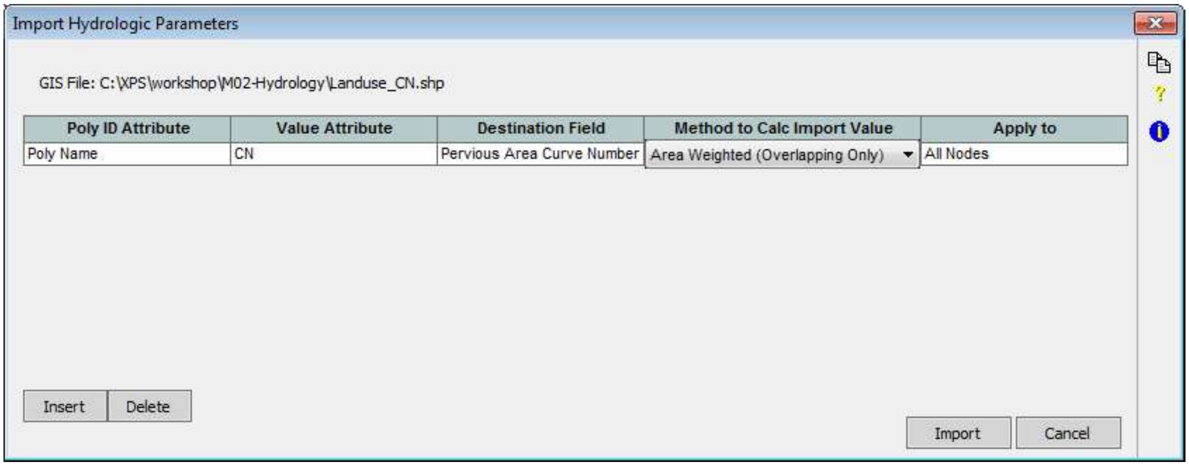
4. Turn on the Quick Data View. Select the **Quick Data View** icon  to enable the quick data view window.

5. With the pointer tool **select** the various **polygons** of the highlighted GIS Files layer. Using **<Ctrl>** and mouse click more than one object can be selected.



6. Import Hydrologic Parameters. A specialized tool has been developed to generate some hydrologic parameters by intersecting the linked catchments with GIS files. **Right-click** on the **GIS Files->Landuse_CN.shp** file layer and choose **Import Hydrologic Parameters...**

7. Complete the table as shown below by Selecting **Poly Name**, **CN**, **Pervious Area Curve Number**, **Area Weighted (Overlapping Only)** and **All Nodes** from left to right.



8. Select **Import**. A report should appear in the default editor with each of the polygon intersects reported as a percentage and the final derived value. These values are now assigned to the nodes. **Save** the model.

Questions

Please answer the following questions and we will review the answers together.

1. In regards to the DTM used in this exercise, what are the:

   Number of suvery points _____

   Minimum elevation _____ ft

   Maximum elevation _____ ft

2. Open the File menu, select **Properties** and click on **Job Statistics**. In the current column, what are the number of:

   _____ links

   _____ nodes

   _____ maximum number of nodes

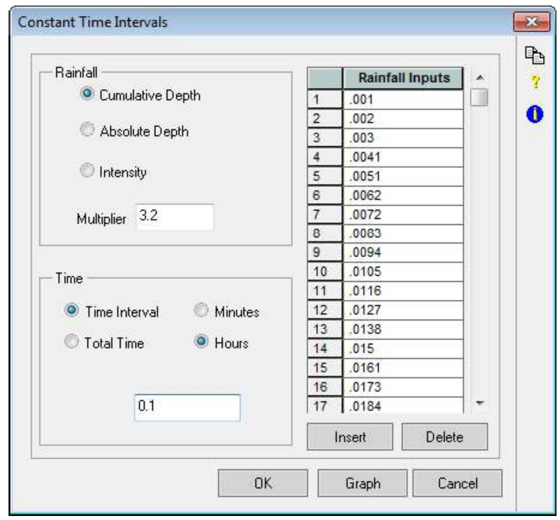
3. How many catchment polygons are in the stormwater model? _______________ catchments

4. Which node and subcatchment number has the largets area? _________________

5. How many ctachments can be assigned to a node? ____________________________

Adding Design Storms with SCS Hydrology

In xp, design storms and rainfall hyetographs can be imported by a variety of methods. In the United States, a set of commonly used design storms are the SCS 24-hour rainfall distributions. This section demonstrates how SCS rainfall distributions are scaled into a design storm. Our template already has the SCS rainfall distributions but these could also be imported to any model file using an XPX text file. These files allow the import of external data into the XP database.



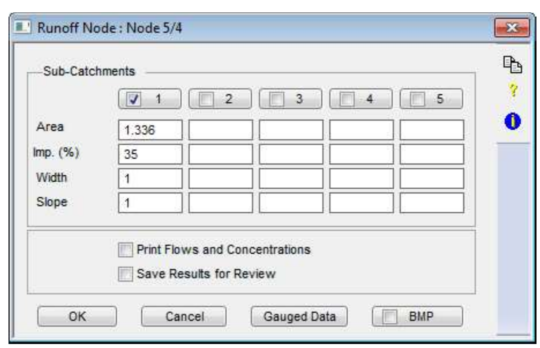
SCS Hydrology

1. Creating the 3.2 inch – 24 hour design storms from the SCS Type II distribution. On the **Configuration** menu, select **Global Data**. In the left panel select **(R) Rainfall**. In the right panel select **SCS Type II**. Click on **Duplicate**. A new storm "**SCS Type II.1**" is created. In the editing box below the record list, change the name to **5yr-24Hr SCS Type 2**. Click on **Rename**.

2. Click on the **Edit** button to open the (R) Rainfall dialog. Select **Constant Time Intervals**. Enter **3.2** as the **Multiplier** and click on **Graph** to view the rainfall hyetograph.

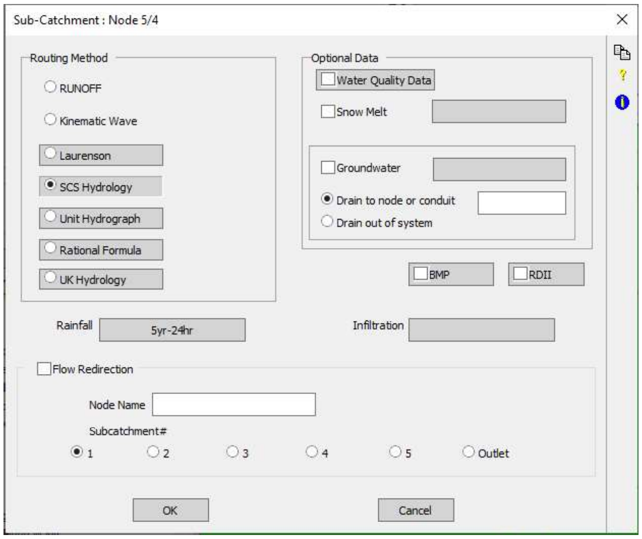
   Note: The graph always displays intensity vs. time.

