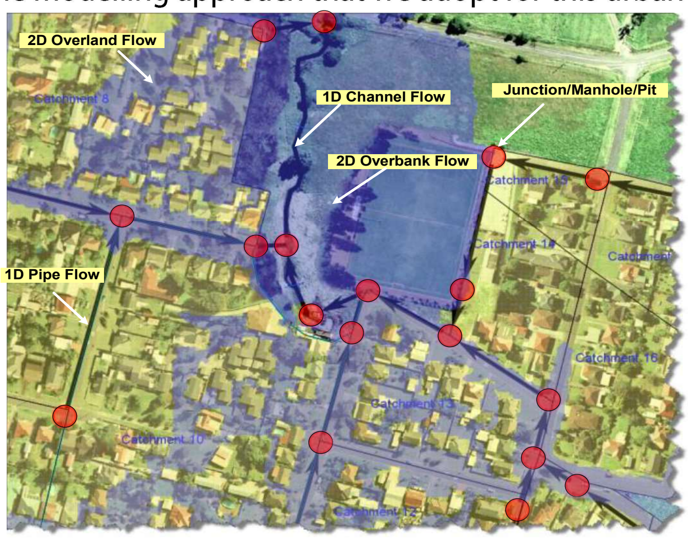
1D/2D Urban Flood Modeling

This tutorial describes how to set up an integrated 1D/2D urban flood model for a post-development scenario. The study area is the same as that of the previous pre-development river flood model except the area is urbanized. Now the area has an urban development and associated pits and pipes for the stormwater drainage. The flood pattern for this scenario will be different from the river flooding. The flooding will be a combination of flood due to the overflow of drainage pits and river flood due to the overbank flow. Generally this happens in an urban area during higher return period storms. The user will set up a flood model using the xp tools and perform an analysis for the same 100 year return period storm event that was used in the river flood module. Note that the flow from the urban catchments will be simulated using the Runoff Mode and these hydrographs will be transferred to the Hydraulics Mode for Dynamic Wave Routing. The below diagram shows the modelling approach that we adopt for this urban flood model:



Objectives

Users will learn how to utilize xp's tools to create 1D/2D urban flood model. You will learn how to:

1. Integrate the 1D hydrology, 1D hydraulic, and 2D hydraulic models
2. Model buildings in the floodplain
3. Prepare flood hazard maps

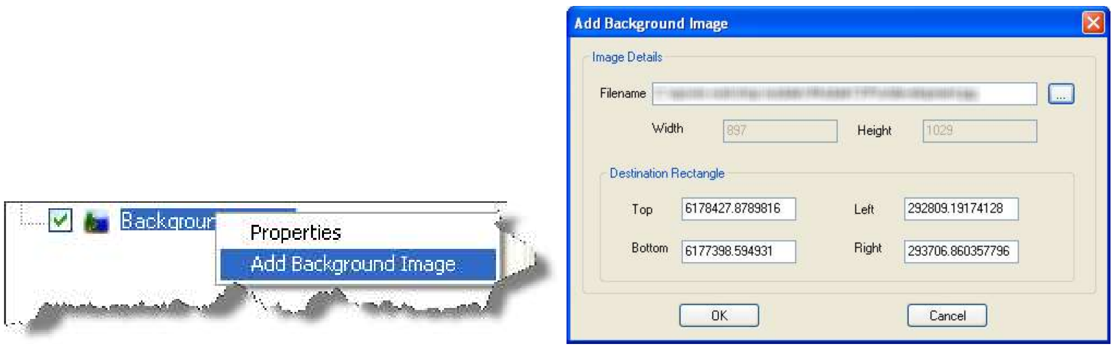
Data files:
- 1D2D_Urban_starter_model.xp
- 1D-2D_Urban_Flood_m.xp
- 1D2D_Urban_completed_buildings.xp
- 1D-2D_Urban_completed.xp
- Model Data.xls
- Postdevelopment.xptin
- Postdevelopment.jpg, jpw
- Ponds_Postdevelopment.shp
- Roads_Postdevelopment.shp
- Creek_Postdevelopment.shp
- Buildings_Postdevelopment.shp
- 1D_2D_Interface.shp
- 2D_Active_Area.shp
- 2D_Inactive_Area.shp
- Creek & Culverts.XPX

Adding background image and DTM

First, we will setup the background image and DTM using the xp interface as we did for the previous module. **Note:** for advanced and experienced users proceed to section **Using the Starter Model** on page 13-10 and load the **1D2D_Urban_starter_model.xp**.

1. From the **File Menu**, create a **New Blank Job** and name the file as **1D-2D_Urban_Flood1_m.xp** and save the file. Select the **Unit** as **Metric**.

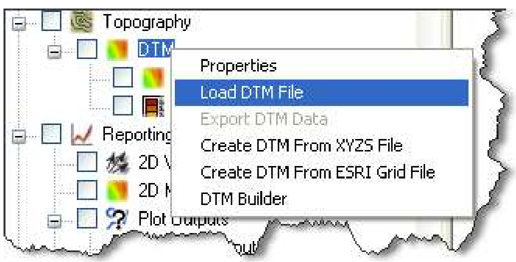
2. Now tick on the **Background Image Layer**, highlight with the left click. Now right click on the layer and select the **Add Background Image** from the menu. Click on the ellipsis, browse for the file **Postdevelopment.jpg**, select and **Open** it.

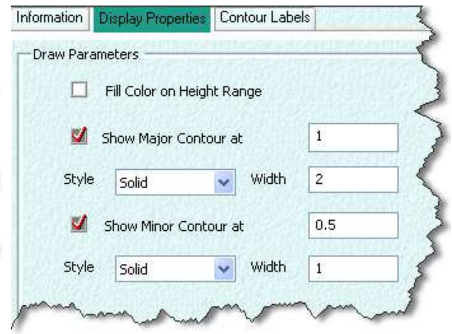


Click on **OK** to see the background image using the georeferenced coordinates.

