Advanced Stormwater Modeling Tools

The purpose of this training module is to teach users how to use xpswmm/xpstorm's design tool for sizing system and other tools for determining missing elevations, ponding options and pond optimization. In addition, the use of dual drainage and advanced conduit factors will be covered.

Objectives

Using model features, users will learn how to utilize xp's tools for sizing, optimize pond elevations or outflow, and simulate dual drainage. You will learn how to:

1. Determine optimal pipe diameters.
2. Use node storage modeling options.
3. Model parallel street and storm sewer (dual drainage).
4. Optimize pond storage and outflow.
5. Model pond structures.
6. Use conduit factors.

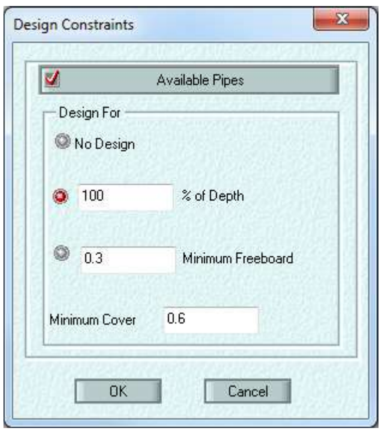
Data files:	YARRA_area.dwg	yarra_network_pt.shp
	yarra_link_arc.shp	Design_Dbase.xls
	Design.xp	Rational_method.xp
	Design1.xp	Design2.xp
	Design3.xp	Design4.xp

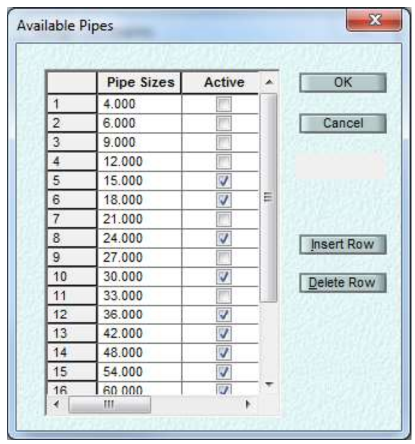
Calculating Pipe Diameters

Determining pipes sizes are often done using a trial and area approach. Using a hydrology method, the peak flow is determined and the pipe size is calculated using Manning's equation. In xp, a tool can be used to automate this design process. As can be shown, the 1-foot diameter pipes are not able to convey the flows created from the 10-year storm. We will use the pipe sizing design function to size all the pipes in our model.

1. Open the file **Design1.xp** and save the file as **My_Design2.xp**

2. Open the **HDR: Job Control** and **click** on the **Design Constraints**. Select **Design For 100**% of Depth. Click on the **Available Pipes** button and turn off the active check box for 21, 27 and 33-inch Pipe Sizes. Click the **OK** button three times.





3. **Solve** the model. The pipe length warning will be displayed. The model status will start over as it solves the model and increases the pipe sizes. Note: Using the configuration parameter, DESIGN_RESTART=OFF, will stop the restarting. However, the model should be rerun in such a case to ensure that the changing pipe diameters do not affect the final design.

4. Right click on Node **5/5** and pick **Select Downstream Objects**. Click on the **Dynamic Section View** and then click File pull down and select **Properties**. Using the icons in the toolbar turn on the **Text** and the **Diameter Info**. Note that some of the pipes increase as you move downstream and that the maximum HGL is below the crown. Click on the **Close** Button. Do the same thing for Node **3/2**.

5. The results of the Hydraulic design routine final results is shown in the output file, after Table 5a.

	<-------- Original	-------->		<--------- Designed	-------->	
Conduit Name	Height	Width	Barrels	Height	Width	Barrels
Link1	1.0000	1.0000	1.0000	1.2500	1.2500	1.0000
Link2	1.0000	1.0000	1.0000	1.2500	1.2500	1.0000
Link5	1.0000	1.0000	1.0000	1.2500	1.2500	1.0000
Link9	1.0000	1.0000	1.0000	1.2500	1.2500	1.0000
Culvert	1.0000	1.0000	1.0000	2.0000	2.0000	1.0000
Link11	1.0000	1.0000	1.0000	1.5000	1.5000	1.0000

6. Click on the **Job Control** button and click on the **Design Constraints** to turn off the pipe design feature.

7. **Save** the model.

Node Modeling Options and Dual Drainage

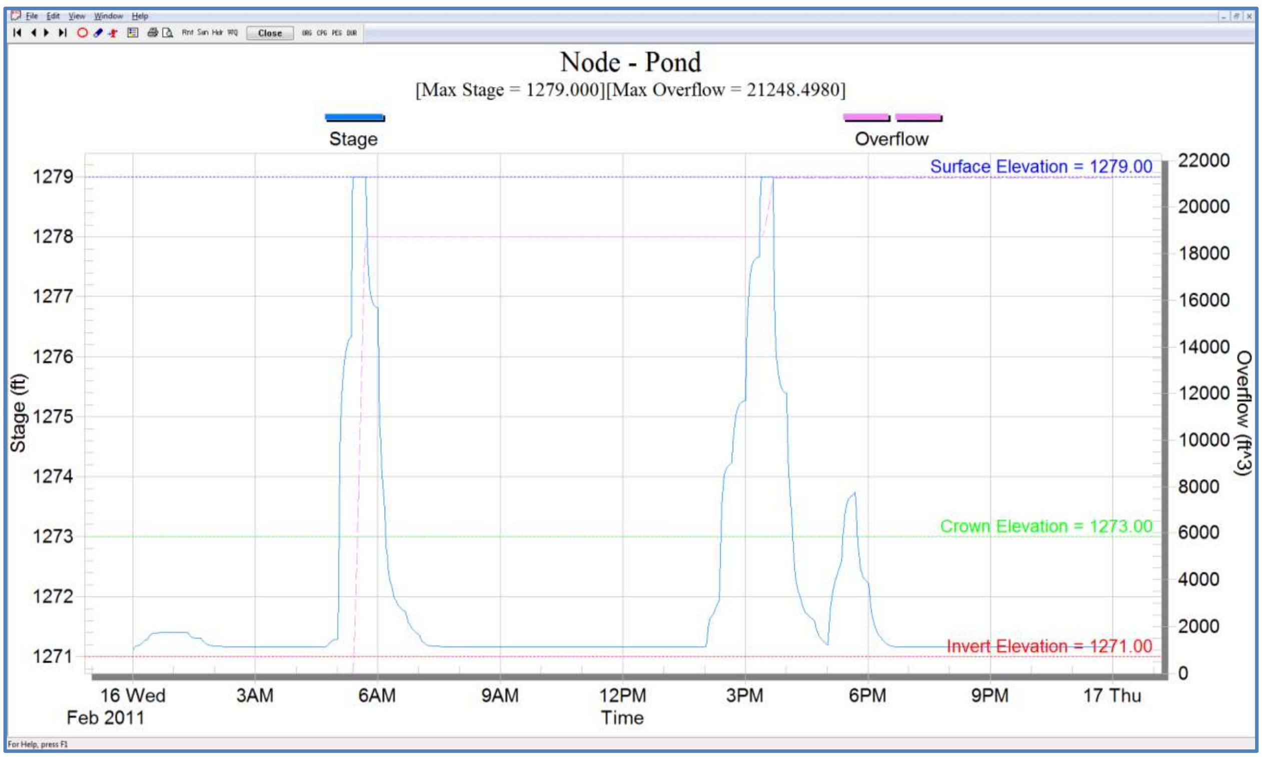
In xp, nodes can be modeled with inlet capacity and 5 different options for ponding alternatives. In this portion of the workshop, we will investigate these options and their impacts on model performance. In addition, the modeling of both sewers and streets will be shown.

