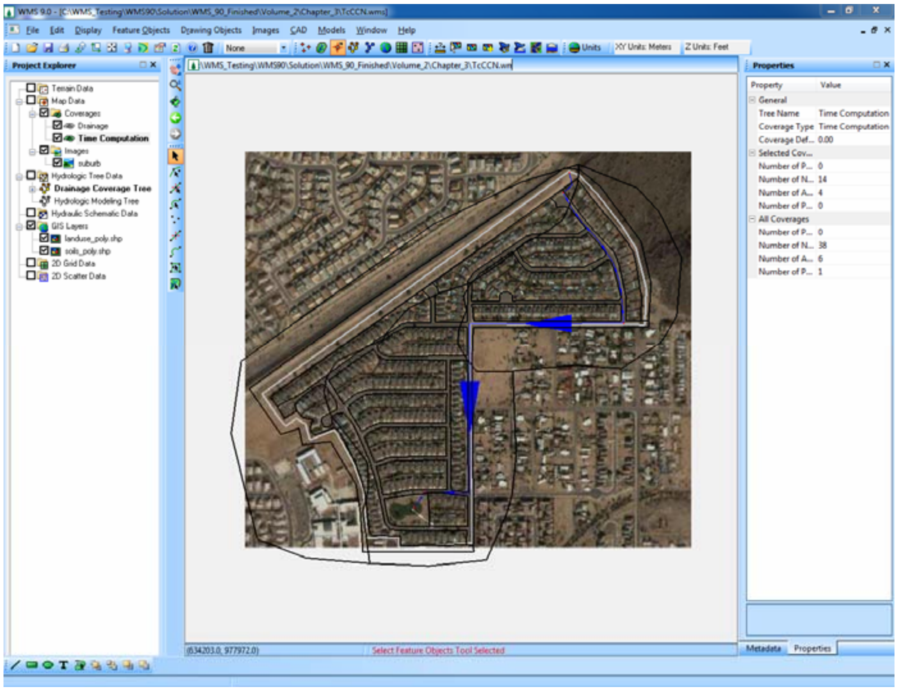
v. 9.0

WMS 9.0 Tutorial

Watershed Modeling – Time of Concentration Calculations and Computing a Composite CN

Compute hydrologic parameters such as sub-basin time of concentration and curve number



Objectives

This tutorial shows you how to compute coverage overlay percentages, time of concentration, and curve numbers for sub-basins and how to apply these parameters to a TR-55 model.

Prerequisite Tutorials

- Watershed Modeling – DEM Delineation

Required Components

- Data
- Drainage
- Map
- Hydrology
- Hydrologic Models

Time

- 30-60 minutes

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1 Contents

2 Introduction

This exercise will discuss tools that are helpful in calculating the time of concentration and in computing a composite curve number (CN). In particular, two models, the United States Geological Survey's (USGS) National Streamflow Statistics (NSS), and the National Resources Conservation Service's (NRCS) TR-55, will be discussed.

3 Opening the Drainage Basin

First we will open a WMS Project file (*.wms) that contains a DEM that was previously downloaded from the Internet. A single watershed basin has been delineated from the DEM data and converted to feature objects.

1. Close all instances of WMS
2. Open WMS
3. Switch to the *Drainage* module
4. Select ***File* | *Open***
5. Locate the ***nss*** folder in your tutorial files. If you have used default installation settings in WMS, the tutorial files will be located in ***\My documents\WMS 9.0\Tutorials\\.***
6. Open *"NSS_FL.wms"*

4 Prepare the Basin for Use with NSS

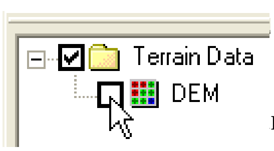
We will now use WMS to calculate the basin area, basin slope, and other parameters that can be used in conjunction with NSS.

1. Select ***DEM | Compute Basin Data***
2. Select the *Current Projection...* button
3. Set the Vertical units to *Meters*
4. Select *Set Projection*
5. Select *METERS* in the *Planar Units* Field
6. Select *OK*
7. Select *OK*
8. Set the Basin Areas to *Square miles*
9. Set the Distances to *Feet*
10. Select *OK* to compute the parameters

In order to see the parameters that will be used with the NSS program, you can turn them on for display.