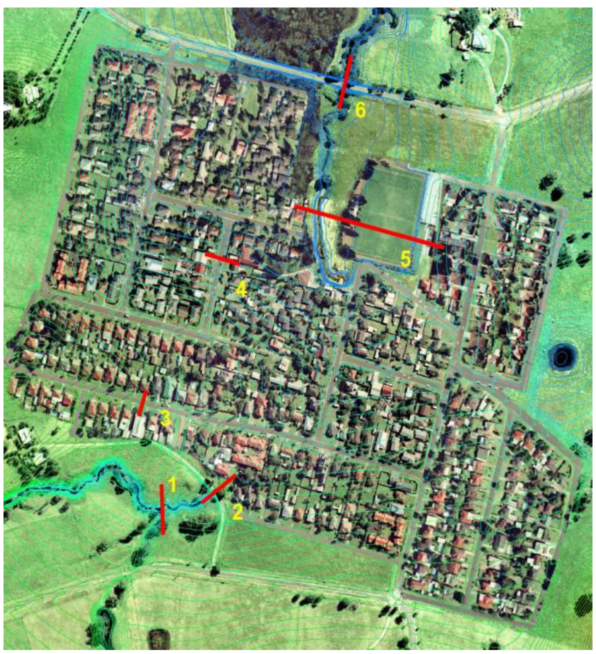
You will see the area is developed with many buildings and a sports field. The creek is partially covered and the water is conveyed through underground pipes, which are connected to the urban drainage network. For this post development site the hydrology will be essentially urban. The primary objectives of the flood modeling of such a site are: Mapping flood inundation due to the urban flooding and checking the safety of the houses and roads during flood events by creating hazard maps.

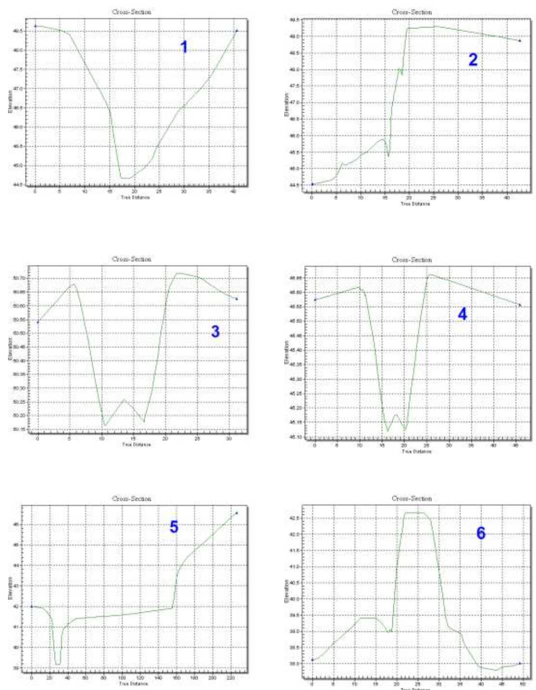
3. Next we will load DTM to the model. Load the DTM file **Postdevelopment.xptin**. Now display the **Major Contour at 1m** interval and **Minor Countours** at **0.5 m** interval. Adjust the **Transparency** to see the aerial image and DTM together.



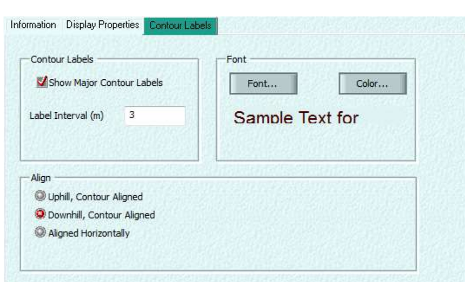


Get a few cross-sections and examine the terrain.





You can access the **Contour Labels Tab** and switch on the **Show Contours Labels** tab.

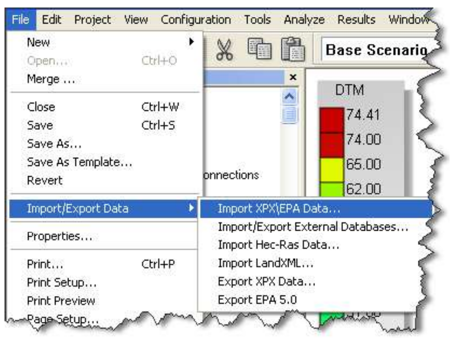


Now **Save** the file.

1D Domain Definition

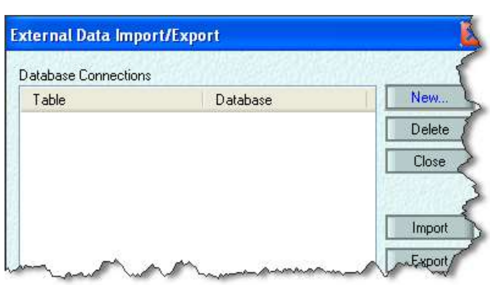
The next step is to define the 1D domain. We have pits, pipes, open channels, and culverts in the 1D network. We will get the 1D open channels and culverts through xpx import and the rest of the network through an external database linkage.

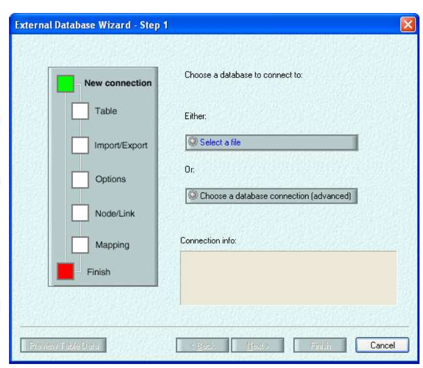
1. From the **File Menu**, select **Import/Export Data**, then **Import XPX/EPA Data**. Browse for the file **Creek & Culverts.XPX**, select, **Open** it and **Import**. Click on **OK** and ignore the generic warning message that reminds that this process overwrites existing data.



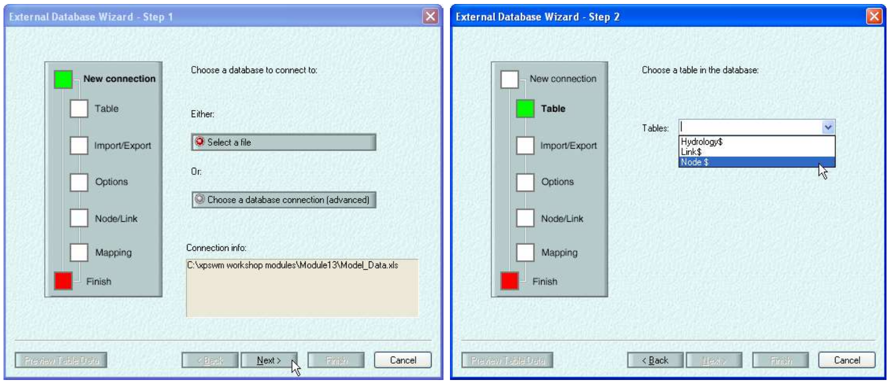
You can now see the natural creek and the culverts. The rainfall and infiltration data used in the hydrologic calculations has also been imported in this file as well as 2D Landuse Categories. **Open** the **Global Database** from the Configuration menu to see these items.