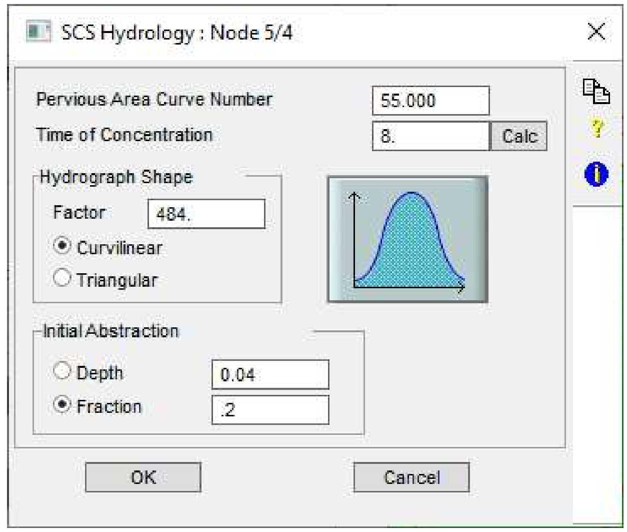
   Click on **Close** and then **OK** three times to return to the network view.



3. Enter the remaining Hydrology data. Double-click on node **5/4** or its catchment polygon to open the Runoff Node dialog. The catchment area and percent impervious were previously imported. The Width and Slope are not used in SCS Hydrology. However, xp requires that these fields have positive nonzero values. We will use the value of **1** and **1** for both the **Width** and **Slope**.

4. **Double-Click** on the **Sub-Catchments 1** flag to activate the subcatchment and advance to the Subcatchment dialog. This dialog allows the selection of the Hydrologic Routing Method and supporting parameters and the Rainfall record to be applied to this catchment.

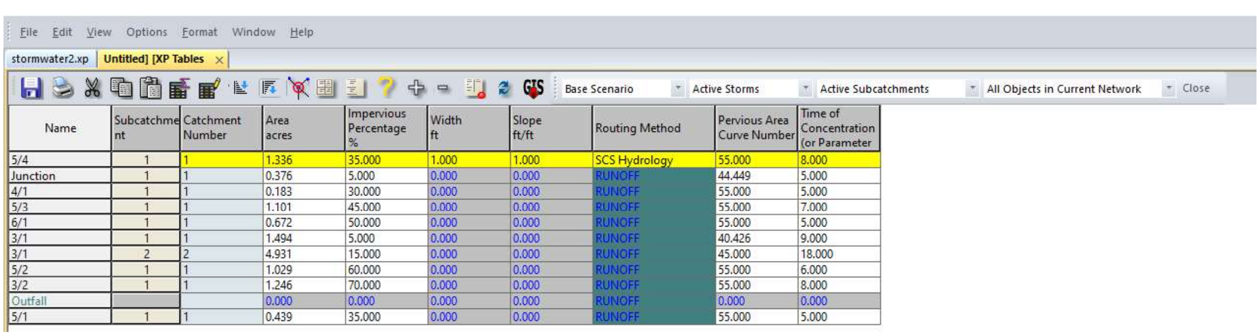




5. Click on the **SCS Hydrology** button. The values of **55** and **8** respectively for the Pervious Area Curve Number and Time of Concentration were imported and derived from GIS attributes. Click **OK** to use the Hydrograph Shape Factor default value of 484 and other defaults such as initial abstraction values. Click on **OK**.

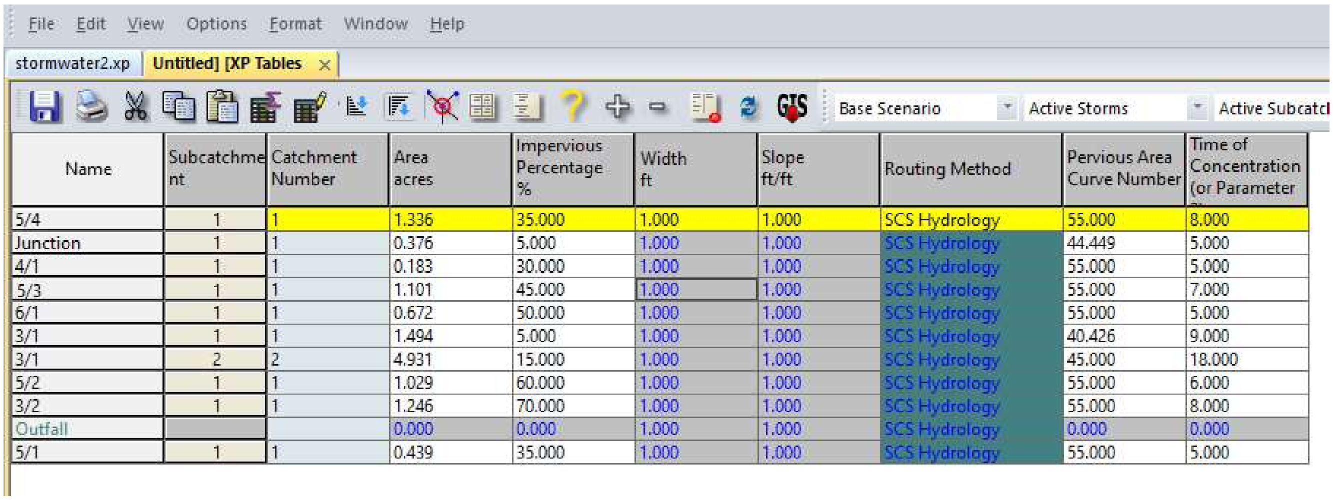
6. Click on the **Rainfall** button. Select the **5yr-24hr** storm from the Global Database and click on the **Select** button. Copy the record using the Copy Icon in the upper corner of the dialog. Click on **OK** two times to return to the network view. Select all the nodes and then Paste so they all have the rainfall record.

7. We could repeat the selection of each node and following the above procedure, enter the data in the table below for the remaining runoff nodes. However, using **XP Tables** data can be entered more efficiently. Click on the **XP Tables** icon or press **F2**. Select the **Physical Hydrology** table (using tabs at the lower right-hand corner). Use the All Objects in Current Network combo box option as Opposed to Selected to see all object rows.



Name	Subcatchment	Catchment Number	Area acres	Impervious Percentage %	Width ft	Slope ft/ft	Routing Method	Pervious Area Curve Number	Time of Concentration (or Parameter
5/4	1	1	1.336	35.000	1.000	1.000	SCS Hydrology	55.000	8.000
Junction	1	1	0.376	5.000	0.000	0.000	RUNOFF	44.449	5.000
4/1	1	1	0.183	30.000	0.000	0.000	RUNOFF	55.000	5.000
5/3	1	1	1.101	45.000	0.000	0.000	RUNOFF	55.000	7.000
6/1	1	1	0.672	50.000	0.000	0.000	RUNOFF	55.000	5.000
3/1	1	1	1.494	5.000	0.000	0.000	RUNOFF	40.426	9.000
3/1	2	2	4.931	15.000	0.000	0.000	RUNOFF	45.000	18.000
5/2	1	1	1.029	60.000	0.000	0.000	RUNOFF	55.000	6.000
3/2	1	1	1.246	70.000	0.000	0.000	RUNOFF	55.000	8.000
Outfall			0.000	0.000	0.000	0.000	RUNOFF	0.000	0.000
5/1	1	1	0.439	35.000	0.000	0.000	RUNOFF	55.000	5.000

8. Select **Active Subcatchments** in the subcatchment pull down above the top of the table. Now type, or copy (ctrl-c) and paste (ctrl-v), values of **1** for all **Widths** and **Slopes**. Ensure all **Subcatchment Flags** except for node Outfall are ON, select **SCS Hydrology** and the Rainfall Reference **5yr-24hr.** When you are finished, click on the **Save** button and then on the **Close** button.