11. Select ***Display | Display Options***
12. Select *Drainage Data*
13. Check the display toggle for *Basin Slopes* (Basin areas should already be on)
14. Select *OK*

Basin attributes are displayed at the centroid of the basin. In order to see the parameters more clearly, turn off the display of the DEM



15. If needed, expand the Terrain Data folder in the Project Explorer
16. From the Project Explorer, toggle off the check box for the DEM

reen should now look like Figure 4-1

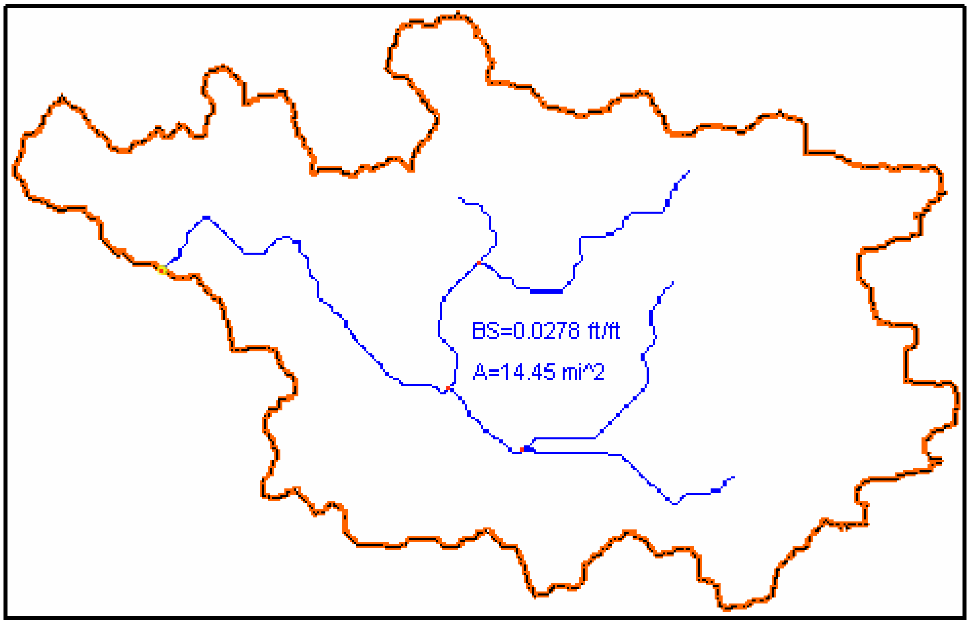


Figure 4-1: Drainage basin with parameters computed

5 Calculating Percentage of Lake Cover

The regression equation for Region B of Florida includes a parameter (LK) to define the ratio of the area of lakes in the basin to the total basin area (as a percent). We will use the Compute Coverage Overlay calculator in WMS to calculate the percentage of lake cover in our drainage basin. The only other parameter in the regression equation for Region B of Florida is drainage area (DA), something that is automatically computed using the Compute Basin Data command.

5.1 Opening the Land Use Coverage

In order to compute the percentage of lake cover in our watershed, we will read in land use data from a typical USGS land use file. Each polygon in the coverage is assigned a land use code that corresponds to a land use type. For this land use coverage, the codes for water bodies (lakes, reservoirs, wetlands) include 52, 53, 61, and 62. We will look for these codes to determine the value for LK.

1. Right-click on the Coverages folder in the Project Explorer
2. Select ***New Coverage***
3. Change the coverage type to *Land Use*
4. Select *OK*
5. Right-click on *GIS layers* and select ***Add Shapefile Data***
6. Open *"valdosta.shp"* and make it the active layer

This land use shapefile was obtained from www.webgis.com, but the EPA and other websites contain similar information. Alternatively, we could have digitized land use polygons from an image (discussed in Volume 1, Chapter 3: Basic Feature Objects).

