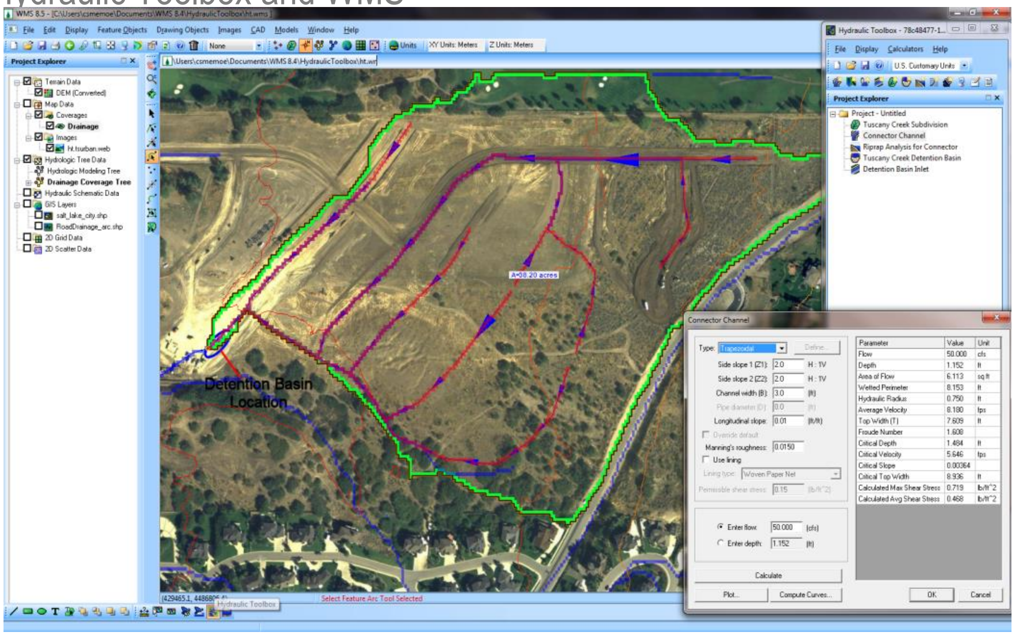
WMS v. 10.1

WMS 10.1 Tutorial

Hydraulics and Floodplain Modeling – Modeling with the Hydraulic Toolbox

Learn how to design inlet grates, detention basins, channels, and riprap using the FHWA Hydraulic Toolbox and WMS



Objectives

Learn how to use several Hydraulic Toolbox calculators and how they are integrated with WMS. Delineate a suburban watershed and estimate the watershed runoff using the Rational calculator. Design a grate inlet, a detention basin, a channel, and the channel's riprap.

Prerequisite Tutorials

- Watershed Modeling – Advanced DEM Delineation Techniques

Required Components

- Data
- Drainage
- Map
- Hydrology

Time

- 30-45 minutes

AQUAVEO™

1 Introduction

The US Federal Highway Administration's Hydraulic Toolbox is a MS Windows-based program with a set of calculator tools that can be used for such things as computing channel properties using Manning's equation and computing a sub-basin's discharge using the Rational method. The hydrologic and hydraulic calculations in the hydraulic toolbox have been integrated with feature objects in the WMS map module. When points, arcs, or polygons are defined in the WMS map module, hydraulic toolbox calculations can be assigned to these objects and WMS-computed data is passed to the hydraulic toolbox.

This tutorial shows how to delineate a small suburban sub-basin and then how to compute the sub-basin discharge and design hydraulic structures based on this discharge using the hydraulic toolbox calculators. It is recommended that to be familiar with some of the more advanced watershed modeling techniques in WMS by following the advanced watershed modeling tutorial before attempting this one.