Ponding Options

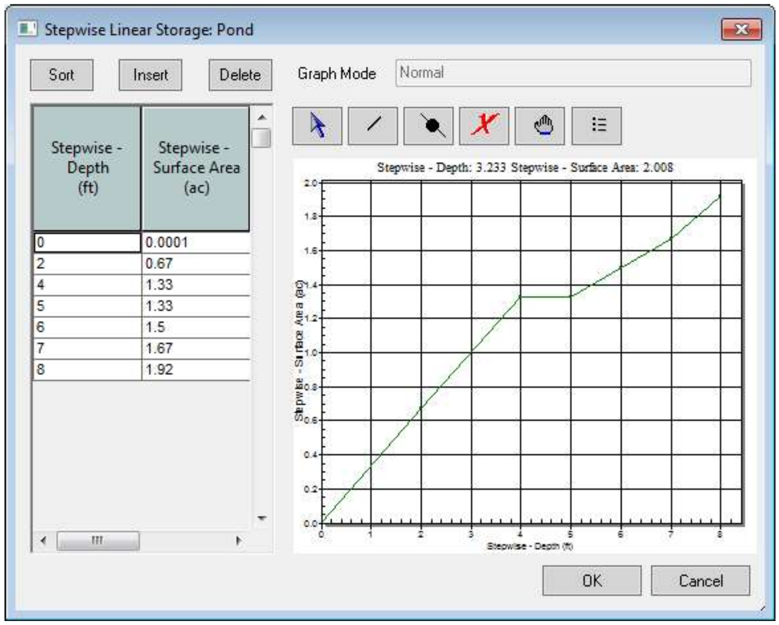
1. Open the file **Design2.xp** and save the file as **My_Design3.xp**. This version of the model is using the Runoff method, a rainfall and an infiltration global database.

2. **Solve** the model.

3. Review Results for the Node **Pond**. Notice that the HGL goes above the Crown Elevation which means that node was surcharged, and it goes to the ground elevation which means it has flooded and water is lost from the model. This is the default condition for nodes in xp. In the output file (Table E20) summarizes the duration of surcharge and flooding as well as the water lost.