2. Now we will import the pits and pipe network from the external database. From the **File Menu** select **Import/Export Data** and **Import/Export External Databases** option. Click on **New**, and **Select a File** button. Browse for the file **Model_Data.xls**, select and **Open**.

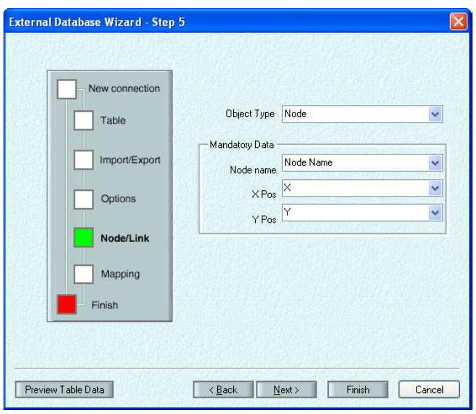




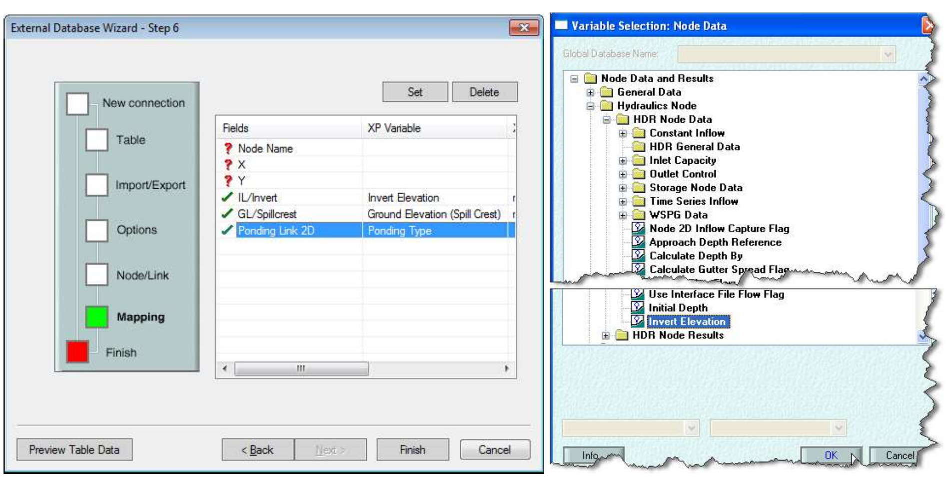
Now click on the **Next** button, and select the **Node** table from the **Tables** dropdown menu.

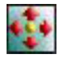


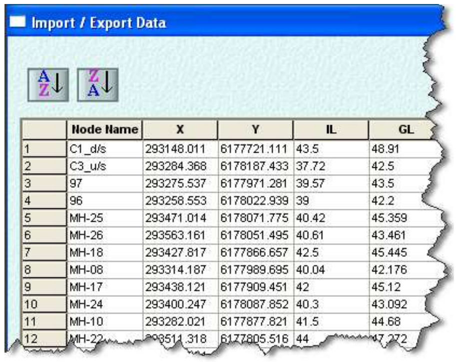
Again click on the **Next** button and select **Import data only** radio button. Again click on **Next**, and select the **Create New or Update Existing** option from the **On Import Object Creation** dropdown menu. Click on **Next** button again. In the step 5, select the **Object Type** as **Node** from the dropdown menu. Map the **Mandatory Data** as shown below:

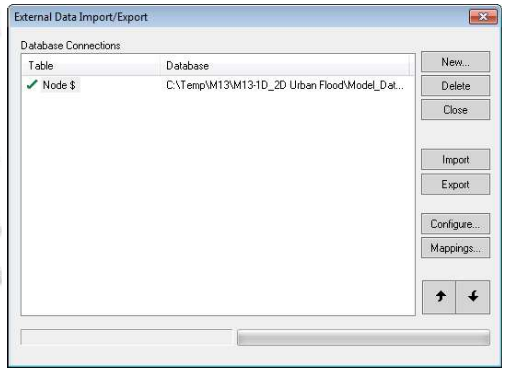


Click on **Next** button again, select the Field **IL** and click on the **Set** button. You will see the **Node Variable Selection** dialog now. Expand the **Node Data and Results** and go to **Hydraulic Node**, select **Invert Elevation** and click on **OK**.

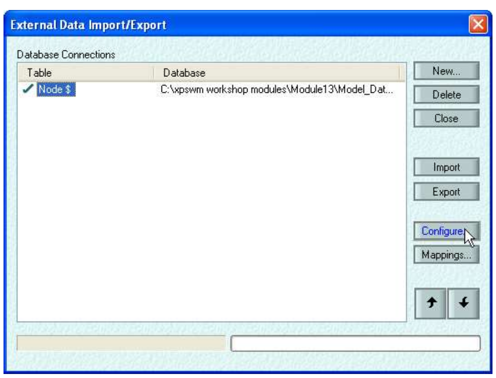


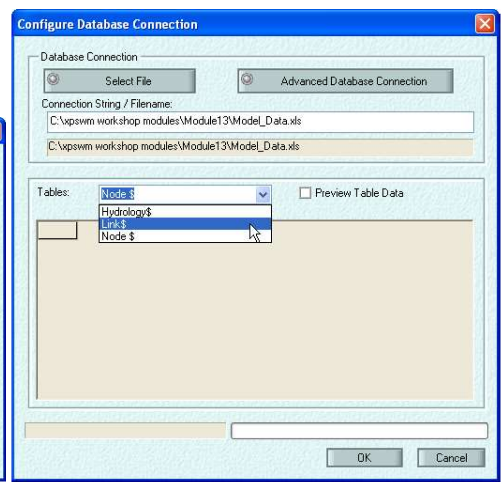
Similarly Map the field **GL/Spillcrest** to **Ground Elevation (Spill Crest)** and the **Ponding Link 2D** to the **Ponding Type**. Now click on the **Finish** button and **Import** in the next dialog. You will see all the data ready to be imported, click on **OK** two times and **Close**. When you click on the  button, you will see all 26 nodes imported with 78 variables read.



