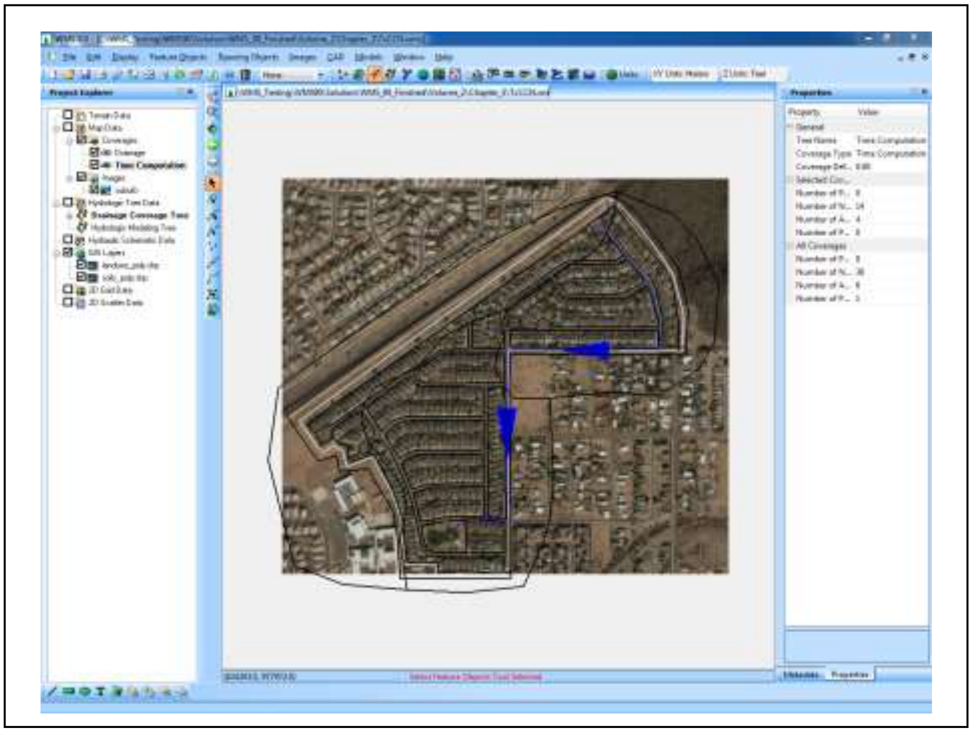
v. 10.0

WMS 10.0 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 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 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.

2 Opening the Drainage Basin

First users 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. In the *Open* dialog, locate the "nss" folder in the files for this tutorial. If needed, download the tutorial files from www.aquaveo.com.
6. Open "NSS_FL.wms". The image will appear in the Main Graphics Window.

3 Prepare the Basin for Use with NSS

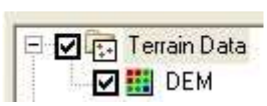
Users will now use WMS to calculate the basin area, basin slope, and other parameters that can be used in conjunction with NSS.

1. Select *DEM* **| Compute Basin Data.**
2. In the *Units* dialog, select the **Current Projection...** button.
3. The *Display Projection* dialog will appear. Set the *Vertical units* to “Meters”.
4. Select **Set Projection**.
5. In the *Select Projection* dialog, select “METERS” in the *Planar Units* Field.
6. Select **OK** to close the *Select Projection* dialog.
7. Select **OK** to close the *Display Projection* dialog.
8. Back in the *Units* dialog, 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, users can turn them on for display.

11. Select *Display* **| Display Options** .
12. In the *Display Options* dialog, select “Drainage Data” from the menu on the right.
13. Make sure *Basin Slopes* is toggled on. (*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.

The screen should now look like Figure 1.

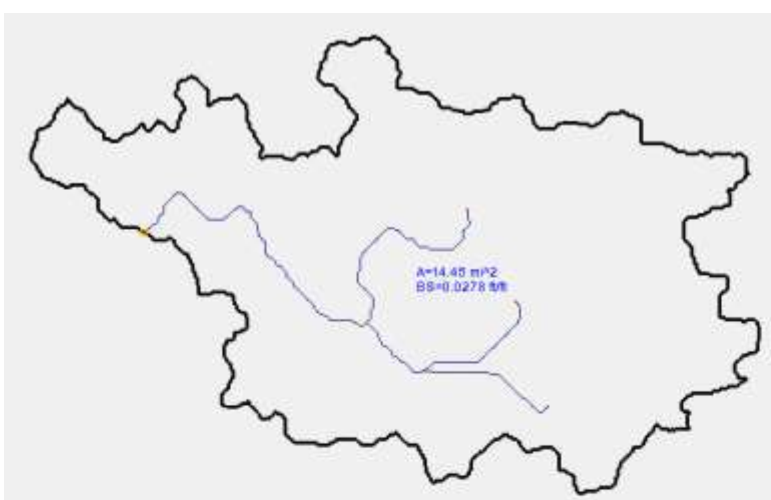


Figure 1   Drainage basin with parameters computed

4 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). Users will use the Compute Coverage Overlay calculator in WMS to calculate the percentage of lake cover in the 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.