Name	Subcatchment	Catchment Number	Area acres	Impervious Percentage %	Width ft	Slope ft/ft	Routing Method	Pervious Area Curve Number	Time of Concentration (or Parameter
5/4	1	1	1.336	35.000	1.000	1.000	SCS Hydrology	55.000	8.000
Junction	1	1	0.376	5.000	1.000	1.000	SCS Hydrology	44.449	5.000
4/1	1	1	0.183	30.000	1.000	1.000	SCS Hydrology	55.000	5.000
5/3	1	1	1.101	45.000	1.000	1.000	SCS Hydrology	55.000	7.000
6/1	1	1	0.672	50.000	1.000	1.000	SCS Hydrology	55.000	5.000
3/1	1	1	1.494	5.000	1.000	1.000	SCS Hydrology	40.426	9.000
3/1	2	2	4.931	15.000	1.000	1.000	SCS Hydrology	45.000	18.000
5/2	1	1	1.029	60.000	1.000	1.000	SCS Hydrology	55.000	6.000
3/2	1	1	1.246	70.000	1.000	1.000	SCS Hydrology	55.000	8.000
Outfall			0.000	0.000	1.000	1.000	SCS Hydrology	0.000	0.000
5/1	1	1	0.439	35.000	1.000	1.000	SCS Hydrology	55.000	5.000

9. Save your file as **stormwater3.xp.**

Questions

Please answer the following questions; we will also review the answers together.

1. In regards to the 5yr-24 storm used in this exercise, what is the:

   Total rainfall ____ in.

   Maximum intensity ____ in/hr

   Time of Maximum intensity ____

2. Must the rainfall to be the same over the entire network? Yes or No

3. Can xptables show only 1 index of subcatchments such as Number 2? Yes or No

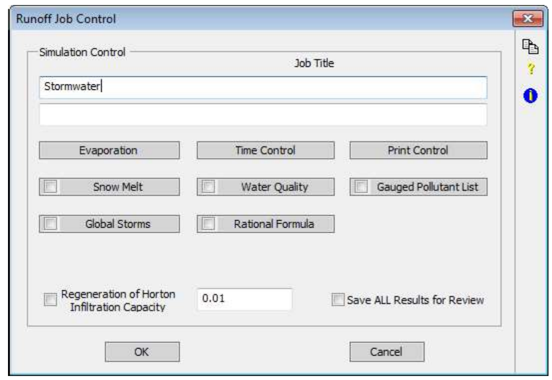
Job Control Settings & Running the Model

Settings for running the model are managed in the Job Control dialog. This section reviews some of the Job Control settings for the Runoff mode.

Job Control Settings

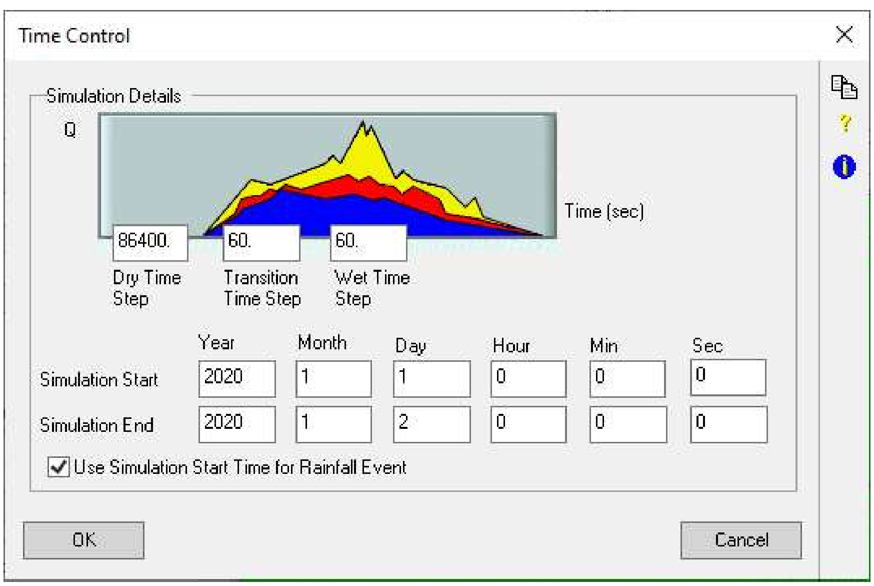
1. Open the file **stormwater3.xp** if not already open.

2. On the Configuration menu, select **Job Control → Runoff**. Enter the optional text in the **Job Title** field.



3. Click on **Evaporation**. Evaporation data can be entered as either daily or monthly values, or a default value of 0.1 inch/day. Select the default value of **0.1** inch/day. Click on **OK**.

4. In the Runoff Job Control dialog, click on **Time Control**. Check the box next to **Use Simulation Start Time for Rainfall Event**. Click on **OK**. We will use the default dates and duration.



5. Use the respective default time steps of **86400**, **60** and **60** seconds for Dry Time Step, Transition Time Step and Wet Time Step.

6. Save your file as **stormwater4.xp**.

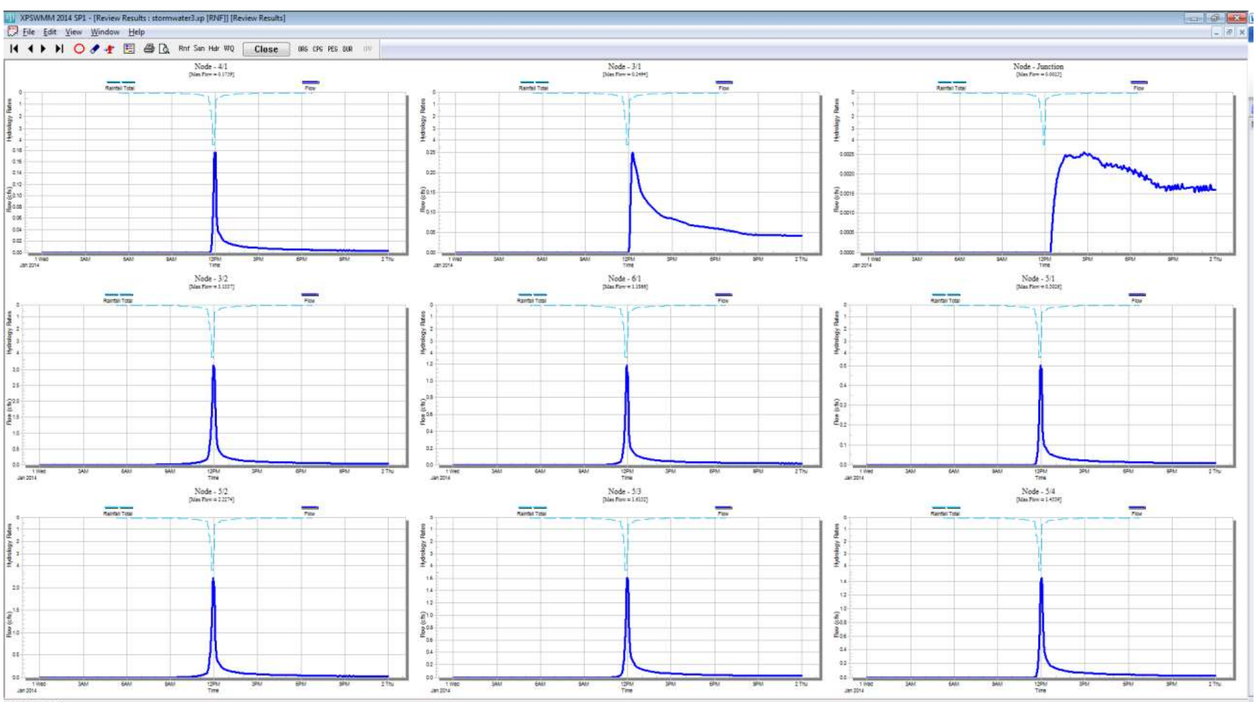
Running the analysis and Reviewing results