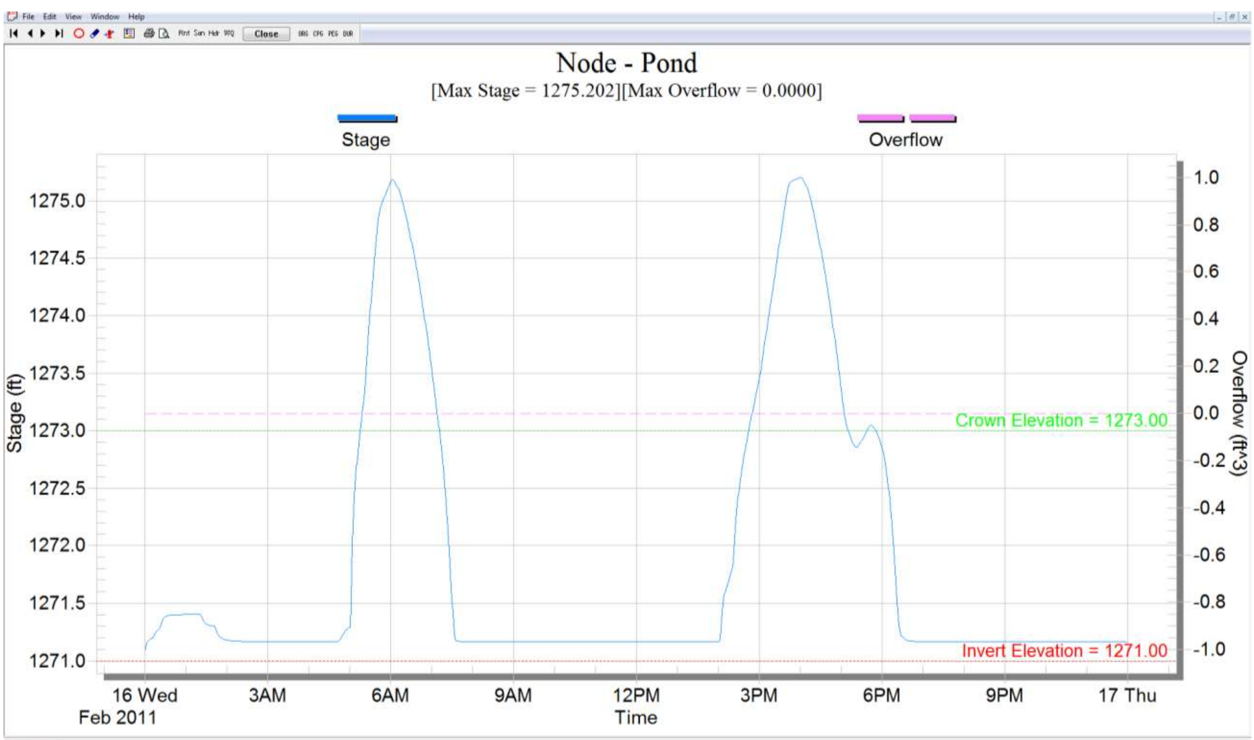


4. Convert the Pond node from a default manhole area to a Storage node. Double-click on Node **Pond**. Click on the **Storage** button. Three storage methods are available as shown. This pond will be defined using the stepwise linear method. Open the file **Design_Dbase.xls** to retrieve the stage storage information found in the worksheet called Pond. Click on the **Stepwise Linear** Button and click on the **Insert** Button to add one row. Then copy the data from worksheet Pond and paste it into Stepwise Linear Storage. Then click **OK** three times to return to the project window.



5. **Solve** the model.

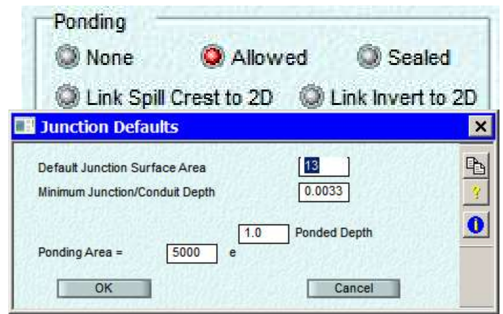
6. Review Results for the Node **Pond**. Notice that the HGL only slightly exceeds the Crown Elevation. By adding the storage data, the Pond is still surcharging but no water is lost from this node. However, the maximum volume in the node is now 26,700 cubic feet. Using the Dynamic Long Section see that other nodes are flooding.



7. Right Click on Node **5/5** and choose **Select Downstream Objects**. Click on the **Dynamic Long Section** icon and click on the **Play** button. Notice that all nodes upstream from **5/1** have flooding occurring during the run. Repeat the above starting at node **3/2**. Notice that node **Junction** is in a sag location.

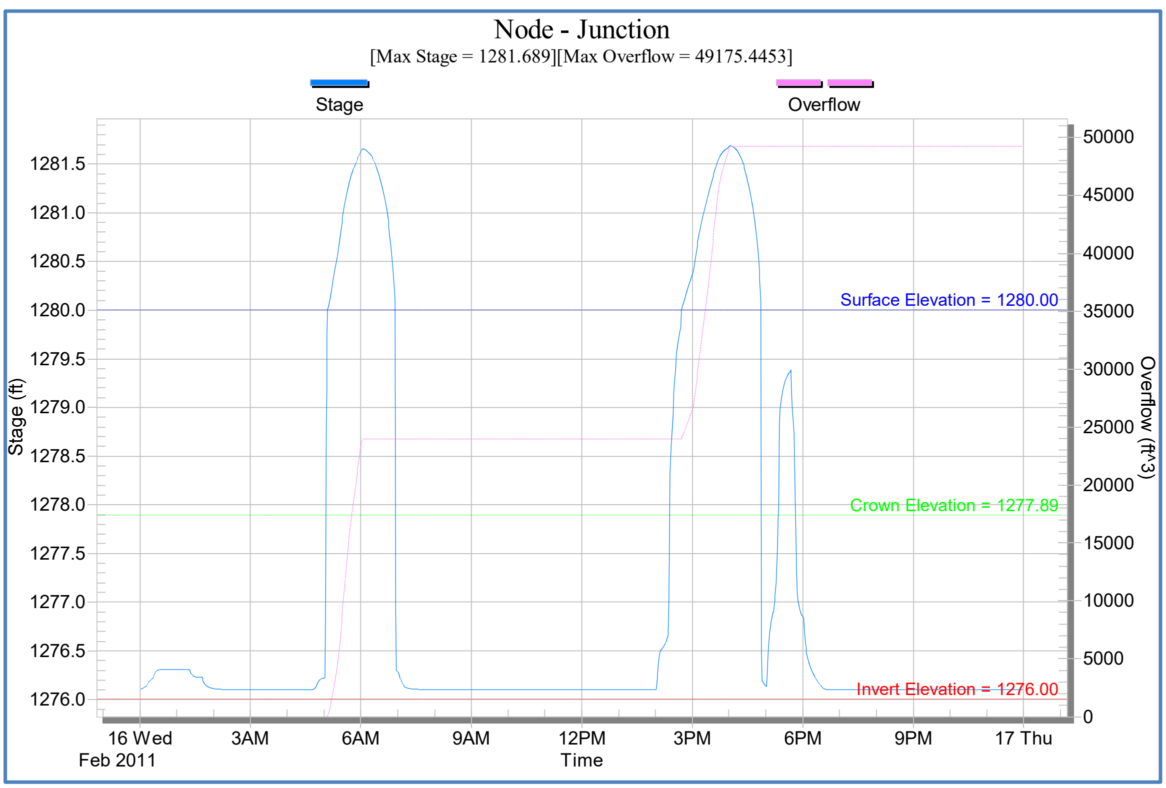
8. Review Results for the Node **Junction**. Notice that the HGL goes up to the Surface Elevation and then goes flat. Water was lost as described earlier.

9. Double-click on Node **Junction**. Ponding options are located in the middle of the node dialog. Since this node is in a sag location, click on the **Allowed** button. The ponding area will be determined from the Junction Defaults in the HDR Job Control as shown to the right.