4.1 Opening the Land Use Coverage

In order to compute the percentage of lake cover in the watershed, users 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. Users 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. In the *Properties* dialog box, change the coverage type to “Land Use”.
4. Select **OK.**
5. Right-click on “GIS Data” in the Project Explorer and select **Add Shapefile Data**.
6. The *Select Shapefile* dialog will appear. Open “valdosta.shp” and make it the active layer by clicking on it in the Project Explorer.

This land use shapefile was obtained from www.webgis.com, but the EPA and other websites contain similar information. Alternatively, users 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. In the *GIS to Feature Objects Wizard* dialog, select **Next**.
11. The LUCODE with the land use ID is automatically mapped so users can continue by selecting **Next**.
12. Select **Finish.**

13. Hide “valdosta.shp” by toggling off its check box in the Project Explorer (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.

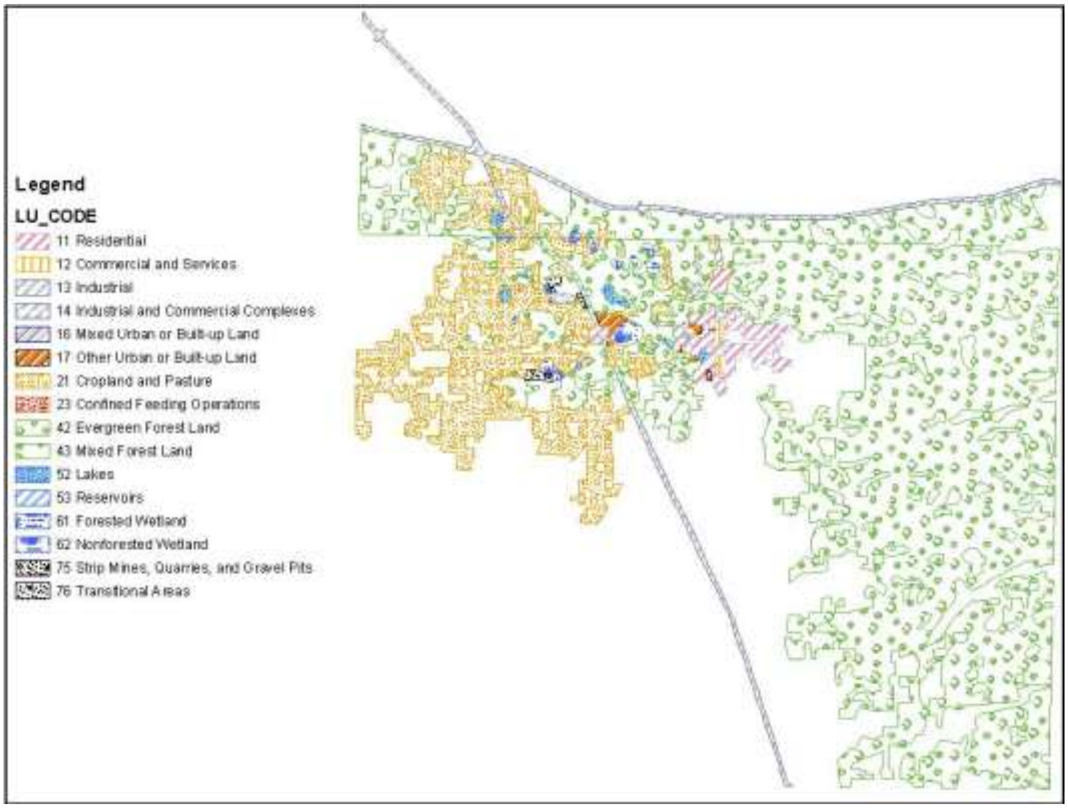
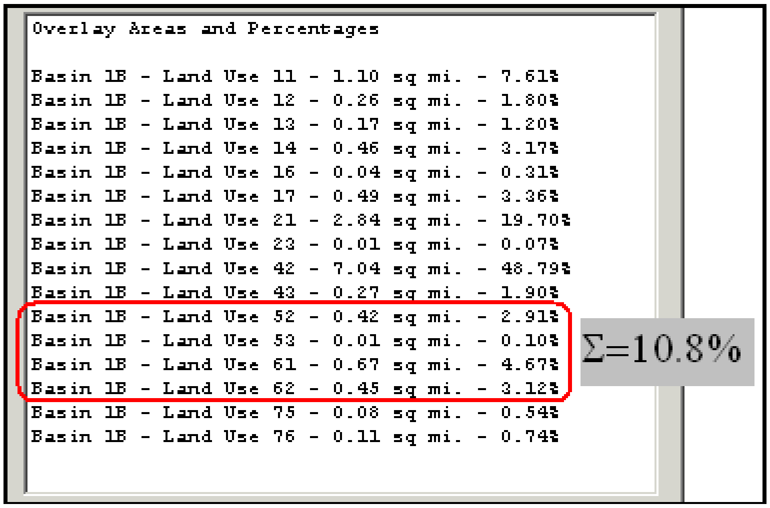