7. Choose the *Select Shapes* tool
8. Drag a selection box around the drainage basin polygon
9. Select ***Mapping | Shapes -> Feature Objects***
10. Select *Next*
11. The LUCODE with the land use ID is automatically mapped so you can continue by selecting *Next*
12. Select *Finish*

13. Hide *valdosta.shp* by toggling off its check box in the Project Explorer (you may need to expand the GIS Layers folder to see it)

Only the portion of the shapefile that was selected will be used to create polygons in the Land Use coverage. The following figure displays the resulting land use polygons and their respective land use codes. This land use classification is consistent among all of the USGS land use data, where codes from 10-19 are urban, 20-29 agricultural, etc. A complete listing of code values can be found in the WMS Help file.

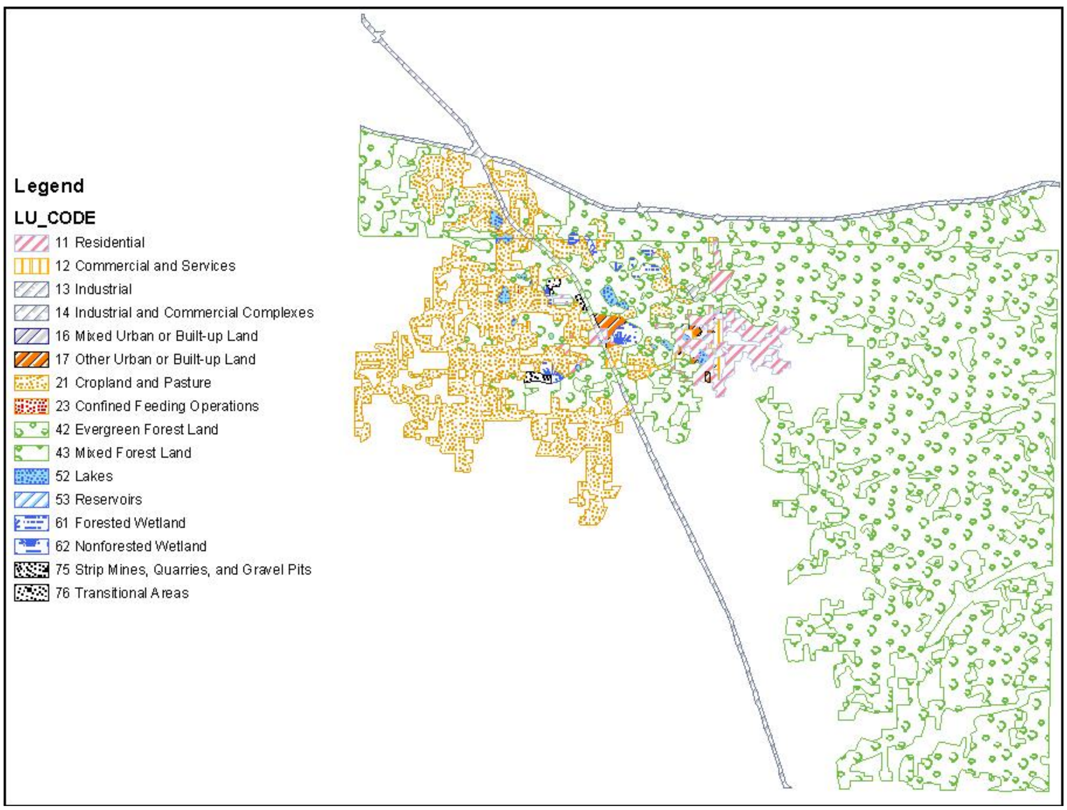


Figure 5-1: Land use codes used in Valdosta.shp.

5.2 Using the Compute Coverage Overlay Calculator

1. Switch to the *Hydrologic Modeling* module
2. Select ***Calculators | Compute Coverage Overlay***
3. Make sure that *Drainage* is chosen as the Input Coverage

4. Make sure that *Land Use* is set as the Overlay Coverage
5. Select the *Compute* button

According to the USGS land use classification, code values in the 50’s and 60’s represent water bodies. To obtain the value for LK, we sum together the computed overlay percentages for Land Uses 52, 53, 61, and 62, as shown in Figure 5-2.