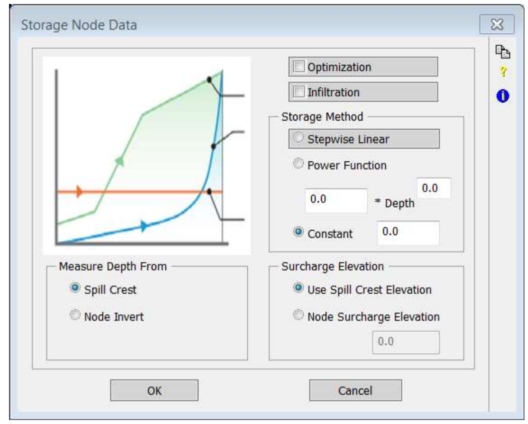


10. **Solve** the model.

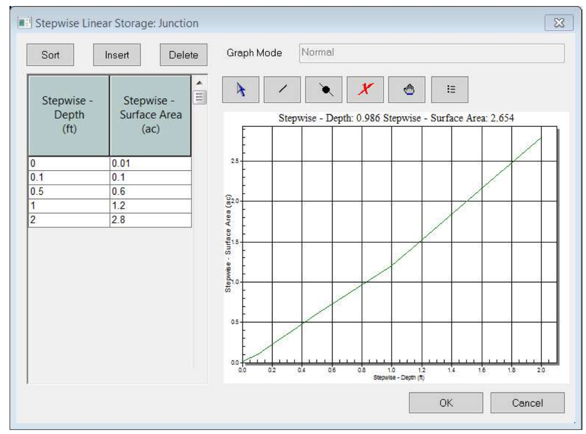
11. Review Results for the Node **Junction**. Notice that the HGL now exceeds the Surface Elevation by more than 1.5 feet. By allowing ponding, **Junction** is still flooding, but no water is lost from this node and the water above the node returns to this same node during the recession limb.



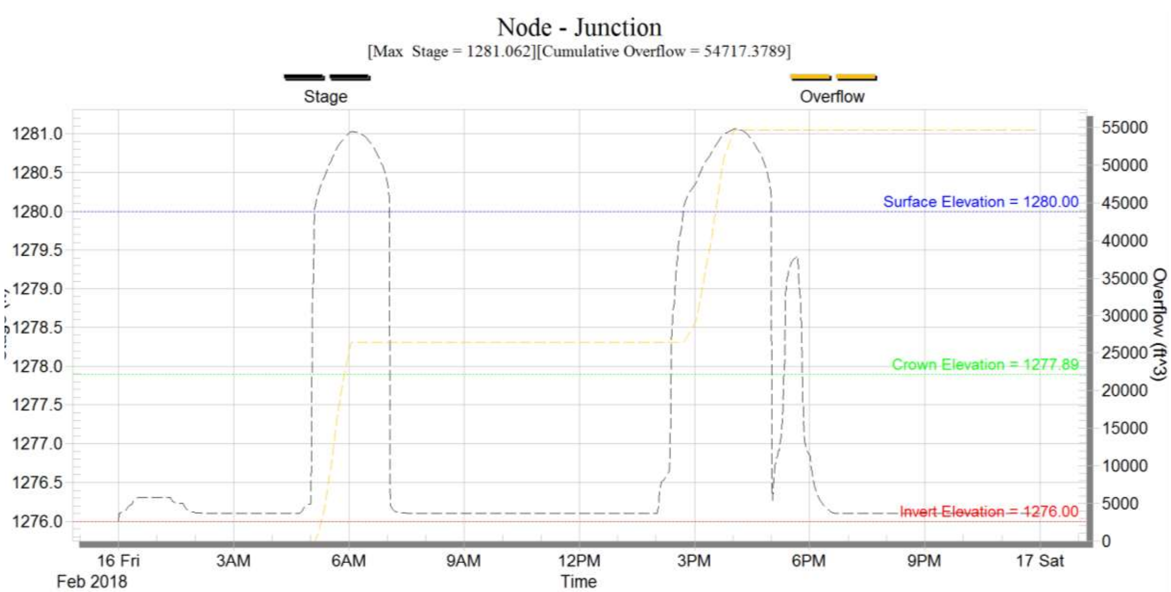
12. The next step is to define specific storage data for this node. Double-click on **Junction**. Click on the **Storage** button. Three storage methods are available as shown to the right. This pond will be defined using the stepwise linear method. Under Measure Depth From: Click on the **Spill Crest** Button.



13. Open the source data file **Design_Dbase.xls** which is where the node ponding information is located. Click on the **Stepwise Linear** Button and click on the **Insert** Button to add one row. Then copy the data from worksheet **Junction** and paste it into Stepwise Linear Storage. Then click **OK** three times to return to the project window.



14. **Solve** the model and compare the results at Junction. Note that elevation is now lower as compared to the previous simulation. The storage has a big influence on the HGL as demonstrated in the last few models.



15. **Save** the model database.

Inlet Capacity and Dual Drainage

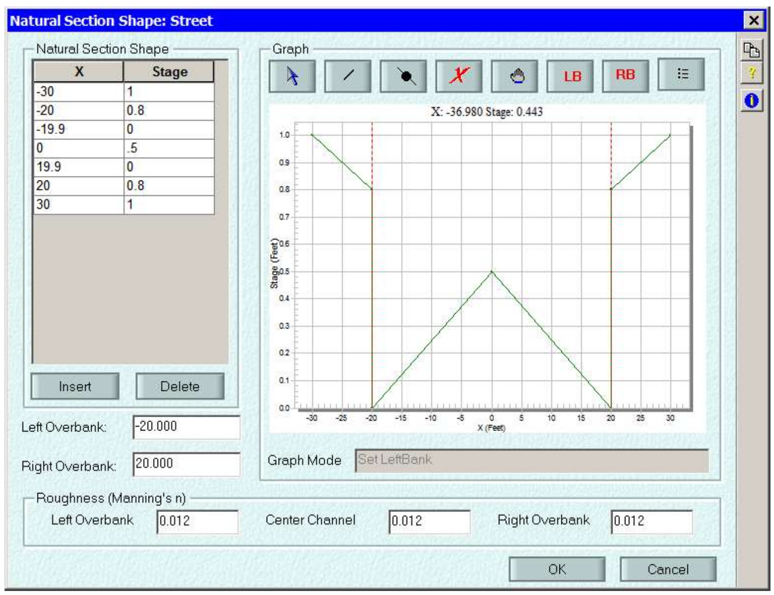
1. Open the file **Design3.xp** and save the file as **My_Design4.xp**.