2 Objectives

The task in this workshop is to design the drainage associated with Tuscany Creek, a small suburban development. This exercise demonstrates how to use the WMS link to the Hydraulic Toolbox to simulate a drainage design in a suburban area. The following tasks will be demonstrated in this workshop:

- Delineating a suburban watershed.
- Estimating the runoff from the watershed using the Rational Method.
- Designing a grate inlet for conveying street discharges into a storm drain.
- Designing a detention basin to handle the flow from the Rational Method hydrograph.
- Designing a channel and its riprap to convey flow from a detention basin to a natural stream.

3 Define Drainage Data

3.1 Read Data

1. Open WMS
2. From the ***File*** menu, Select ***Open***.
3. Locate the ***HydraulicToolbox*** folder in the files for this tutorial. If needed, download the tutorial files from www.aquaveo.com.
4. Open *RoadDrainage.shp*. This is an ArcInfo shapefile containing roadway drainage paths in the watershed being modeled. If a window appears asking if to "keep this current projection, define a new projection, or set the project projection to the coordinate system defined by the projection file", select *Use the projection file* and select *OK*.
5. Select ***File*** | ***Open*** again and open *tuscanycreek.jpg*. This is an image of the area under consideration for the Tuscany Creek subdivision.
6. Select ***File*** | ***Open***.
7. Browse to the ***HydraulicToolbox\TuscanyCreekDEM\ 42093886*** folder. Open *42093886.hdr*. This is a high-resolution DEM with approximately 3-meter cell sizes.
8. In the Importing NED GRIDFLOAT File dialog, select the *OK* button to read the DEM.

3.2 Define Project Coordinate System

1. A message will appear, advising that the DEM coordinates are geographic and should be converted to a planimetric coordinate system for basin delineation. Select *Yes* to convert the coordinates to a planimetric coordinate system.
2. In the Reproject Object dialog, under Project projection, select *Set*.
3. Select the *Global Projection* option.
4. If the Select Projection dialog does not show up, click on the *Set Projection* button.
5. In the Select Projection dialog set:
    - Projection to *UTM*
    - Zone to *12 (114°W - 108°W – Northern Hemisphere)*
    - Datum to *NAD83*
    - Planar Units to *Meters*
6. Select *OK*.
7. Set the Vertical Projection to *NAVD 88(US)* and Vertical Units to *Meters*.
8. Select *OK*. The DEM is read and the contours from the DEM are displayed.

3.3 Convert Roadway Drainage Paths to Streams

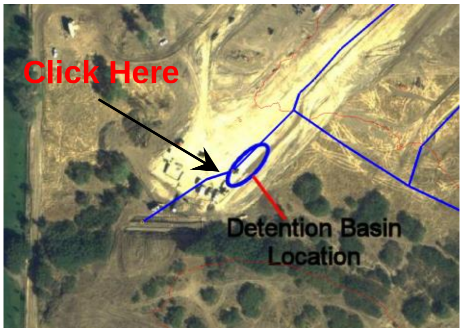
Since the drainage in the sub-basin of interest will be modified by the addition of roads, curbs, and other drainage conveyance structures, these drainage paths have been defined using a shapefile. Convert these drainage paths to stream arcs in the map module to use them to delineate the sub-basin.

1. Select the *RoadDrainage.shp* file in the project explorer.
2. Select ***Mapping | Shapes -> Feature Objects.***
3. Select *Yes* to use all shapes in all the visible shapefiles for mapping.
4. Select *Next.*
5. Select *Next.*
6. Select *Finish.*
7. Hide the *RoadDrainage.shp* file by deselecting its check box in the Project Explorer.
8. Select the *Drainage* coverage in the Project Explorer.

3.4 Define the Drainage Basin

With the streams and flow directions defined, thee flow directions and accumulations can be computed and the streams used to define the drainage basins.

1. Choose the *Select Feature Point/Node* tool.
2. Double-click on the node at the downstream end of the detention basin location shown in the background image and change *Drainage Feature Point Type* to *Drainage outlet*. This outlet point defines the terminus of the upper sub-basin. The boundaries for this upper sub-basin are the same as the boundaries for the subdivision being modeled. Select *OK* to close the Feature Arc Type dialog.