1. Run the analysis. Click on the solve icon or select **Analyze->Solve** from the menus or press the **F5** key. A default name for the output (**stormwater4.out**) will be produced. The analysis engine will launch if there are no errors. Errors will be displayed in the assigned default text editor of the program. The engine will display a dialog indicating the status of the calculation such as percent complete. When the simulation is completed, user control returns to the main user interface.

Note: If there are errors they will need to be fixed before a "Solve" can be performed. Following the above procedures should produce 1 error related to node 3/1 subcatchment 2 does not have selected rainfall. Fix the error in order to proceed.

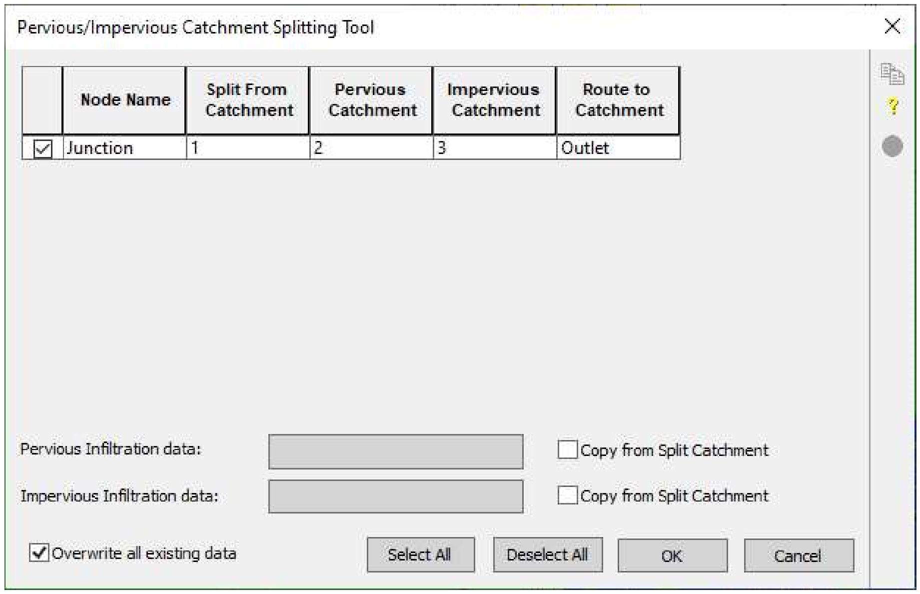
2. Select all the nodes with subcatchments by holding down the left mouse button and dragging a box around the active nodes. Click on the **Review Results** tool. The program will display graphs of rainfall and runoff for each of the selected nodes.

3. **Save** your file.

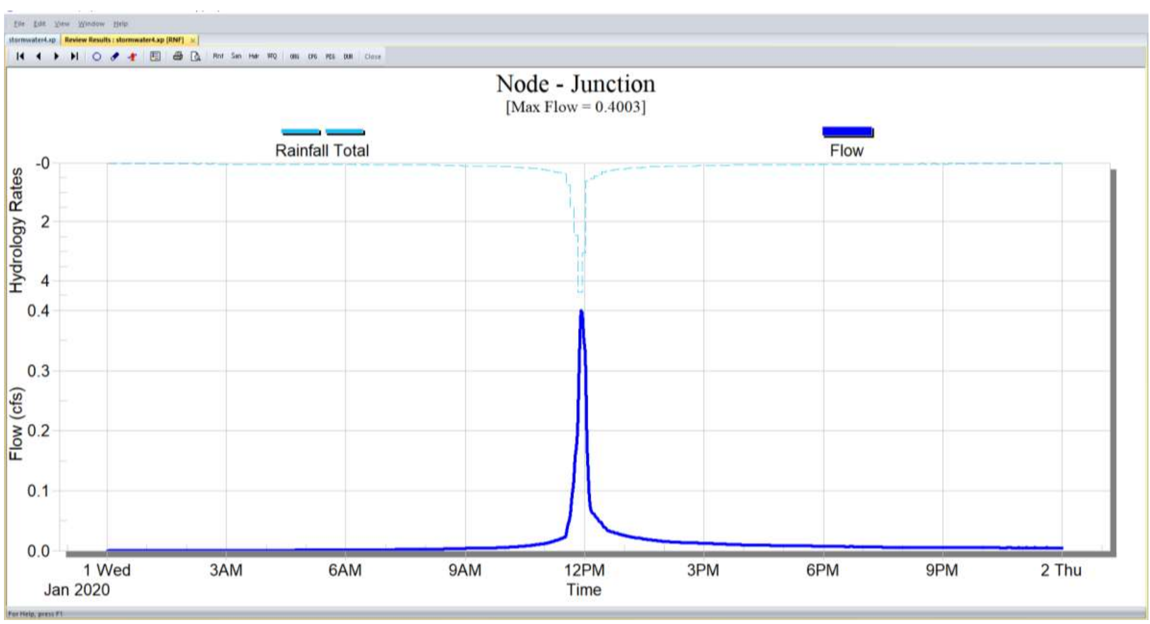


4. At the Junction node almost all the rainfall becomes infiltrated, but it is 5% directly connected impervious. A fault of the SCS method is that all subcatchments are homogenous and an area weighted curve number is derived using CN=98 for the impervious portion. In order to model directly connected impervious with SCS the impervious and pervious parts of the subcatchment should be split.

5. **Select** only the **Junction** node. Use the **Tools->Calculate Node->Split Catchments Into Perv/Imperv, check** the **box** for the row and for **Overwrite existing data.**



6. Make this change or **Open** the file **stormwater4a.xp**. **Solve** and **Review Results** to see the new hydrograph representing some directly connected impervious area.



Questions

Please answer the following question and we will review the answers together.

1. Many other nodes do not show flow until just before 12PM, but it had been raining for the previous 12 hours, can you explain why?