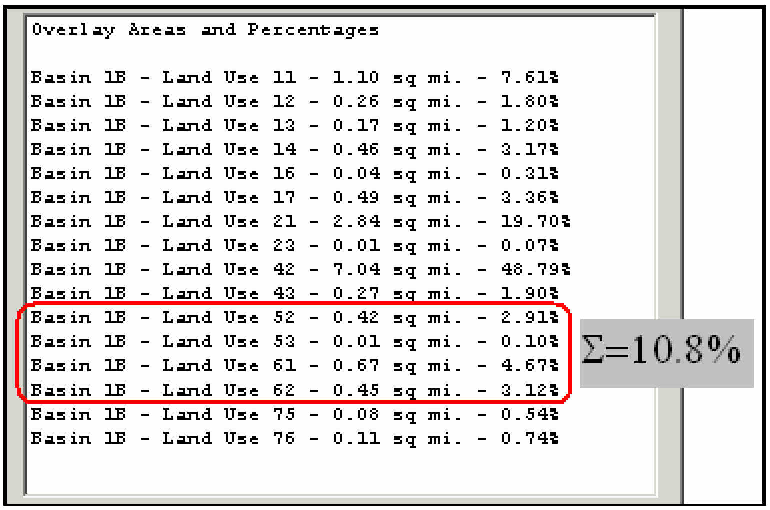


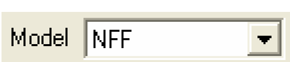
Figure 5-2: Summing the percentages of the codes representing water cover

The Coverage Overlay command can be used in a similar fashion to determine the percentage of forested areas (codes in the 40’s), or any other classification type in a land use file, or a soil file.

6. Select *Done*

6 Running NSS

The geometric data computed from the DEM has automatically been stored with the NSS data. You can now run a simulation using the derived data.



1. Make sure that the Model combo box is set to *NSS*
2. Select the *Frame* macro
3. Select the *Select Basin* tool
4. Double-click on the basin icon for Basin 1B
5. Choose *Florida* from the list of states
6. Highlight *Region B* from the list of Regional regression equations
7. Select the *Select->* button to move Region B to the Selected Equations window
8. Enter **10.8** for the Lake Area variable (you may have to scroll the Variable Values window in order to see the Lake Area variable)
9. Select the *Compute Results* button

The peak flow (Q) values are displayed in the window at the bottom of the dialog.

6.1 Exporting the Flow Data

Once flow data is computed it may be exported to a text file in the format shown in the window, along with pertinent information used in computing the peak flow values.

1. Select the *Export* button
2. Locate a directory, and define a name for the file
3. Select *Save*

The exported file can be viewed using any word processor, or inserted into a separate report document.

7 Time Computation / Lag Time Calculation

The NSS program provides a way to determine an "average" hydrograph based on the computed peak flow and a basin lag time. A dimensionless hydrograph is used to define a basin hydrograph for the watershed based on the computed peak flow.

1. Scroll down in the Results window if necessary, and select the line of text corresponding to a Recurrence [years] of 50
2. Select the *Compute Hydrograph* button
3. Select the *Compute Lag Time* - *Basin Data* button
4. Change the Method combo box to the *Custom Method* (the very last one in the list)
5. Select *OK*

The computed lag time in minutes is shown in the lag time edit field. Time of concentration equations can also be used to calculate the basin lag time. WMS will convert the time of concentration to lag time by the equation: $T_{lag} = 0.6*T_c$

6. Select the *Compute Lag Time – Basin Data* button
7. Change the Computation type combo box to *Compute Time of Concentration*
8. Change the Method combo box to the *Kerby Method for overland flow*
9. Select *OK*

Note the difference in the calculated lag time between the two methods. These two equations, along with the other available options in the Basin Time Computation calculator, can be used to estimate the lag time of the basin. Compare the results of the different equations available to best describe the characteristics of the basin.

10. Select *OK*
11. Select the *Done* button

A hydrograph icon will appear next to the basin icon for Basin 1B. You can examine the hydrograph in more detail:

12. Select the *Select Hydrograph* tool 
13. Double-click on the hydrograph icon

The hydrograph is displayed in the Graphics window.