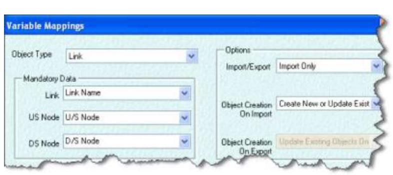


3. We will repeat the procedure for link import by modifying our existing connection. Select **File Menu/ Import or Export Data/ Import or External Database**. Highlight the **Node $** and click on the **Configure** button. Select the **Link $** and click on **OK**.





Click on the **Mapping** button and **Map** the **Mandatory Data** as follows:

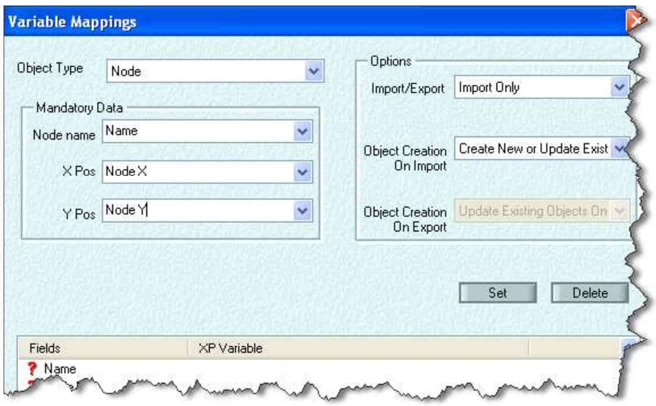


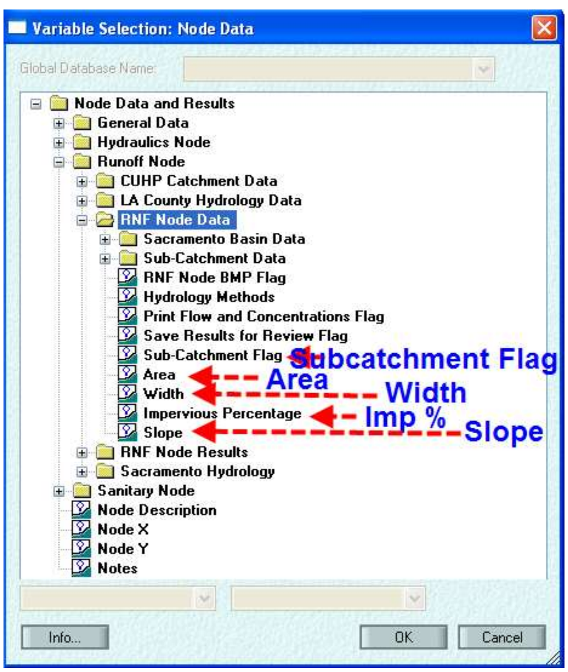
Excel Source Field	XPSWMM Target Field
Length	Conduit Data->Length
Shape	Shape
U/S Invert	Upstream invert elevation
D/S Invert	Downstream invert elevation
Diameter	Diameter (Height)
Conduit Factors Flag	Conduit Factors Flag
Number of Barrels	Conduit Factors->Number of Barrels

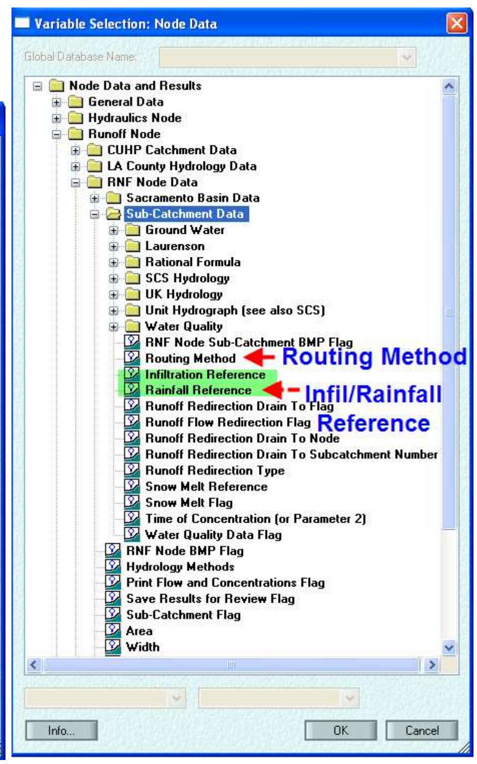
Finally click on **OK** and **Import** as we did for the nodes. You should see a message of 27 links created and 189 variables read.

Now select the **Runoff Mode** by clicking on the  button. Select all the nodes except the culvert and open channel nodes and make them active n the **Rnf Mode** by pressing the **+** button.

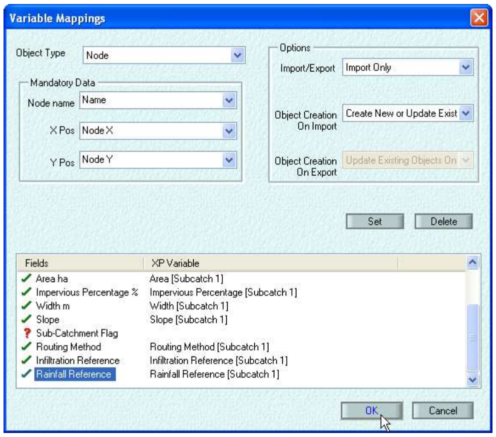
Repeat the **External Database Import** procedure for **Hydrology$** as well. Map the fields as shown below:

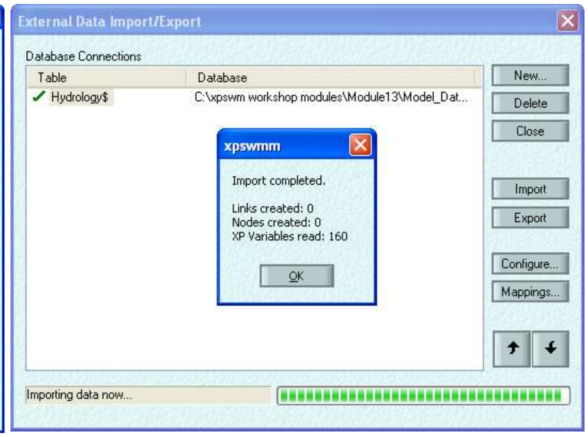




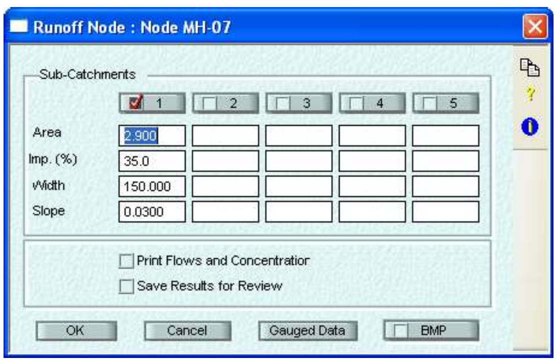


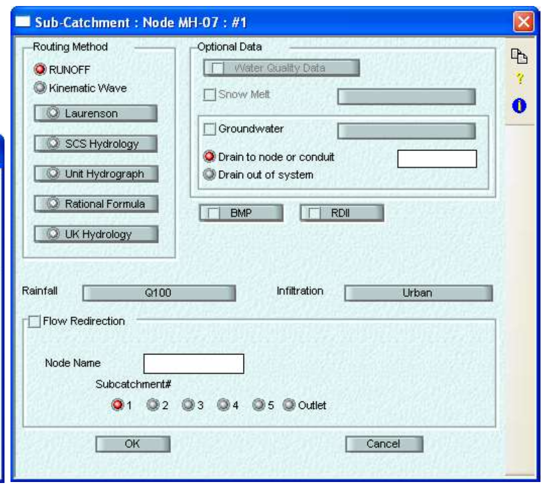
Click on **OK** and **Import**.





You can open the nodes and check the hydrology data imported including the rainfall and infiltration records.



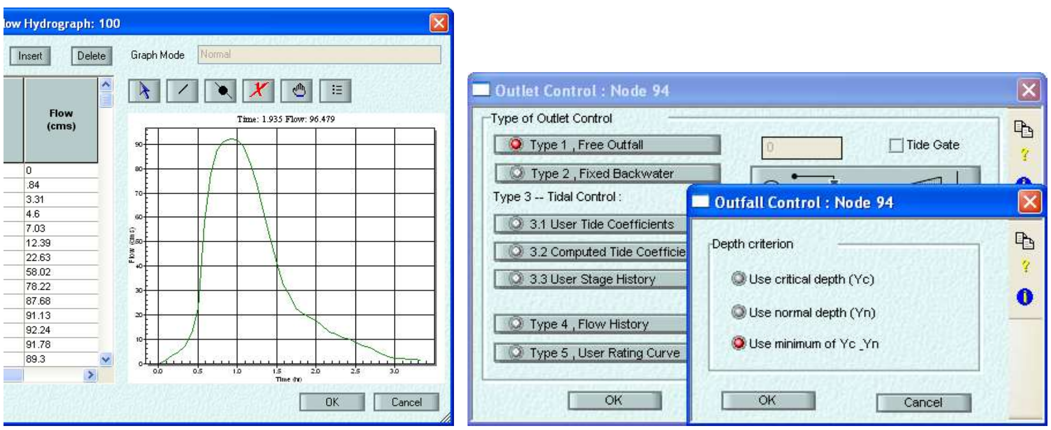


Using the Starter Model

All steps to this point have been completed in the starter model called **1D2D_Urban_starter_model.xp**

4. Now **Add New Layers** for **Inactive Areas**, **1D/2D Interfaces**, and **1D/2D Connections**. Import the **2D_Inactive_Area.shp** to **Inactive Areas Layer** and **1D_2D_Interface.shp** to **1D/2D Interface Layer**. Highlight the **1D/2D Connections Layer**, **Snap** and digitize **1D/2D Connections Lines** or import from the corresponding shape file from all the nodes to 1D/2D Interface Lines. Repeat this for all the nodes of channels and culverts.

5. Double-click and open node **100** and **94**. You will see the inflow hydrograph from the upstream area and the 1D outfall definition.



6. Right click and **Generate Water Level Lines** for all the open channel links. Trim the water level lines to the 1D/2D Interface Lines. Please refer to the previous module for details on the steps to generate and trim WLLs.

7. Now **Save** the file as **1D-2D_Urban_Flood2_m.xp**.

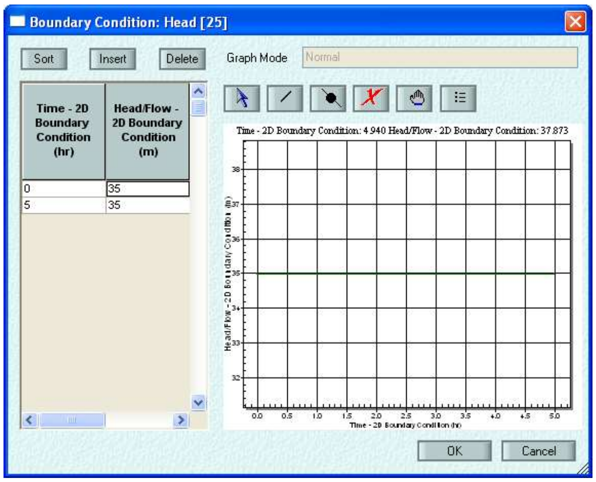
2D Domain Definition

We will define the 2D modeling domain in the same manner as the previous module.

1. Digitize the **2D Grid Extent** to the edges of the aerial image. Make the grid size **3m**. Typical sizes would range from 2m-5m. Click on **OK**. You may switch off the grid extents layer for better visibility of the model.

2. **Add New Layer** for **2D Active Areas** and create the 2D Active Area by importing the **2D_Active_Area.shp**.

   Now add a new layer for the **Head Boundaries** and digitize and snap a polyline to the 2D active area. Right click and **Edit** the **Head Boundary Polyline** and enter the data as follows to ensure a free outflow from the 2D domain.