2. In order to represent flows in the street and the pipe Link8 needs to been changed to a multilink and display as a dashed line. Right-click on **Link8** and change the single link to a multi-link.

3. Double-click on **Link8** which will take you to the Multiple Link dialog box. Enter Conduit Names for Conduits 1 and 2 as **SewerL8** and **StreetL8**.

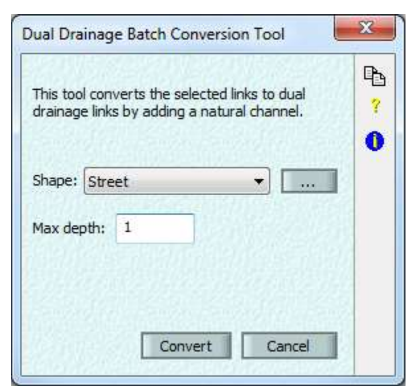
4. Double-click on the checkbox for **SewerL8** (Conduit 1). Click on **Conduit Profile**. This is the original closed conduit of the multilink. Then click **OK**.

5. Double-click on the checkbox for **StreetL8 (**Conduit 2). Click on the **Natural** Button and then click on the **Edit** button to view the Natural Section Shapes global database used to represent the overland flow.



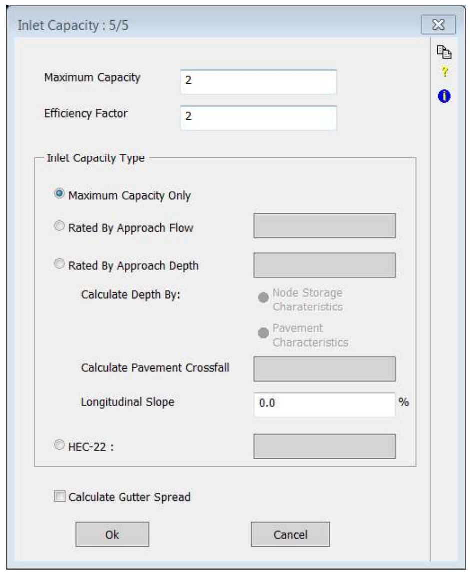
6. Click **OK**, then **Select**, then click **OK** three times to return to the project window.

7. Select **Link7** and **Link6** using the CTRL key. Then choose the **Tools->Dual Drainage Batch Converter…** menu item.

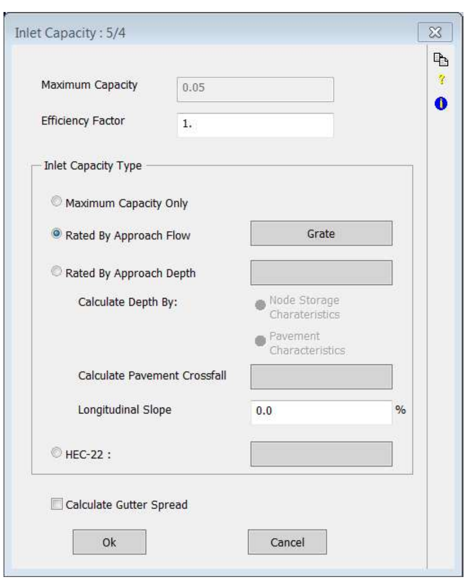


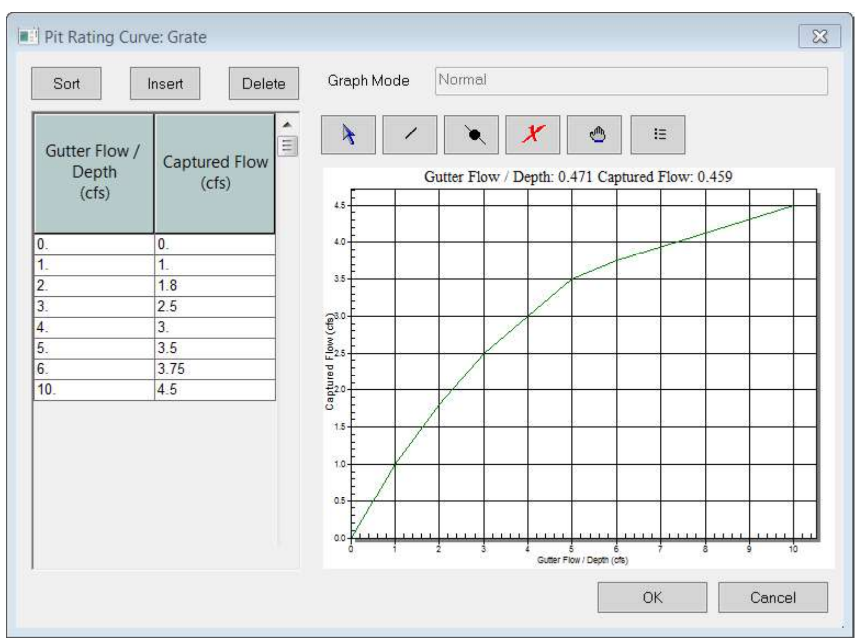
8. Select the **Street** shape already in the Global Database. Add Max depth of **1** so that the new open conduit has top of bank equal to the new adjusted spillcrest elevations. Select the **Convert** button to perform the conversion.

9. The next step is to use inlet capacity to control the amount of water in the sewer and on the street. Double click on Node **5/5** and click on the **Inlet Capacity** button. Type in a Maximum Capacity of **2** cfs and an Efficiency Factor of **2** (two inlets of 2cfs each).