14. Close the hydrograph plot window by clicking on the X in the upper right corner of the window
15. Select ***File* | *New***
16. Select *No*

8 Using TR-55 to Compute Tc and CN

Travel times (time of concentration, lag time, and travel time along a routing reach) are critical to performing analyses with any of the hydrologic models. You will learn of two different ways WMS can be used to compute time of concentration for a TR-55 simulation (lag times are computed in the same way):

- Runoff distances and slopes for each basin are automatically computed whenever you create watershed models from TINs or DEMs and compute basin data. These values can then be used in one of several available equations in WMS to compute lag time or time of concentration
- If you want to have a little more control (and documentation) over the lag time or time of concentration, you will use a time computation coverage to define critical flow paths. Time computation coverages contain flow path arc(s) for each sub-basin. An equation to estimate travel time is assigned to each arc and the time of concentration (or lag time) is the sum of the travel times of all arcs within a basin. Lengths are taken from the length of the arc and slopes derived if a TIN or DEM are present.

In this exercise you will compute the time of concentration for the two sub-basins and the travel time between outlet points in the watershed shown below. You will use the TR-55 library of equations, but you could just as easily use one of the other pre-defined equations, or enter your own equation.

9 Reading a TR-55 Project

You will first read in a project file of an urban area that has been processed and delineated as a single basin. The project includes a drainage coverage, a time computation coverage, and two shapefiles for the land use and soil type data.

1. Switch to the *Map* module
2. Select ***File* | *Open***
3. Locate the folder ***\Tutorials\General WMS\tr-55***
4. Open *"suburbtr55.wms"*

10 Assigning Equations to Time Computation Arcs

A flow path arc has already been defined for the basin. This arc represents the longest flow path for the urban area, starting from a sandy area at the top of the basin, following along the streets and down towards a detention pond at the bottom of the basin. The arc has been split into four different segments to assign different equations to determine the travel time for the arc. Use the following figure as a guide while defining the equations.

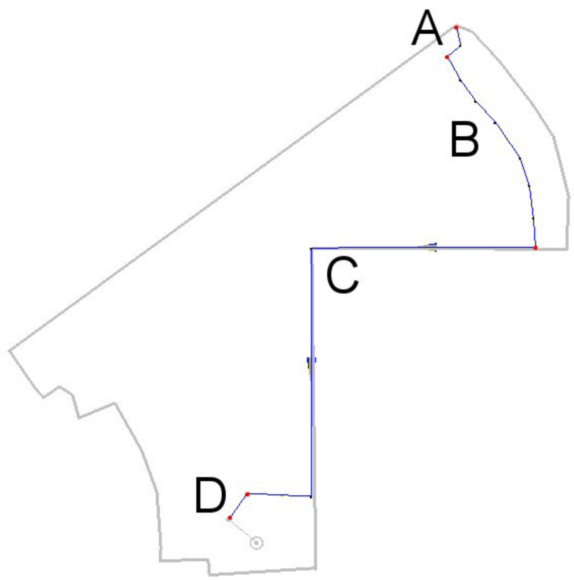
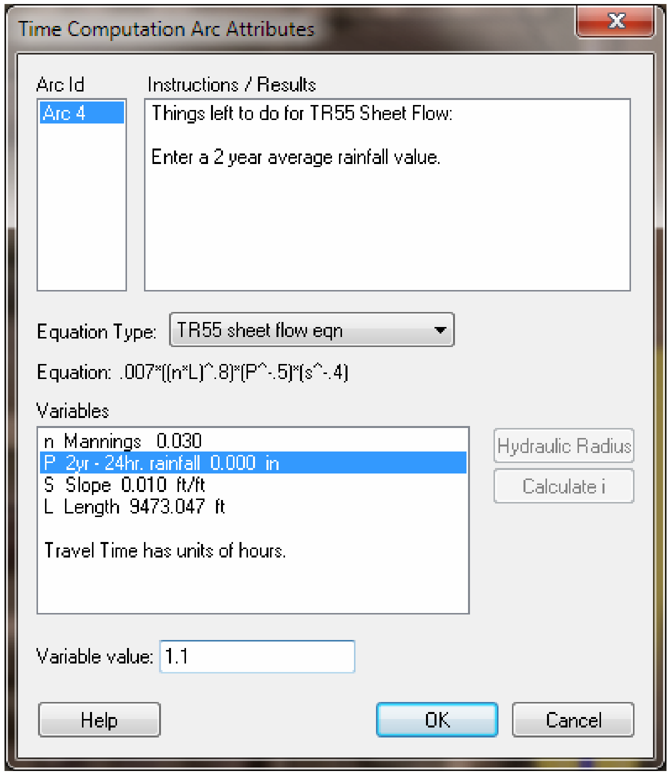