Using SWMM Hydrology

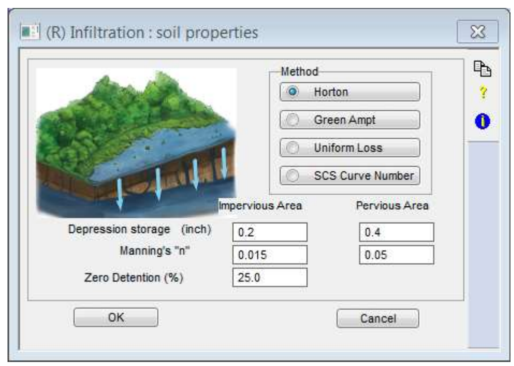
Another popular routing procedure is the EPA SWMM non-linear runoff method. Overland flow hydrographs are generated by a routing procedure using Manning's equation and a lumped continuity equation. Surface roughness and depression storage for pervious and impervious area parameters further describe the catchment. The subcatchment width parameter is related to the collection length of overland flow and is easily calculated based on the watershed properties. The method can include infiltration modeled with the Horton or Green-Ampt equations, using a uniform loss rate, or SCS loss method.

Using SWMM Hydrology

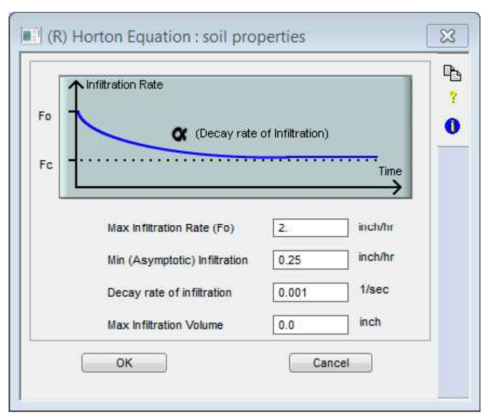
1. Open the file **stormwater4a.xp**

2. In the network view double-click on **Node 5/4** to open the data dialog. Enter **300** ft for the width and **0.02** ft/ft for the slope in the Subcatchment 1 column. **Double-click** on the **1** button to open the Subcatchment dialog. In **Routing Method**, select the **Runoff** radio button.

3. Click on the **Infiltration** button to open the Infiltration Global Database list. Type **soil properties** in the blank box and then click on **Add**. With the soil properties record highlighted, click on **Edit**. Enter the Impervious (Depression storage = **0.2** in, Manning's n = **0.015**, and Zero Detention = **25**%) and Pervious Area (Depression storage = **0.4** in and Manning's n = **0.05**) data as shown.



4. Click on the **Horton** button and in the Horton dialog enter Maximum Infiltration Rate = **2** in/hr, Minimum rate = **0.25** in/hr and Decay Rate = **0.001** 1/sec. Click on **OK** twice.

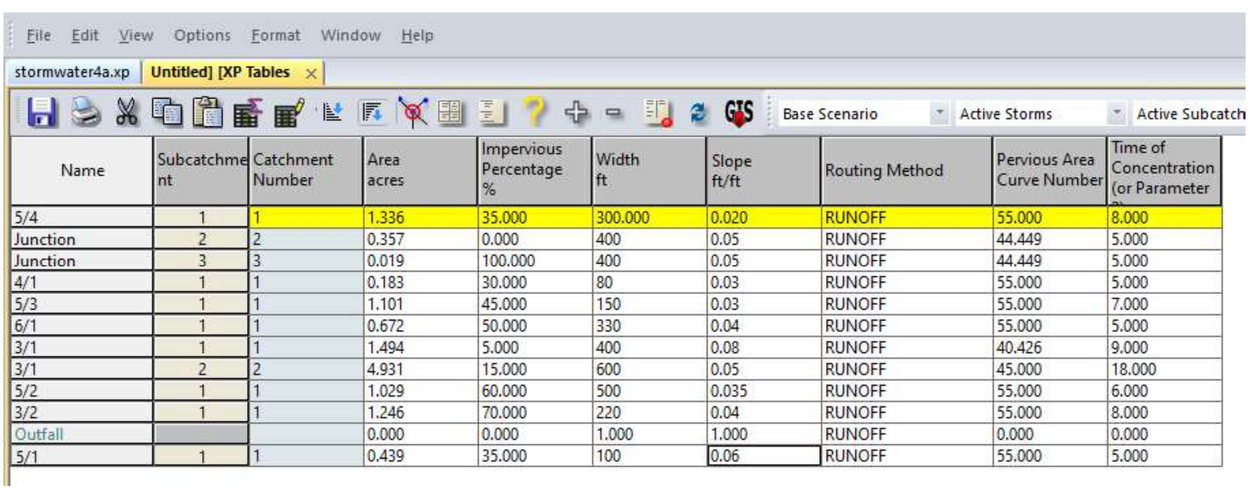


5. In the Global Database list for Infiltration, highlight **soil properties** and click on **Select**, returning to the Subcatchment dialog with **soil properties** listed on the Infiltration button. Click **OK** twice to return to the network graphic.

6. Select the **XP Tables** icon and check that you are viewing the **Physical Hydrology** table. Then change the routing method to **RUNOFF** using Copy/Paste or the Block Edit tool.

7. Enter Width and Slope data for all catchments. Pay attention to the node name and the data order to ensure the data is entered in the correct node. When you are finished, click on the **Save** button and then on the **Close** button. You can also copy and paste from the supplied Excel file the parameters listed below. The file is **stormwater.xls**.

Node	***Catchment***	***Width, ft***	***Slope, ft/ft***
5/4	1	300	0.02
Junction	2	400	0.05
Junction	3	400	0.05
4/1	1	80	0.03
5/3	1	150	0.03
6/1	1	330	0.04
3/1	1	400	0.08
3/1	2	600	0.05
5/2	1	500	0.035
3/2	1	220	0.04
Outfall	n/a	n/a (1)	n/a (1)
5/1	1	100	0.06



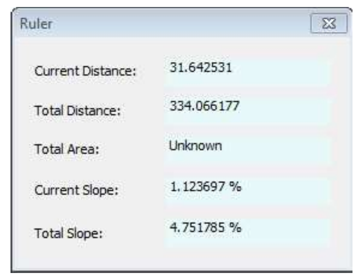
Name	Subcatchment	Catchment Number	Area acres	Impervious Percentage %	Width ft	Slope ft/ft	Routing Method	Pervious Area Curve Number	Time of Concentration (or Parameter
5/4	1	1	1.336	35.000	300.000	0.020	RUNOFF	55.000	8.000
Junction	2	2	0.357	0.000	400	0.05	RUNOFF	44.449	5.000
Junction	3	3	0.019	100.000	400	0.05	RUNOFF	44.449	5.000
4/1	1	1	0.183	30.000	80	0.03	RUNOFF	55.000	5.000
5/3	1	1	1.101	45.000	150	0.03	RUNOFF	55.000	7.000
6/1	1	1	0.672	50.000	330	0.04	RUNOFF	55.000	5.000
3/1	1	1	1.494	5.000	400	0.08	RUNOFF	40.426	9.000
3/1	2	2	4.931	15.000	600	0.05	RUNOFF	45.000	18.000
5/2	1	1	1.029	60.000	500	0.035	RUNOFF	55.000	6.000
3/2	1	1	1.246	70.000	220	0.04	RUNOFF	55.000	8.000
Outfall			0.000	0.000	1.000	1.000	RUNOFF	0.000	0.000
5/1	1	1	0.439	35.000	100	0.06	RUNOFF	55.000	5.000

8. Select the **Rain + Infiltration** table. **Block Edit** the string "soil properties" for Infiltration Reference for all catchments. You could also simply **Copy** and **Paste**.