Figure 2 Land use codes used in Valdosta.shp.

4.2 Using the Compute Coverage Overlay Calculator

1. Switch to the **Hydrologic Modeling** module.
2. Select *Calculators* **| Compute Coverage Overlay**.
3. The *Coverage Overlay* dialog will appear. 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, sum together the computed overlay percentages for Land Uses 52, 53, 61, and 62, as shown in Figure .


Overlay Areas and Percentages

Basin 1B - Land Use 11 - 1.10 sq mi. - 7.61%
Basin 1B - Land Use 12 - 0.26 sq mi. - 1.80%
Basin 1B - Land Use 13 - 0.17 sq mi. - 1.20%
Basin 1B - Land Use 14 - 0.46 sq mi. - 3.17%
Basin 1B - Land Use 16 - 0.04 sq mi. - 0.31%
Basin 1B - Land Use 17 - 0.49 sq mi. - 3.36%
Basin 1B - Land Use 21 - 2.84 sq mi. - 19.70%
Basin 1B - Land Use 23 - 0.01 sq mi. - 0.07%
Basin 1B - Land Use 42 - 7.04 sq mi. - 48.79%
Basin 1B - Land Use 43 - 0.27 sq mi. - 1.90%
Basin 1B - Land Use 52 - 0.42 sq mi. - 2.91%
Basin 1B - Land Use 53 - 0.01 sq mi. - 0.10%
Basin 1B - Land Use 61 - 0.67 sq mi. - 4.67%
Basin 1B - Land Use 62 - 0.45 sq mi. - 3.12%
Basin 1B - Land Use 75 - 0.08 sq mi. - 0.54%
Basin 1B - Land Use 76 - 0.11 sq mi. - 0.74%

Figure 3 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**.

5 Running NSS

The geometric data computed from the DEM has automatically been stored with the NSS data. Users 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. It may be small, so zoom if necessary.
5. The *National Streamflow Statistics Method* dialog will appear. Choose “Florida” from the list of states.
6. Highlight “Rural Region 2 2011 5034” 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 *Percent Storage from NLCD1992* variable (users may have to make the window larger in order to see the Percent Storage variable).
9. Select the **Compute Results** button.

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

5.1 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. A dialog box will appear titled *Select the file name for the spreadsheet export file.* Locate a directory, and define a name for the file.
3. Select **Save.** The window will close. Do not close the *National Streamflow Statistics Method* dialog.

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

6 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. A *NSS Hydrograph Data* dialog will appear. Select the **Compute Lag Time - Basin Data** button.
4. A *Basin Time Computation* dialog will appear. 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.** The *NSS Hydrograph Data* dialog will disappear.
11. Select the **Done** button.

A hydrograph icon will appear next to the basin icon for Basin 1B. Users 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, in a *Hydrograph* dialog box.

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** if asked to make changes.

7 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. Users 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 users 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 users want to have a little more control (and documentation) over the lag time or time of concentration, users 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 users will compute the time of concentration for the two sub-basins and the travel time between outlet points in the watershed shown below. Users will use the TR-55 library of equations, but users could just as easily use one of the other pre-defined equations, or enter their own equation.

8 Reading a TR-55 Project

Users 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. In the *Open* dialog, locate the “tr-55” folder in the files for this tutorial. If needed, download the tutorial files from www.aquaveo.com.
4. Open “suburbtr55.wms”.

9 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.