Figure 10-1: Time Computation Arcs.

1. Switch to the *Time Computation* coverage
2. Choose the *Select Feature Arc* tool 
3. Double-click on the arc labeled A in Figure 10-1

By default the arc will be a TR-55 sheet flow equation arc, so all you need to do is define the overland Manning's roughness coefficient and the 2yr-24hr rainfall. Length and slope will already be entered (from the selected arc).

4. Click on the Manning's line in the Variables text window
5. Enter a value of **0.03** in the Variable value edit window
6. Click on the 2 yr - 24 hr rainfall line in the Variables text window
7. Enter a value of **1.1**



You should notice in the Instructions/Results window that you are told what variables need to be defined before a travel time can be computed. Once you have entered all the necessary values, this same window reports the travel time for this arc. In this way, you can compute travel time for any arc segment no matter what the application is.

8. Select *OK*

You have now defined an equation for the overland sheet flow segment in the basin and you are ready to define the next segments as shallow concentrated flow.

9. Double-click on the arc labeled B in Figure 10-1
10. Change the equation type to *TR-55 shallow conc eqn*
11. Click on the Paved line in the Variables text window
12. Enter *"yes"* in the Variable value edit window
13. Select *OK*
14. Repeat for the arc labeled D, using the same equation type. In this case set the Paved value to *"no"*

The remaining arc will be defined as an open channel flow arc.

15. Double-click on the arc labeled C in Figure 10-1
16. Change the arc type to *TR-55 Open channel eqn*
17. Click on the Manning's n line
18. Enter a value of **0.017** in the Variable value edit window
19. Select the hydraulic radius line in the Variables window

20. Select the *Hydraulic Radius* button to open up the channel calculator so that the hydraulic radius can be computed from estimates of the curb in the subdivision
21. Change the Channel type to *Triangular*
22. Enter a longitudinal slope of **0.010** ft/ft
23. Enter a Side slope 1 (Z1) of **10**
24. Enter a Side slope 2 (Z2) of **0.01**
25. Choose the *Enter depth* option
26. Enter a depth of **0.5** (an approximated depth since we do not know what the flow is at this point)
27. Select the *Calculate* button
28. Select *OK* for both dialogs

You have now defined the necessary parameters for computing travel time using the TR-55 open channel flow (Manning's) equation. If you wish you can continue to experiment with the channel calculator to compute the hydraulic radius rather than entering the given values.

You now have defined equations and variable values for each flow path segment. You can change these equations and variables, add new flow path segments, etc. in order to determine the best flow paths and most appropriate equations for each basin. In other words, the process is subjective and it may take a few iterations to get the best value.

11 Computing Time of Concentration for a TR-55 Simulation

Before assigning time of concentrations to each basin you need to decide which model you want to use. For this exercise you will be running TR-55, but the same time computation tools you learn in this exercise could be used for any of the supported WMS models (such as in the TR-20 basin data dialog, the HEC-1 Unit Hydrograph method dialog, and the Rational Method dialog).

1. Select the *Hydrologic Modeling* module 
2. Change the Model drop-down list to *TR-55*
3. Select the *Select Basin* tool 
4. Select the basin
5. Select ***TR-55 | Run Simulation***

In the TR-55 dialog, notice the two drop-down boxes at the top. These provide the ability of changing TR-55 information for basins and outlets individually or collectively.