9. Save your file as **stormwater5.xp**. **Solve** the model. On the **Analyze** menu, select **Solve**. If errors or warnings are produced, they will be displayed. If no errors or warnings are produced, the error log does not appear. The engine dialog will appear, and the model will be solved.

10. After a successful solve **Save**. This ensures model results are permanently in the .xp database.

Using graphical tools to obtain data from catchment parameters



1. Using graphical interface tools to measure horizontal and vertical distances and areas. To measure a distance select the **Ruler** tool . Click to begin a measurement. Click to add a vertex and line segment. Double-click to end the measurement. The current distance is the length of the last line segment. Total Distance indicates the length of the polyline. To measure an area, draw a closed polygon by selecting the first point. Slope is also indicated along the segment and the total line.

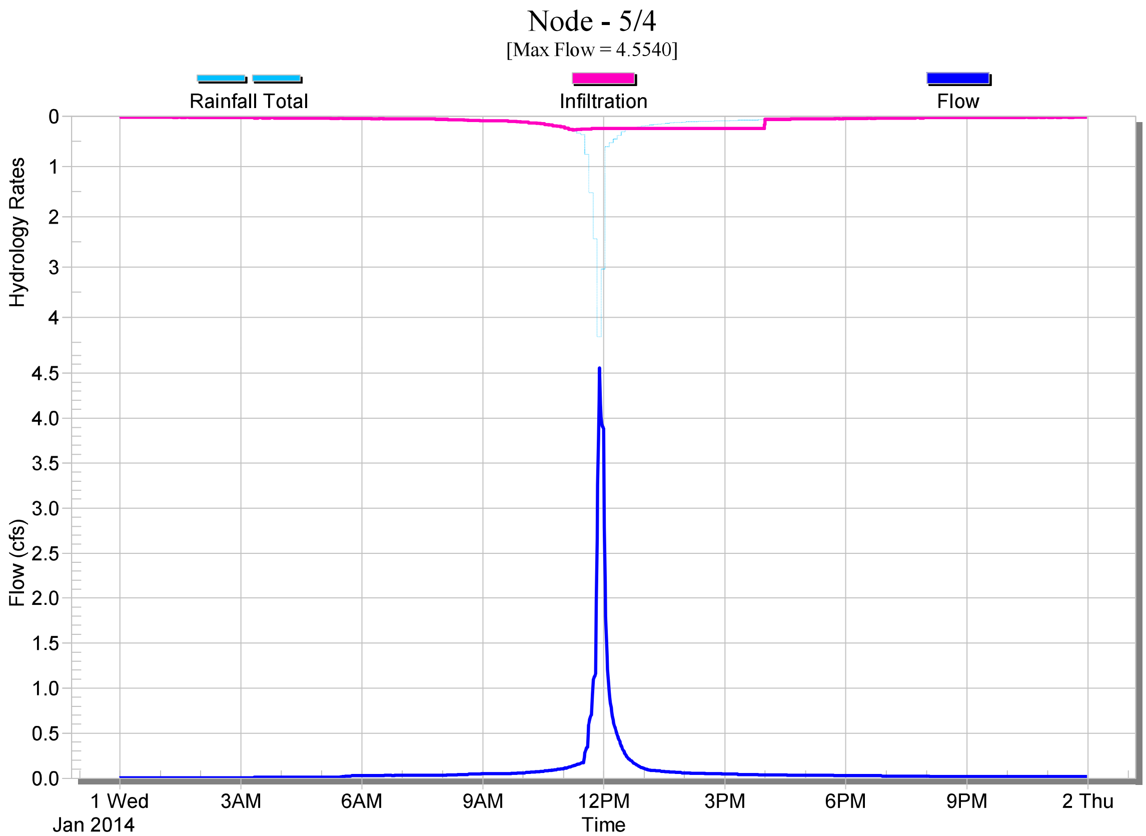
2. To visualize the subcatchment slope, use the **Ruler** tool or Section **Profile** tool . The cursor will show a drawing polyline. Move the cursor to the start point. Click to begin. Move the cursor to a new location. Click to add a vertex. Double click to end. The program displays the cross section of the drawn polyline.

3. To determine the subcatchment width, one can either measure the average width using the Ruler tool or measure the drainage area and the longest flow path. The first method would be an estimate of the width at the average distance using a visual estimate of the location. The second method would be the calculated area divided by the measured flow path or the measured flow path times 2 if surface flows are captured on both sides.

Review results

1. **Select** node **5/4**. Right-click and choose **Review Results** or the icon . A set of hydrographs will display the rainfall and runoff for this node. Click on the **Properties tool** to open the properties dialog. In the Show section, select **1 Graph per Page** from the drop list. Check **Infiltration** in the Hydrology Rates section. Click on **OK**.

2. With the cursor anywhere on the graph grid, **right-click** to reveal a popup menu for graph customization and export options.



Questions

Please answer the following questions and we will review the answers together.

1. In regards to the results for Node 5/4, what is the

   Maximum infiltration rate _____ in/hr

   Maximum rainfall intensity _____ in/hr

2. Why does infiltration peak before the maximum rainfall?

   ____

3. In this simulation the impervious and pervious surfaces generate individual hydrographs that are summed together and presented as the node flow. This is very different than the SCS in that there is a small amount of flow during the low intesity rainfall period before 12PM. Can you think of a way to accomplish this with SCS?

   ____

Reviewing the Model using XP Tables and the Output File

A variety of tools are available for examining model results. We have already looked at the review results portion. Let's look at XP Tables and the output file.

Reviewing a model using XP Tables

1. Open the file **stormwater5.xp** if not already opened.

2. Since the model was solved earlier we do not need to solve it again to generate results.

3. Click the XP Tables icon. Use the arrows at the lower left corner of the screen to navigate to the **Rain + Infiltration** sheet. Cells with light grey shading cannot be edited. Data in cells with a white background is input data.

   Note: The rainfall reference and infiltration can be edited as a drop list from the Global Database.

4. Use the arrows at the lower corner of the screen to navigate to other tables. Select the **Subcatchment Results** table. Data with grey shading are results which cannot be edited. Data with a white background is input data. In the Name column, nodes that are inactive are displayed with a grey text.

5. To sort the table by highest flow, right-click on the Max Flow cfs column and select the sort descending. This will order nodes based on flow. **Close** the XP Tables window.

Reviewing the Output File.

1. On the **Analyze** menu, select **Show Output Logs->1D Log** to open **stormwater5.out** in the default text editor. This file is generated every time the model is solved. It contains information regarding the settings, input data and results. This information is useful for debugging, calibrating and obtaining detailed model results. Selected sections are described here.