3. Switch to the *Drainage* module.
4. Select ***DEM | Compute Flow Direction/Accumulation….***
5. Select *OK*.
6. Change the *Parameter units-Basin Areas* to *Acres*.
7. Select *OK*.
8. Select *Close* once TOPAZ finishes running. This process may take a few minutes, depending on the computer Notice the flow accumulation cells are displayed after TOPAZ is finished.
9. Right-click on DEM (Converted) in the Project Explorer and select ***Display Options*** .
10. Change the Minimum Accumulation For Display to **3.0** acres.

11. Select *OK*.
12. Switch to the *Drainage* module 
13. Select ***DEM | Define Basins***
14. Select ***DEM | Basins->Polygons***
15. Select ***DEM | Compute Basin Data***
16. Select *OK*
17. Right-click on the *Drainage* coverage in the Project Explorer and select ***Zoom to Layer***

Notice that two drainage basins are defined. The smaller sub-basin is the one to be modeled here because it covers the subdivision area. Ignore the other sub-basin for now.

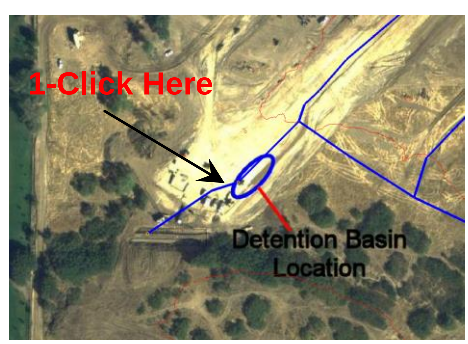
4 Link Drainage Data with the Hydraulic Toolbox

Now that a sub-basin is defined, associate hydraulic toolbox computations with points, arcs, and polygons in the map module.

4.1 Define the Rational Method Computation

1. Select the *Drainage* coverage in the Project Explorer.
2. Select the *Select Polygon* tool.
3. Double-click on the sub-basin upstream from the detention basin.
4. Select *Edit Attributes…*.
5. Turn on the toggle box next to *Rational Method Analysis*. This will create a new Rational Method Analysis and assign a default name to the analysis.
6. Change the name of the analysis in the drop-down box to *Tuscany Creek Basin* and select *OK*.
7. Select *OK* to close the Drainage Feature Polygon Type dialog.

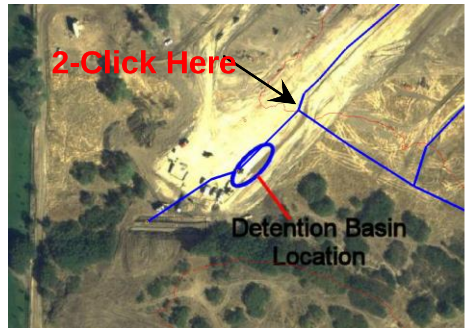
4.2 Define the Inlet and Detention Basin Computations



1. Choose the *Select Feature Point/Node* tool.
2. Double-click on the node at the downstream end of the detention basin location shown in the background image and select the

Edit Attributes… button.

3. Turn on the toggle box next to *Detention Basin Analysis*, change the name to *Tuscany Creek Detention Basin*, and select *OK*.
4. Select *OK* to close the Drainage Feature Point Type dialog.
5. Double-click on the node just above the detention basin location and select the *Edit Attributes…* button.
6. Turn on the toggle box next to *Curb Inlet Analysis*, change the name to *Inlet Analysis*, and select *OK*.
7. Select *OK* to close the Drainage Feature Point Type dialog.