6. Enter a Rainfall value of **1.5**
7. Change the Rainfall distribution to *Type II*
8. Select the *Compute Tc - Map Data* button. You will see the four time computation arcs that are in the basin

9. You can create a detailed report as a text file if you want by selecting the *Export Data* or *Copy to Clipboard* buttons
10. Select *Done*
11. Select *OK*

The sum of the travel times for these arcs will be used as the time of concentration for this basin

Note that you could bring up the time computation attributes dialog and change the equation or any of the equation variables by selecting the *Edit Arcs* button.

12 Computing a Composite Curve Number

In this part of the exercise, you will learn how to overlay land use and soil coverages on your delineated watershed in order to derive a curve number (CN).

12.1 Land Use Table

Now you need to create a land use table with IDs and CNs for each type of land use on your map. A table has been provided, but it is incomplete. To finish the table with all of the IDs and CNs for the shapefiles in the project, or just to edit the table in general, complete the following steps:

1. Select ***File | Edit File***
2. Open *landuse.tbl*
3. If prompted, choose a text editor to edit the file with, by choosing Notepad or another favorite editor in the Open With drop down list, and select *OK*

In the text editor, you will find three lines of text listing three IDs along with their CN values. The file format for this file is an ID value, followed by a comma, the name of the land use ID in quotation marks, followed by a comma, followed by the comma separated CN values for soil types A, B, C, and D, respectively. This file includes CN values for landuse types “Transportation, Communications”, “Other Urban or Built-Up Land”, and “Bare Ground”. The landuse shapefile in this project also contains landuse polygons for residential areas, with an ID for 11. Complete the land use table by editing the file:

4. Add the following line to the file: *11, "Residential", 61, 75, 83, 87*
5. Save the file and close the editor

12.2 Computing Composite Curve Numbers

In order to compute composite curve numbers, WMS needs to know which type of soil underlies each area of land. You will need either a landuse and soil type coverage, or a landuse and soil type shapefile with the appropriate fields. For this exercise, we will be using landuse and soil type shapefiles.

1. Select ***Calculators | Compute GIS Attributes***
2. Make sure the *SCS Curve Numbers* option is selected in the Computation section of the dialog

3. Select *GIS Layers* in the Using section of the dialog
4. Select the Soil Layer Name to be *soils_poly.shp*
5. Make sure the Soil Group Field has been set to *HYDGRP*
6. Select the Land Use Layer Name to be *landuse_poly.shp*
7. Make sure the Land Use ID Field has been set to *LU_CODE*

You may have your land use and soil type tables stored in data files, such as the one you previously edited. Instead of manually assigning the data as you have here, you would read these tables in from this dialog using the Import button.

Whether you have manually created tables or read them in from files, you should see the land use IDs and CNs for each soil type, and land use descriptions in the window of the Mapping section.

8. Select the *Import* button near the bottom of the dialog
9. Find and open the mapping table *"landuse.tbl"*

You should now see the assignment of CN values for the land use table previously edited.

10. Select *OK* to compute the composite CNs

A Runoff Curve Number Report is generated and opened automatically. The composite curve number appears at the bottom of the report.

11. Select the *Select Basin* tool 
12. Double-click on the basin

Notice that the Curve number edit field has been updated with the calculated value from the Compute GIS Attributes dialog.

13 More TR-55

While you were entering the data for the basin you may have noticed that instructions are given in the TR-55 data window to let you know what must be entered before a peak Q can be determined. Once you enter all of the data the peak Q is computed and displayed in the same window. You can also get help for anything listed in the window.

1. Notice that the TR-55 reference equation for computing peak flow is displayed next to Peak Discharge
2. Select the *Compute Hydrograph(s)* button
3. Select *OK* to close the TR-55 dialog
4. Choose the *Select Hydrograph* tool 
5. Double-click on the hydrograph icon that is displayed by the upper basin to view the hydrograph in a separate window

14 Conclusion

This completes the chapter on using the time computation coverage to compute time of concentration and travel times and the land use and soil coverage to compute a composite CN value. In the process you have also learned about the TR-55 interface.