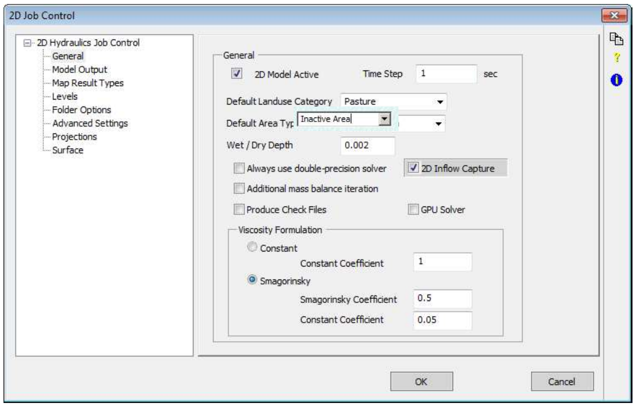


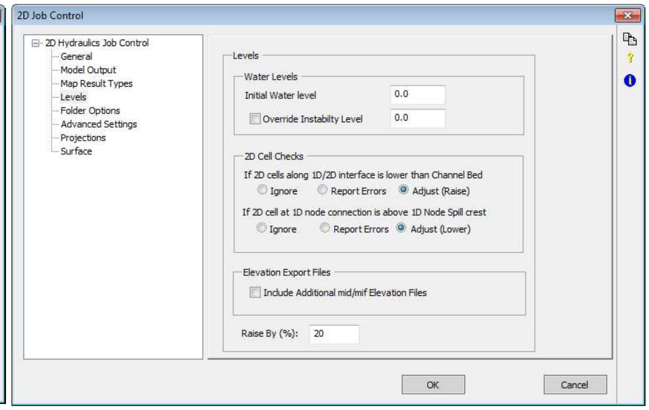
3. Next step is to define 2D land uses. Right click on each layer and import the land use polygons as we did in the previous model. Make sure that the priorities are as shown:

2D Landuse Layer	GIS File
Roads	Roads_Postdevelopment.shp
Vegetated Creek	Creek_Postdevelopment.shp
Ponds	Ponds_Postdevelopment.shp
Buildings	Buildings_Postdevelopment.sh

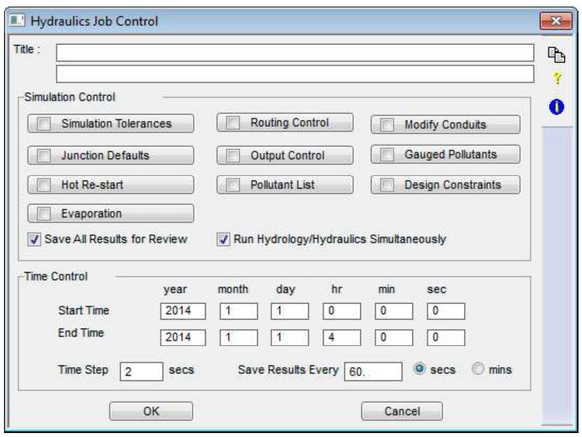
Landuse	n Value	Priority
Pasture	0.06	1
Ponds	0.025	2
Vegetated Creek	0.09	3
Roads	0.025	4
Buildings	0.3	5

4. Go to **Configuration Menu/ Job Control/ 2D Model Settings** and complete the settings as shown:

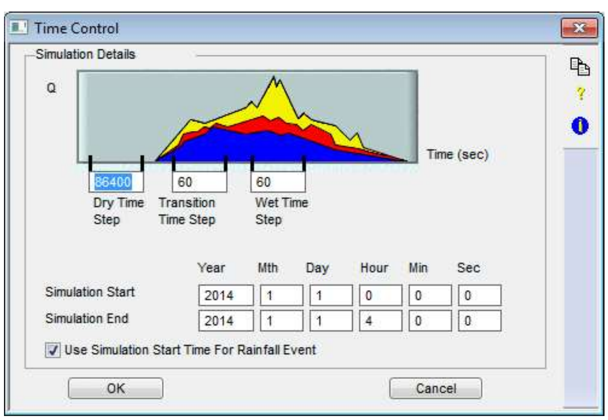




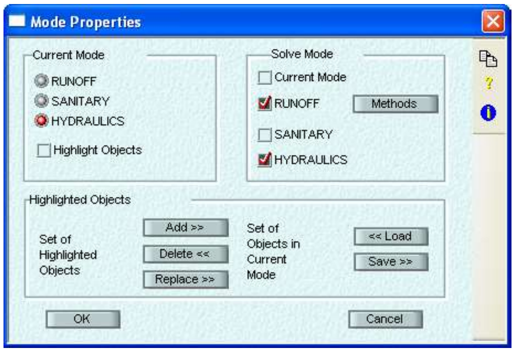
Under **Configuration/Job Control/Hydraulics**, complete the settings as shown:



Under **Configuration/Job Control/Runoff/Time Control** complete the data entry as follows:



Now, go to **Configuration/ Mode Properties** and tick on both the **Runoff** and **Hydraulics** tick boxes.

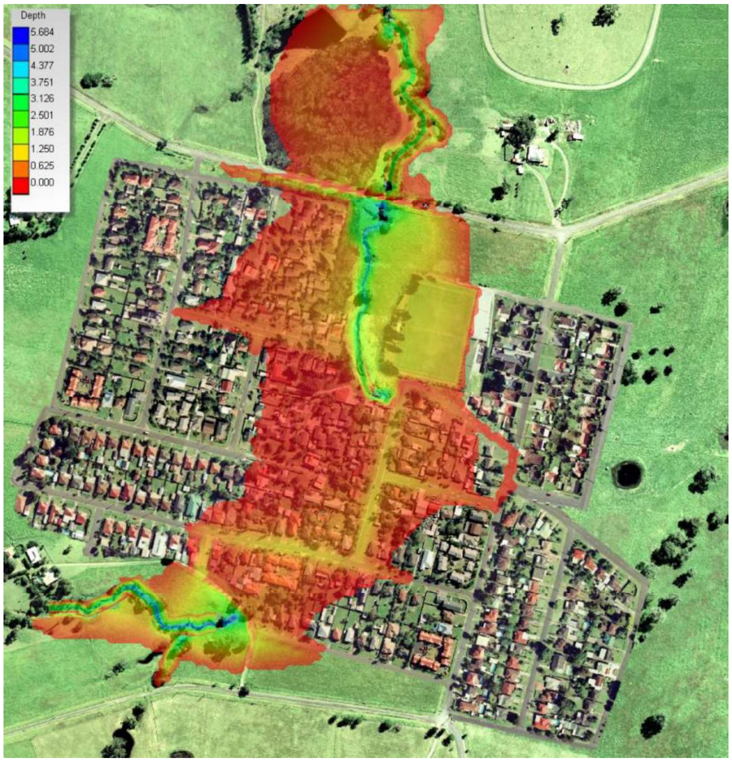


Finally, add few **Plot Output Points** as shown in the map near the **Culvert1**:

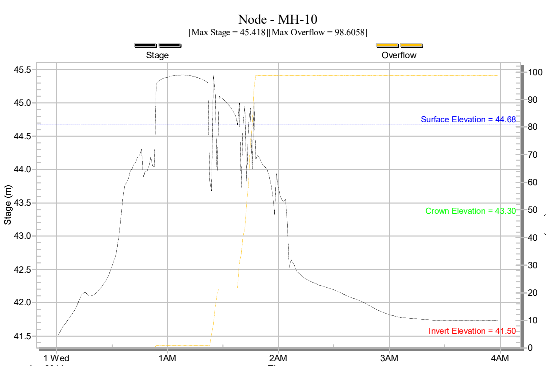
Note: The model **1D-2D_Urban_completed.xp** could be loaded as a completed model with all of the previous steps.