2. The beginning section presents information about the software version and the input data file. Users are encouraged to use the latest version of the program.

```
*===============================================*
|                    xpswmm                     |
|      Storm and Wastewater Management Model    |
|          Developed by XP Software Inc.        |
|===============================================|
|                                               |
| Last Update      : June, 2014                 |
| Interface Version: 2012                       |
| Engine Version   : 12.0                       |
| Data File Version: 12.6                       |
|                                               |
|                                               |
*===============================================*
```

3. The tables produced by a runoff analysis are listed below.

```
*==========================================================*
|         RUNOFF TABLES IN THE OUTPUT FILE.                |
|  These are the more important tables in the output file. |
|  You can use your editor to find the table numbers,      |
|  for example: search for Table R3 to check continuity.   |
|  This output file can be imported into a Word Processor  |
|  and printed on US letter or A4 paper using portrait     |
|  mode, courier font, a size of 8 pt. and margins of 0.75 |
|                                                          |
| Table R1  - Physical Hydrology Data                      |
| Table R2  - Infiltration data                            |
| Table R3  - Raingage and Infiltration Database Names     |
| Table R4  - Groundwater Data                             |
| Table R5  - Continuity Check for Surface Water           |
| Table R6  - Continuity Check for Channels/Pipes          |
| Table R7  - Continuity Check for Subsurface Water        |
| Table R8  - Infiltration/Inflow Continuity Check         |
| Table R9  - Summary Statistics for Subcatchments         |
| Table R10 - Sensitivity analysis for Subcatchments       |
*==========================================================*
```

4. Table R5 contains the continuity check and basin wide results for various runoff parameters.

```
############################################################
* Table R5. CONTINUITY CHECK FOR SURFACE WATER             *
*       Any continuity error can be fixed by lowering the  *
*       wet and transition time step. The transition time  *
*       should not be much greater than the wet time step. *
############################################################
                                                       Inches over
                                          cubic feet   Total Basin
 Total Precipitation (Rain plus Snow)     1.487661E+05     3.200
 Total Infiltration                       7.528257E+04     1.619
 Total Evaporation                        4.648941E+03     0.100
 Surface Runoff from Watersheds           6.673215E+04     1.435
 Total Water remaining in Surface Storage 2.171484E+03     0.047
 Infiltration over the Pervious Area...   7.528257E+04     2.310
                        --------
 Infiltration + Evaporation +
 Surface Runoff + Snow removal +
 Water remaining in Surface Storage +
 Water remaining in Snow Cover.........   1.488351E+05     3.201
 Total Precipitation + Initial Storage.   1.487661E+05     3.200

  The error in continuity is calculated as
   #######################################
   * Precipitation + Initial Snow Cover  *
   *      - Infiltration -               *
   *Evaporation - Snow removal -         *
   *Surface Runoff from Watersheds -     *
   *Water in Surface Storage -           *
   *Water remaining in Snow Cover        *
   *-------------------------------------*
   * Precipitation + Initial Snow Cover  *
   #######################################
```

```
Percent Continuity Error..............           -0.0464
```

5. Table R9 shows detailed runoff data for each node.

```
##################################################
# Table R9. Summary Statistics for Subcatchments #
##################################################

Note:      Total Runoff Depth includes pervious & impervious areas.         Pervious  and
Impervious Runoff Depth is only the runoff from       those two areas.
           For catchments receiving redirected flow, this flow will only    be  shown  if
the flow is not directed directly to the outlet.      Flow that is getting redirected is
also listed with the    original subcatchment.

  Subcatchment...........          4/1#1           3/2#1
  Area (acres)...........        0.18300         1.24600
  Percent Impervious.....       30.00000        70.00000
  Total Rainfall (in)....        3.20000         3.20000
  Max Intensity (in/hr)..        4.38720         4.38720

  Pervious Area
  -------------
  Total Runoff Depth (in)        0.80311         0.80392
  Peak Runoff Rate (cfs).        0.47910         1.42150

  Total Impervious Area
  ---------------------
  Total Runoff Depth (in)        2.94843         2.94202
  Peak Runoff Rate (cfs).        0.24263         3.81999

  Impervious Area with depression storage
  ---------------------------------------
  Total Runoff Depth (in)        2.17382         2.16902
  Peak Runoff Rate (cfs).        0.18197         2.86500

  Impervious Area without depression storage
  ------------------------------------------
  Total Runoff Depth (in)        0.77461         0.77300
  Peak Runoff Rate (cfs).        0.06066         0.95500

  Total Area
  ----------
  Total Runoff Depth (in)        1.44670         2.30059
  Peak Runoff Rate (cfs).        0.72173         5.24150

  Rational Formula
  ----------------
  Pervious Tc. (mins)....        0.00000         0.00000
  Perv. Intensity (in/hr)        0.00000         0.00000
  Pervious C ...........         0.00000         0.00000
  Impervious Tc. (mins)..        0.00000         0.00000
  Imp. Intensity (in/hr).        0.00000         0.00000
  Impervious C .........         0.00000         0.00000
  Partial Area (Ha)......        0.00000         0.00000
  Partial Area Tc........        0.00000         0.00000
  Partial Area Intensity.        0.00000         0.00000
```

The output file ends with notes indicating that the calculation ended successfully.

```
===> Runoff simulation ended normally.
===> XP-SWMM Simulation ended normally.
===> Your input file was named  : C:\XPS\workshop\M02-Hydrology\stormwater5.DAT
===> Your output file was named : C:\XPS\workshop\M02-Hydrology\stormwater5.out

*==============================================================*
|             SWMM Simulation Date and Time Summary            |
*==============================================================*
| Starting Date... December   29, 2014  Time...   15:14:53:64  |
|   Ending Date... December   29, 2014  Time...   15:14:54:56  |
|  Elapsed Time...    0.01533 minutes or      0.92000 seconds  |
*==============================================================*
```

Questions

Please answer the following questions and we will review the answers together.

Review the output file (**stormwater5.out**) to answer the following questions.

1. In the network, what are the areas:

   Total catchment _____ ac
   Impervious area _____ ac
   Pervious area _____ ac

2. For the storm event, what are the volumes of

   Rainfall _____ ft^3
   Runoff _____ ft^3
   Evaporation _____ ft^3
   Surface storage _____ ft^3

3. Which subcatchment had the highest peak runoff rate?

   Subcatchment _____
   Peak runoff rate _____ ft^3/s

4. Circle if it was the Pervious or Impervious Area with the largest contribution to peak flow?

5. Did that pattern hold true for all nodes? Circle Yes or No.

6. Can you explain why? ____

Advanced Surface Water Hydrology

The purpose of this section is to teach users how to use xpswmm's tools for advanced hydrologic components. You will learn how to model multiple storm events with global storms.

In Runoff mode, xpswmm simulates the rainfall, infiltration, evaporation and depression storage, for each subcatchment, and calculates the runoff to a collection node. This allows xpswmm to model many difficult hydrologic elements.

Add Global Storms

Global storms allow users to run multiple storms in both runoff and hydraulics. The user can also review multiple storms on one graph using review results. An xpswmm model includes a series of input and output files. The main file is the .xp file that holds the data for the model and references other files needed, such as background images or DTM data. The .mdb file stores the global storm data.