4.3 Define the Channel and Channel Lining Computations

1. Choose the *Select Feature Arc* tool.
2. Double-click on the stream arc downstream from the detention basin location and select the *Edit Attributes…* button.
3. Turn on the *Channel Analysis* and the *Channel Lining Design Analysis* toggles. Change the Channel Analysis name to *Detention Basin Channel* and the Channel Lining Design Analysis to *Detention Basin Lining*. Select *OK* to close the Stream Arc Attributes dialog.
4. Select *OK* to close the Feature Arc Type dialog.

5 Define Hydraulic Toolbox Parameters

With the locations of the hydraulic toolbox structures defined, now start the Hydraulic Toolbox from WMS and the structures and the associated geometric data is copied to the Hydraulic Toolbox.

5.1 Start the Hydraulic Toolbox and Compute the Rational Method Hydrograph

1. Select the *Hydraulic Toolbox* button  from the WMS Get Data toolbar.
2. Double-click on the *Tuscany Creek Basin* rational method computation.
3. Notice that the basin area has been copied from the WMS interface. A runoff coefficient (C) and a rainfall intensity (i) need to be defined. Enter a value of *0.3* for the runoff coefficient since this is a low-density suburban area.
4. Select the *Compute…* button under the *Compute I-IDF Curves* row of the spreadsheet. Select the option to *Define User Supplied Data*.
5. Select the *Define Storm Data…* button.

6. Change the *Recurrence Interval* to *100 years*.
7. Enter the following data for the 100-year storm (from NOAA Atlas 14) and select *OK*:

Duration (min)	Intensity (in/hr)
5	7.03
10	5.35
15	4.40
30	2.98
60	1.84

8. Select the *100-year recurrence interval* line in the IDF curve table.
9. Enter a *Specified Tc* of 12 minutes.
10. Select the *Compute Intensity* button and then select *Done*.
11. Notice the peak flowrate of 57.0 cfs from the basin. Select the button to compute a hydrograph.
12. Select *Rational method hydrograph* for the hydrograph computation method and select *OK*.
13. The rational method hydrograph appears. Copy/paste the data in this rational method hydrograph to a spreadsheet or to a text file for future use. Select *OK* to close the hydrograph and *OK* to close the Tuscany Creek Basin rational method computation.

5.2 Route the Rational Method Hydrograph through the Detention Basin

1. Double-click on the *Tuscany Creek Detention Basin* computation.
2. Select the *Define Storage…* button.
3. Select the *Known geometry* option to define a detention basin with the following data:

Length: 60 ft

Width: 30 ft

Depth: 10 ft

Side slope: 0.5 ft/ft

Base elevation: 0 ft

4. Select the *OK* button.
5. Select *Define Outflow Discharges…*
6. Select the *Add Weir* button and define the following parameters (use the default values for all other parameters):

Weir Length: 3.0 ft

Height above Base Elevation: 8.0 ft

7. Select the *Add Riser* button and define the following parameters (use the default values for all other parameters):

Opening Shape Type: Circular

Opening Diameter: 0.5 ft

8. Select the *Add Standpipe* button and define the following parameters (use the default values for all other parameters):

Pipe diameter: 1.0 ft

Height above Base Elevation: 2.0 ft

9. Select the *OK* button.
10. Select the *Define Inflow Hydrograph* button. Change the *Number of x,y points* to *25* and copy the hydrograph data from the rational method calculation. Select the *OK* button.
11. Select the *Route Hydrograph* option. Note the peak discharge of 33.82 cfs. Before this detention basin was added, the rational method computed a peak discharge of 57.0 cfs. Plot the inflow and outflow hydrographs in order to compare them in the detention basin calculator window, if desired.
12. Select *OK* and then *OK* again to close the detention basin calculator.