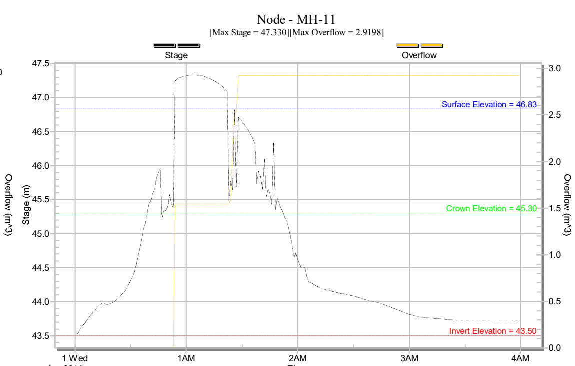
5. Now **Solve** the model. Tick on the **2D Maps (Water Depth) Layer** and you will be able to see the flood inundations.

   Note: If the model was not built from the starter model then a warning message will appear for all active Runoff nodes without subcatchment data. Ignore the warning or make all of the nodes without catchment data inactive in the Runoff mode.



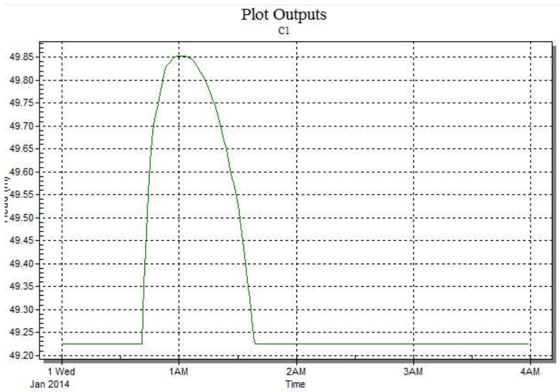
You will see that the maximum inundation depth is **5.7 m** which happens in the deep channel portion. You will see that many roads are acting like flood flow conveyance channels. Review results for **MH-10** and **11**, you will see that these pits are overflowed and the water is conveyed through the roadway. This is the same as that of the dual drainage analysis in 1D hydraulics.

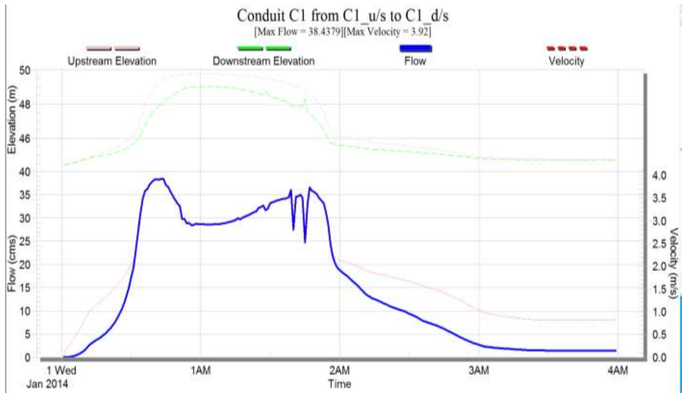




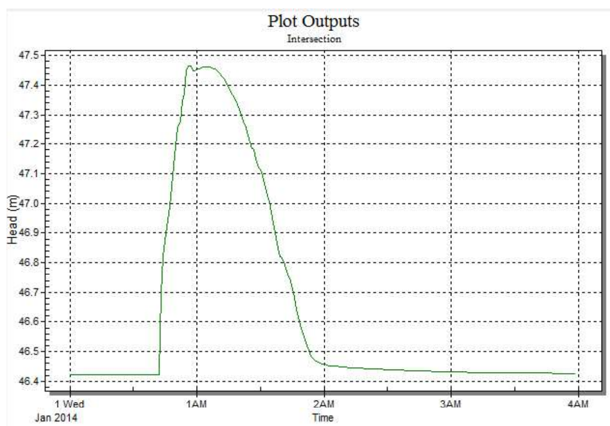
You may notice that the sports field acts like a flood storage area as we predicted early.

Zoom-in to the Culvert 1 area and check the water level output point C1. You will see that the Culvert 1 road is overtopped from about **40 min** to almost **1 hr 40 min**. Click on the Culvert 1 and review result and you will see a dip in the flow through the culvert. This is due to the road overtopping flow.





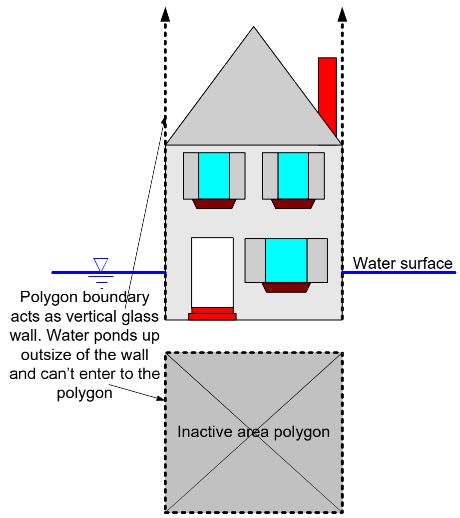
If you review the water level point **Intersection**, you will see the flow reaches at **38 min**. This is due to the road overflow from the further upstream side.



Switch on the maximum velocity vectors; you will notice that water depth is shown at the building locations also. Check the flow vectors and you will see flow is going through the buildings but higher velocity around the buildings. But the buildings can block the flow up to certain depths. Zoom-in and get a cross-section for any building location and you will see that the buildings are not present in the DTM.