10. Then double click on Node **5/4** and click on the **Inlet Capacity** button. Under **Inlet Capacity Type:** Click on the global database box next to **Rated by Approach Flow.** Select **Grate** and then click on **Edit** button to look at the rating curve. Click **OK**, then **Select** and then **OK** twice to return to the project window.



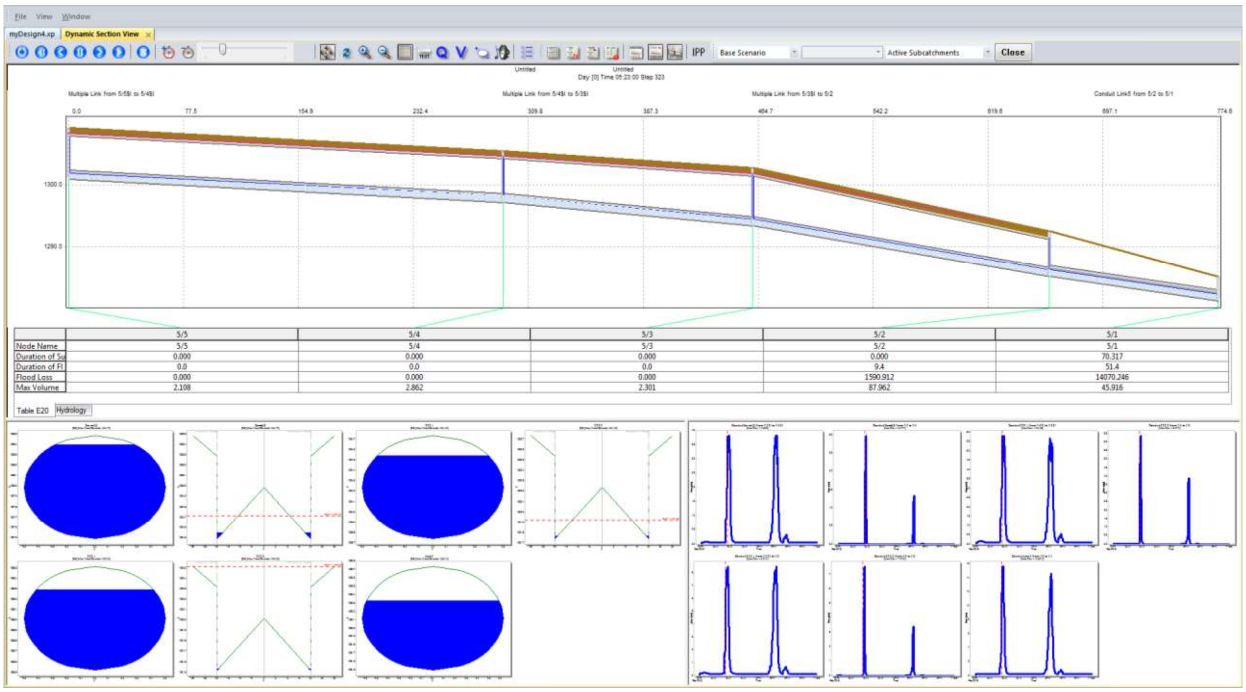


11. Repeat for Node **5/3** and select the **Grate** curve for inlet capacity.

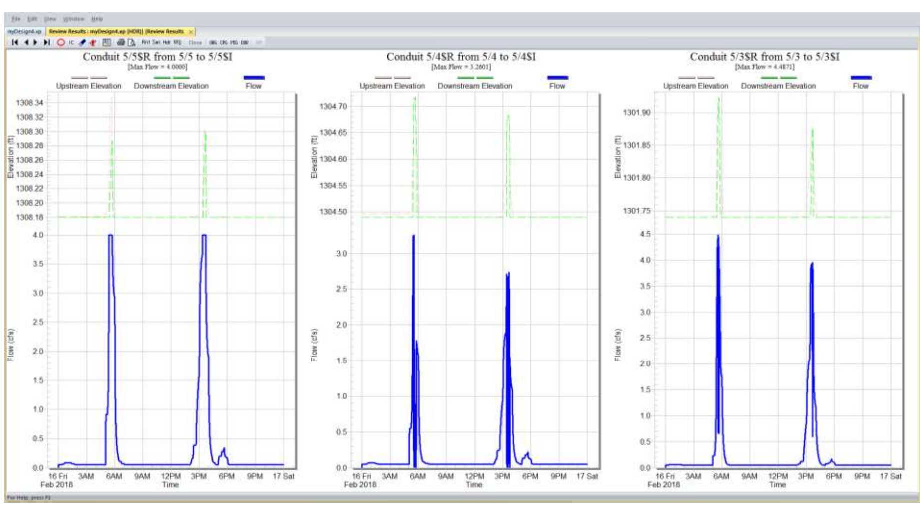
12. Save the model by using the Save button or by using the File Pull-Down or **Ctrl-S**.

13. **Solve** the model.

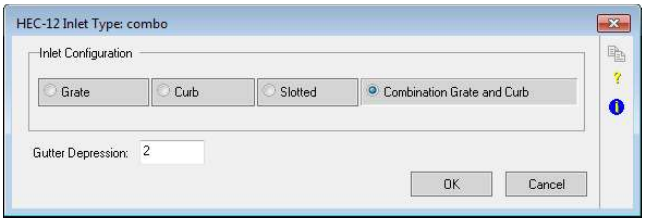
14. Left Click on Node **5/5** and then press Shift and Click on Node **5/1**. Click on the **Dynamic Section Views** icon and click on the **Play** button. Notice that how the model puts water in both the sewer and the street. Use review results to look at different nodes and links associated with dual drainage. **Close** the view.