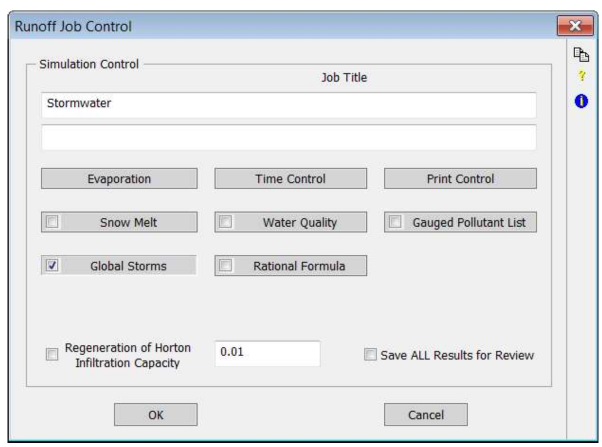
Open Existing Model

6. Close any current model and open the file **Stormwater_Completed.xp**.

7. Save as **Stormwater6.xp**.

Set up Global Storms

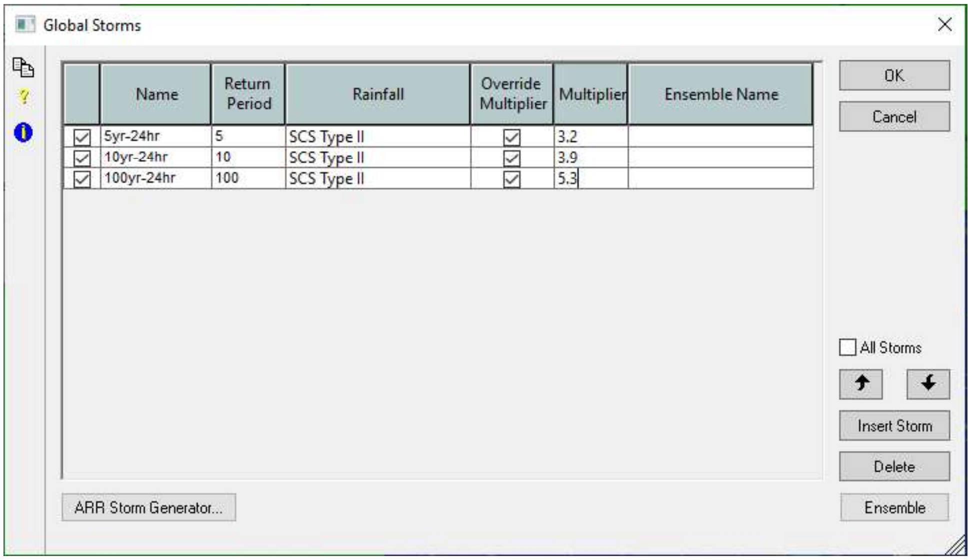
1. Confirm the Mode is **Runoff** by clicking on the icon in the Job, Layer and Mode Control tool bar.



2. Select **Configuration** in the pull down menu. Then select the **Job Control** menu followed by the **Runoff** menu item. Another option is to left click on the **Job Control** icon.

3. Select the **Global Storms** button in the Runoff Job Control dialog as shown to the right.

4. In the global storms dialog, insert three rows using the **Insert Storm** button.



5. On the first row, within the **Rainfall** column using the pull down list, select the **SCS Type II** rainfall. Repeat for the second and third row.

6. The next step defines the rainfall data for the three storms. We will be modeling the 5-year, 10-year and 100-year recurrence storm events. Type the data shown above for all three lines.

7. After the global storm data has been typed in, click on the **OK** button twice to return to the project window.

8. Note that the global storms now appear 

in the global storms tool bar. Users can choose to run one, all or any number of the listed storms.

Run Model(s) with Global Storms

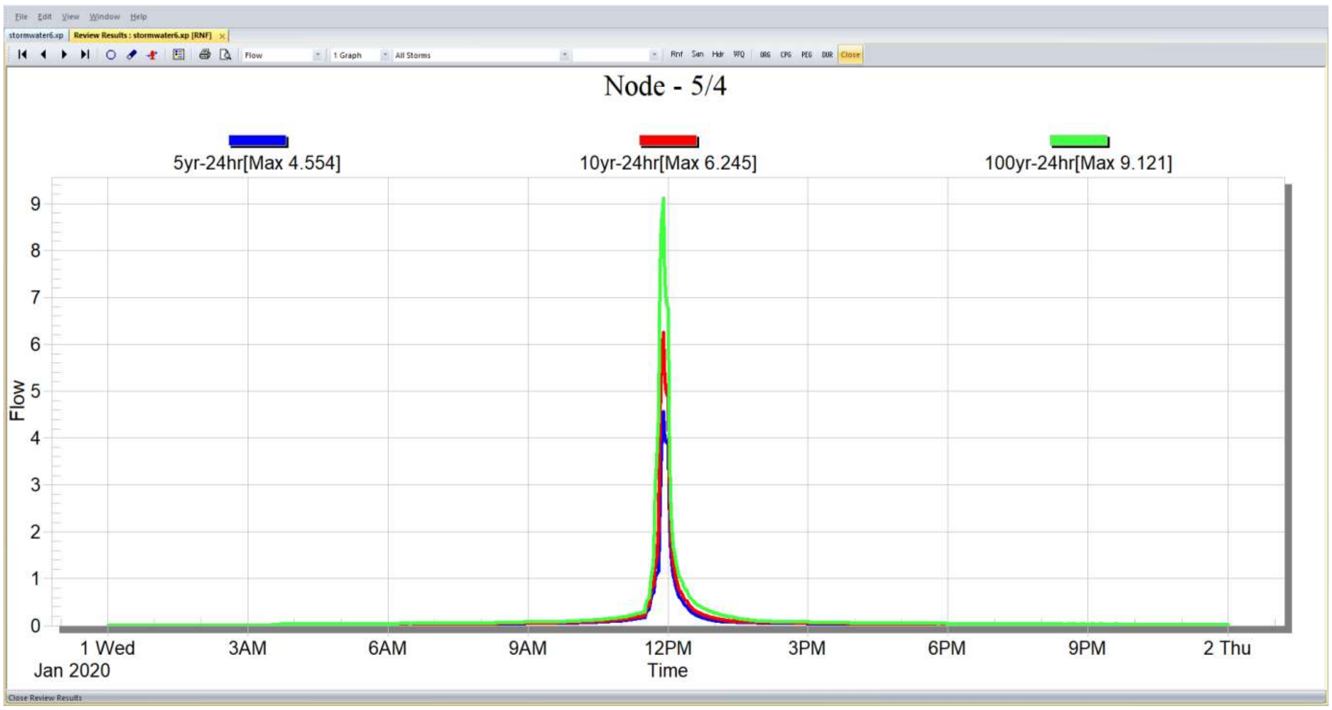
1. In Workshop No 2, the job control settings were set for the model. These settings will work for the global storm runs also. Save your file.

2. Solve the model. On the Analyze menu, select Solve Manager to allow all storms to run concurrently depending on the number of CPU cores.

3. When the models have completed choose the **Load Results** button.

Review Model with Global Storms

11. Close the Solve Manager and Engine Viewer dialogs once the Solve Manager is complete. In the **Results** menu, select **Results ->Reload 1D Results**. Within the Reload 1D Results dialog click on **Load Results**. Select node 5/4. Click on the **Review Results** tool. xpswmm will display the graphs of runoff for the three storms for this node. By selecting the Flow pull down, users may select other graphs for this node, such as rainfall, infiltration, evaporation, etc. In the same way, users may select one of the storms or all of the storms. Using these pull downs, select and review different data for other nodes. Close the review results by clicking on the **Close** button.



Questions

Please answer the following questions and we will review the answers together.

1. What was the highest peak runoff for Node 3/2 for the 5 year storm? ________
2. What was the highest peak infiltration rate for Node 4/1 for the 10 year storm? ________
3. What was the overall continuity error for the Yarra_24HR- 100 year model? ________