5.3 Size a Storm Drain Inlet Grate at the Bottom of the Sub-Basin

1. Double-click on the *Inlet Analysis* computation.
2. Enter the following data for the inlet analysis:

Longitudinal slope of road: 0.04 ft/ft

Cross-slope of pavement: 0.01 ft/ft

Manning's roughness: 0.015

Gutter Width: 2.0 ft

Design flow: 57.0 cfs (from the Rational Method computation)

Inlet Location: Inlet in sag

Percent clogging: 0.0

Inlet Type: Grate

Grate Type: P - 1-7/8

Grate width: 4.0 ft

Grate length: 4.0 ft

3. Select the *Compute Inlet Data* button. Notice the large width of spread at the sag and the large depth at the center of the grate. To avoid flooding, consider subdividing this watershed and add additional inlets and storm drains to better convey water through each sub-basin. Continue with this

analysis, assuming the computed width of spread and depth do not cause flooding problems around the inlet.

4. Select the *OK* button to close the Inlet Analysis dialog.

5.4 Size the Channel and Riprap Downstream of the Detention Basin

The 100-year peak flow in this subdivision has been computed using the rational method and the peak flow has been modified by routing it through a detention basin. In this design, the inlet near the bottom of the subdivision will also provide a degree of routing because of the storage provided by the width of spread and the depth above the inlet. This tutorial will ignore the storage above the inlet in this analysis. Now design the channel and the channel lining to convey flow to the natural channel downstream of the detention basin.

1. Double-click on the *Detention Basin Channel* computation.
2. Enter the following data for the channel analysis:

Size slope 1 (Z1): 2.0 H:1V

Size slope 2 (Z2): 2.0 H:1V

Channel width (B): 5.0 ft

Longitudinal slope: use the default value computed by WMS (0.072).

Manning's roughness: 0.06 (a large-diameter riprap encased in a gabion mattress-a rock-filled wire container will be installed)

Enter flow: 33.82 cfs (from the peak detention basin discharge)

3. Select the *calculate* button. Notice that the flow is supercritical (the depth is less than critical depth) because of the steep slope.
4. Select *OK* to close the Detention Basin Channel calculation dialog.

Riprap can now be designed to be used to control channel erosion. This tutorial uses the Channel Lining Design Analysis Tool to design the riprap, but there is also a Riprap Analysis Tool that can be used in the Hydraulic Toolbox. In addition to riprap, a riprap filter material should be designed to be placed between the riprap and the original soil. The hydraulic toolbox provides a filter calculation and design tool as a part of the Riprap Analysis Tool. Design of a filter is not covered in this tutorial, but the installation of a filter reduces the failure potential of a riprap installation.

5. Double-click on the *Detention Basin Lining* computation.
6. Change the *Lining type* to *Gabion*.
7. Under the *Select Channel* row, select *Detention Basin Channel* as the channel. Notice that all the parameters entered and computed for the channel are copied to this calculator.
8. Enter a *D50* of *0.75* ft.
9. Enter a *Gabion Mattress Thickness* of *1.5* ft.
10. Enter a *Safety Factor* of *1.3*.

Notice the analysis results at the bottom of the window. The Manning's n value has been changed to 0.056 based on the Bathurst equation for computing Manning's n. Both the channel bottom and the channel are stable. Since there will not be any curvature in this channel, a curvature radius does not need to be entered. Riprap or some sort of erosion control should be installed where this channel meets the main channel.

6 Create a Report from the Hydraulic Toolbox

Finally, create a report containing all the information entered in the hydraulic toolbox calculators. Choose to create this report in PDF or RTF format, depending on the software available on the computer being used. The RTF format report can be edited in several word processing programs.

1. From the Hydraulic Toolbox, select ***Calculators* | *Create Report…***
2. Browse to a folder where the report should be saved and enter *Tuscany Creek* as the filename.
3. In the Report Generator dialog, select all the calculations to be included in the report.
4. Select the desired file format: either PDF or RTF (a Word Pad or MS Word-readable format).
5. Select *OK*. The report is created and the default viewer brings up the report. If the report is in RTF format, it can be edited.
6. Close the hydraulic toolbox. The results are saved and read into WMS. When the WMS project file is saved, the hydraulic toolbox input data and results are saved and read back into WMS when the WMS project is read.