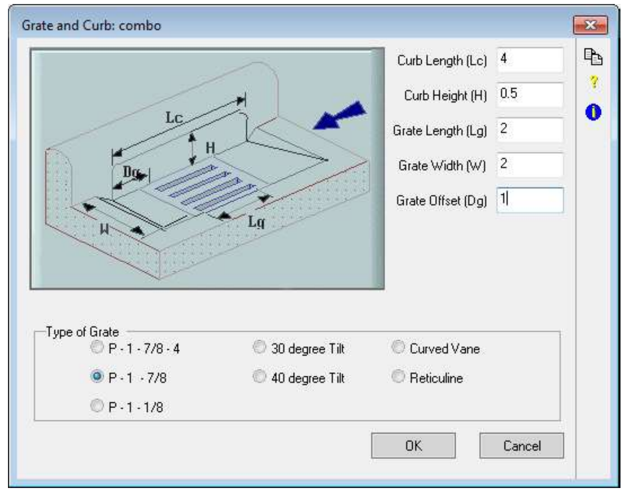


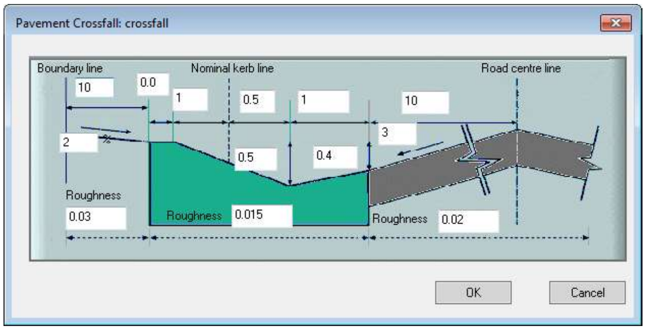
15. A new feature now allows the user to visualize the hydrograph of Inlet Capacity. Select the node **5/5**, **5/4** and **5/3** using the **CTRL** key and then **Review Results**. In the Review Results choose the **IC** icon on the toolbar.



16. Time permitting? Consider trying different types of inlet capacity including HEC-22 option for node 5/3 using the following choices with 1% longitudinal slopes.







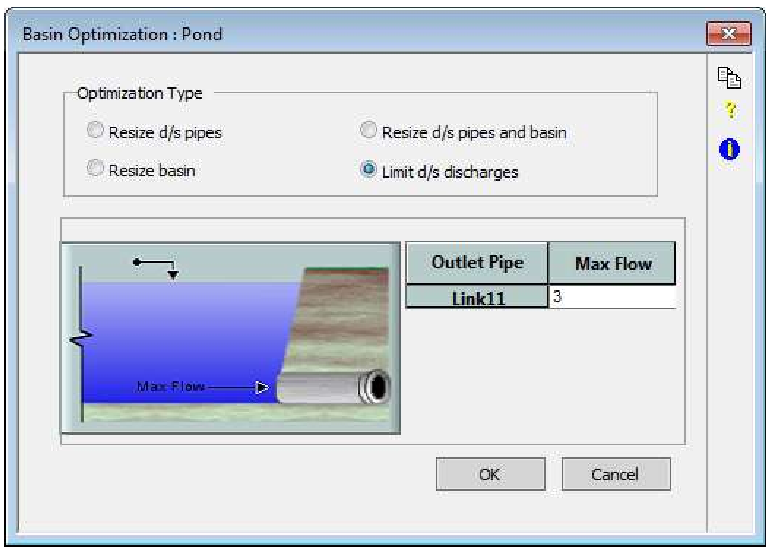
Pond Structures and Optimization

As in pipe sizing, determining the correct size for a pond is based either on the maximum elevation of a pond or the maximum discharge from a pond. The area available for the pond and inflow/outflow regulations will also impact the pond design. The developer wants to limit the size of the pond and regulators often require a predevelopment release rate. These goals usually require several iterations to achieve a successful design.

1. Open the file **Design4.xp** and save the file as **My_Design5.xp**.

2. The node Pond is a wet pond and should have an impounded dead pool of water. Double-click on the node **Pond**. Type **5** as the Initial Depth. Double-click on the **Storage** button. Click **OK** two times to return to the project window.

3. We will also need to change Link11 because Pond has an initial depth. Double-click on **Link11** and change the Upstream Pipe Invert to **1276**. *Hint*: **Right-click->Conduit Profile**. Don't forget to resolve for the conduit slope to avoid a warning message.



4. Double-click on the node **Pond**. Double-click on the **Storage** button. Click on the **Optimization** button to start the pond design process. The first step will be limiting the downstream discharge to a release rate of 3 cfs. Click on **Limit d/s discharges** and enter a Maximum Flow of **3** for Link11. Click **OK** three times to return to the project window.

5. **Solve** the model.

6. **Review Results** of **Pond** and see that the maximum elevation of Pond is about **1278.128**. The rim elevation is 1279.00, which leaves a freeboard of less than 1 ft.

7. **Review Results** of Link11 to verify the flow has been reduced below 3 cfs. This is accomplished by iteration and a reduction of the conduit size. Double-click on **Link11** to see the new conduit diameter to accomplish this flow throttling.

8. **Browse** the model output file to see the optimization results in Table E23:

```
#########################################################
# Table E23. New Basin Design Information               #
#            Maximum Hydraulic Grade Line,              #
#            Out Conduit Sizes and Maximum Flow         #
#########################################################

A) Resize d/s Pipes based on given HGL
B) Resize Basin based on given HGL
C) Resize d/s Pipes and Basin based on HGL and max discharge
D) Resize d/s pipes based on given max discharge

   Basin Name    Type    Max.HGL   Conduit         Depth   Width   Barrels   Max.Flow
                           (ft)                     (ft)    (ft)             (ft^3/s)
--------------- ------  --------- --------------- ------- ------- --------- ---------
           Pond    D)   1278.1283          Link11  0.4167  0.4167    1.0000    2.0426
```

9. The next step is to resize the downstream pipes and the basin to accomplish this maximum release rate of 3 cfs and ensure enough freeboard. Double-click on **Pond**, **Storage** and then **Optimization**. Change the selection to **Resize d/s pipes and basin** and enter a Maximum Water Level of **1278** in that field. Click **OK** three times to return to the project window. **Solve** the model.

10. Review results of **Pond** and **Link11** to see that both the maximum elevation of Pond and maximum discharge criteria are satisfied.