We assigned a very high **Manning's n** value (**3.0**) to overcome this. There are other techniques also to define buildings in the flood plain:

Making the buildings' polygon inactive:

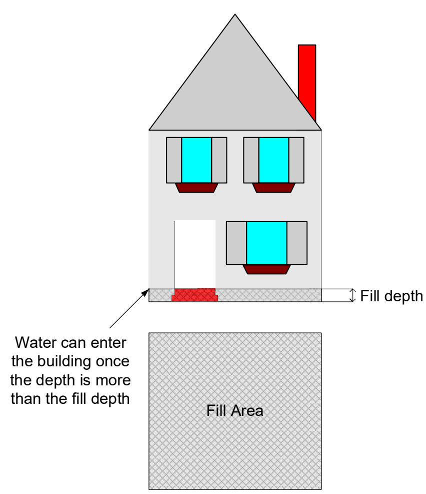


When you make the buildings' areas inactive, the polygon boundary acts as a vertical glass wall so that flood water can't enter the buildings. This might not always be a good modeling approach. The assumption of vertical water proof walls is not valid if the flow exceeds some threshold depth. When the water depth exceeds the sill-level of doors and windows, water can enter the buildings through these openings. Hence, this method may overestimate the water depth around the buildings.

Use model: **1D2D_Urban_completed_buildings.xp**

Adding fill areas to represent the buildings:

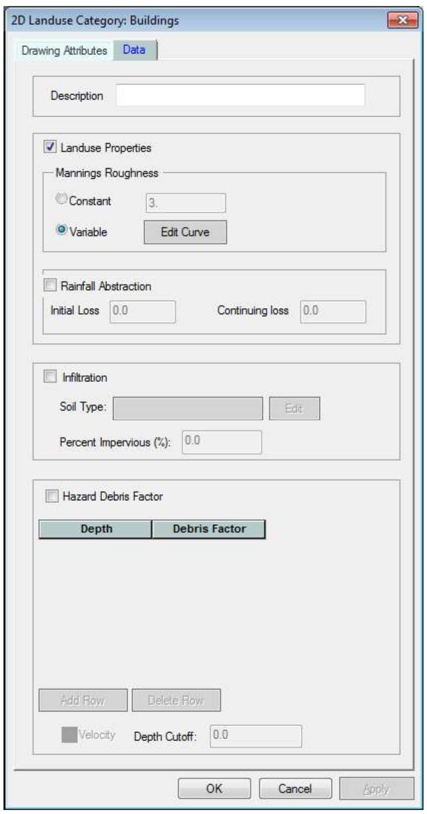
Another technique is adding fill areas on the buildings' locations. User can import polygons to the **Fill Areas Layer** and specify the fill elevation. The fill elevation can be up to the sill of the openings and once the water level reaches above this level, it can enter the buildings. How? Import the buildings.shp file to the fill area.

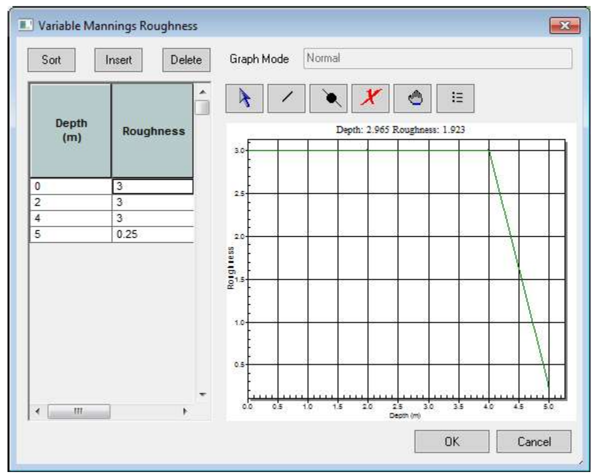


This would be an appropriate approach as it represents the flow condition properly. However estimation of the fill depths for buildings might not be easy as this varies for each building.

Assigning varying Manning's roughness depends on depth:

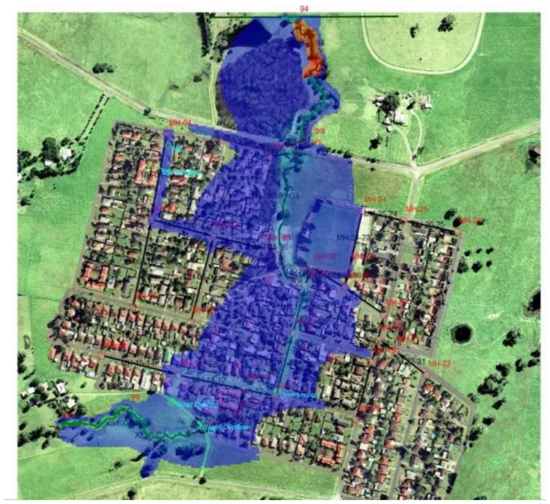
Another technique could be varying Manning's roughness depends upon the depth of flow. The roughness value can be very high up to the sill level of the opening and can be reduced after this depth. User can right click on each **2D Landuse** layer and edit the depth dependant roughness value. As per the entry in the following dialog box, the values change vs. depth.





Hazard Classification

On the **Reporting Layer**, right click and select **Hazard**. Note that this hazard map is obtained by multiplying **maximum depth** and **velocity** for each cell.



You can see from the map that the areas along the open channels and some of the main roads are showing a high hazard value. These areas can probably be classified as high hazardous areas.

Mitigation Option

The manhole/pit overflows are due to the insufficient conveyance of the drainage pipes. The easiest way to tackle this issue is to increase the conveyance of the drainage pipes. However, this increased conveyance will create more floods in the d/s channel overbanks. Due to a large inflow coming from the u/s node during a 100 yr design event the designed drainage system is unable to carry the flow downstream due to insufficient conveyance. Therefore an upstream detention is the most obvious solution in this case.

A model with a detention pond at the upstream area has been completed. Open the model **1D-2D_Urban_completed_buildings_Pond_mitigation.xp**, the detention pond is made using the **Fill Areas** option under the **Topography Layer**. The table below shows the storage characteristics of the pond:

Elevation (m)	Waterspread Area (Ha)
43	1.94
45	2.74
47	3.68
48	4.84
49	6.06

4 2 m diameter concrete pipes are connected from the channel to the pond to divert the flow from the channel to the pond. **Solve** the model and review results. You will see that the flood depth at the urban areas is greatly reduced due to the u/s pond.

If you check the hydrographs at the u/s and d/s of the node where the diversion pipe is connected and the flow from the node to the pond, you will see that significant flow is diverted to the pond. After 1.5 hrs the pond discharges back to the channel and retains 3m depth of water in the pond. Thus pond acts as an offline detention cum retention pond.