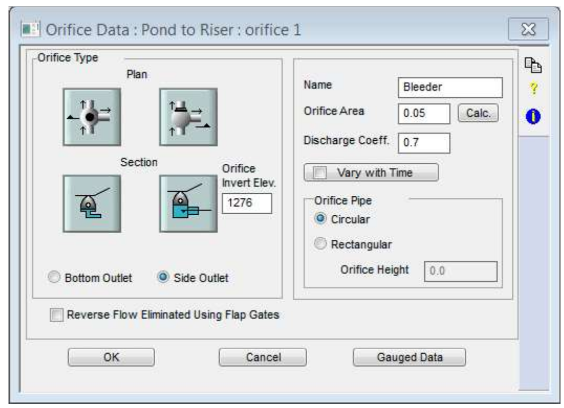
11. **Browse** the model output file and search for the new optimization for the Pond in Table E23.

```
#########################################################
 # Table E23. New Basin Design Information               #
 #            Maximum Hydraulic Grade Line,              #
 #            Out Conduit Sizes and Maximum Flow         #
 #########################################################

 A) Resize d/s Pipes based on given HGL
 B) Resize Basin based on given HGL
 C) Resize d/s Pipes and Basin based on HGL and max discharge
 D) Resize d/s pipes based on given max discharge

    Basin Name    Type    Max.HGL   Conduit         Depth   Width   Barrels   Max.Flow
                            (ft)                     (ft)    (ft)             (ft^3/s)
 --------------- ------  --------- --------------- ------- ------- --------- ---------
            Pond    C)   1277.9639          Link11  0.4167  0.0000    1.0000    2.0152

 Number of Restarts:    9

 #########################################################
 # Table E23A. New Basin Design Information              #
 #             Basin Storage Parameters                  #
 #########################################################

    Basin Name     Storage Type    Parameter   Depth      Area
                                                (ft)      (ft^2)
 --------------- ---------------- ---------- ---------- ----------
            Pond  stepwise linear              0.0000     6.2432
                                               2.0000 43078.3353
                                               4.0000 85580.3718
                                               5.0000 85580.3718
                                               6.0000 96530.0490
                                               7.0000 107479.726
                                               8.0000 123568.068
```

12. Right-click **Link11** and choose **Properties**. Change the link name to **Structure**. Then click on the **Browse** button. Select **Structure.jpg**. Click on **Open**. Then click **OK** to return to the project window. Right-click to open the pop-up dialog and select **View Image** to see the image we just attached to this link.

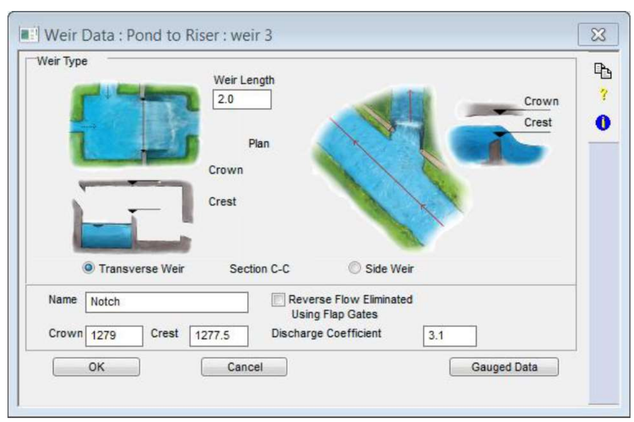
13. Right Click on **Structure** and change to a **Multi-Link**. Double-click on **Structure**. Turn off the **check box** for Conduit 1 and delete the conduit name.

14. The next step is to enter the data for two orifices. The orifice dialog box is shown to the right. Click on **Orifice 1**. Enter **Bleeder** as the Name, **0.05** as the Orifice Area, **0.7** as the Discharge Coeff. and **1276.0** as the Orifice Invert Elev. Make sure that the **Side Outlet** and the **Circular** Orifice Pipe are both selected. Then click **OK**.



15. The second orifice is entered in **Orifice 2**. Enter **Rectangle** as the Name, **0.5** as the Orifice Area, **0.7** as the Discharge Coeff. and **1276.5** as the Orifice Invert Elev. Make sure that the **Side Outlet** and the **Rectangular** Orifice Pipe are both selected. Enter **0.5** as the Orifice Height. Then click **OK**.

16. The next step is to enter the data for the weir. Click on **Weir 3**. Enter **Notch** as the Name, **2.0** as the Weir Length, **1279.0** as the Crown, **1277.5** as the Crest and **3.1** as the Discharge Coefficient. Make sure that the Transverse Weir is selected. Then click **OK**.



17. The second weir is entered in Weir 4. Enter **Rim** as the Name, **10.0** as the Weir Length, **1279.0** as the Crown, **1278.0** as the Crest and **3.1** as the Discharge Coefficient. Make sure that the Transverse Weir is selected. Then click **OK.**

18. Double-click on **Pond**, **Storage** and then single click on the **Optimization** Button to turn off the Optimization routine. Click **OK** twice times to return to the project window.

19. **Solve** the model and review results of **Pond** and see that the maximum elevation of Pond is now a bit more than 1278. The rim elevation is 1279.00, which leaves a freeboard of about 1 ft. Review results of **Culvert** and see that the maximum flow is

about 5.7 cfs. We would need to refine the orifice and weir parameters until we obtained the correct pond elevation and release rate.

20. The final step is to use Conduit Factors to define the Inlet Type for the discharge through Culvert and apply minor losses. The Inlet Type can significantly impact the head water elevation of Pond, if the Pond becomes under Inlet Control. Double-click on **Culvert** and then click on **Conduit Factors**. Click on **Inlet Type** and choose **Square Edge with Headwall (Circ, Conc)**. Enter and Entrance loss of **0.5** and an Exit Loss of **1.0**. Click **OK** three times to return to the project window.

21. **Solve** the model and review results of **Pond** and see that the maximum elevation of Pond is now **1278.022**. Look at Table 13a and see that the Culvert did go into Inlet Control for 510 minutes, but didn't impact the Pond head water elevation.

22. **Review Results** on **Structure** to see the flow rates for the orifices and weirs.