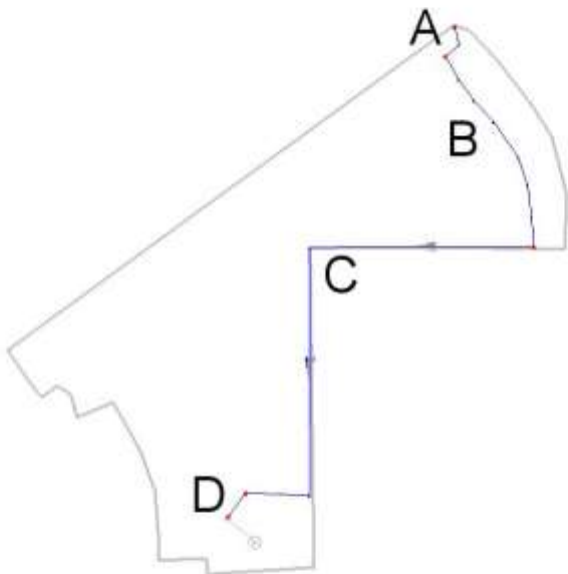


Figure 4 Time Computation Arcs.

1. Switch to the “Time Computation” coverage in the Project Explorer.
2. Choose the **Select Feature Arc**  tool.
3. Double-click on the arc labeled A in Figure . A *Time Computation Arc Attributes* dialog will appear.

By default the arc will be a TR-55 sheet flow equation arc, so all users 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” in the *Variables value* edit box.

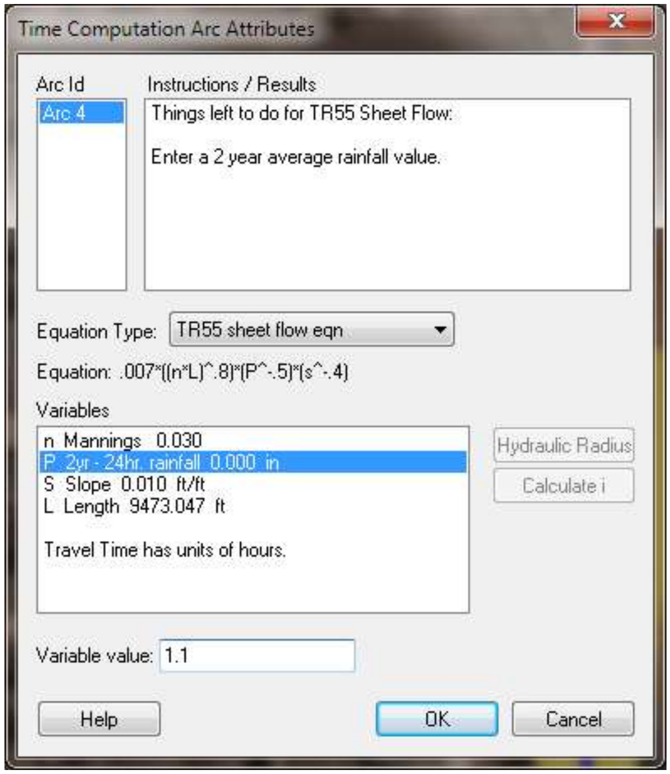


Figure 5 Time Computation Arc Attributes Dialog

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

8. Select **OK**.

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

9. Double-click on the arc labeled B in Figure . The *Time Computation Arc Attributes* dialog will reappear.
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 . The *Time Computation Arc Attributes* dialog will reappear.
16. Change the *equation type* to "TR-55 Open channel eqn".
17. Click on the "Manning's" line in the *Variables* text window.

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 WMS channel calculations window so that the hydraulic radius can be computed from estimates of the curb in the subdivision.
21. A new *Channel Calculations* dialog will have appeared. Select the **Launch Channel Calculator** button to launch the Hydraulic Toolbox Channel Calculator.
22. The *Channel Analysis* dialog should pop up. Change the Channel *type* to “Triangular”.
23. Enter a *Side slope 1 (Z1)* of “10”.
24. Enter a *Side slope 2 (Z2)* of “0.01”.
25. Enter a *longitudinal slope* of “0.010” ft/ft.
26. Choose the *Enter depth* option.
27. Enter a depth of “0.5” (an approximated depth since users do not know what the flow is at this point).
28. Select the *Calculate* button.
29. Select **OK** for all three dialogs.

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

Users now have defined equations and variable values for each flow path segment. Users 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.

10 Computing Time of Concentration for a TR-55 Simulation

Before assigning time of concentrations to each basin users need to decide which model they want to use. For this exercise users will be running TR-55, but the same time computation tools users 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 by clicking on it. Don’t double-click.
5. Select *TR-55* **| Run Simulation.** A *TR-55* dialog will open.

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. In the *Travel Time Computation* dialog that pops up, users will see the four time computation arcs that are in the basin.
9. Users can create a detailed report as a text file if they want by selecting the **Export Data** or **Copy to Clipboard** buttons.
10. Select **Done.**
11. Back in the *TR-55* dialog, select **OK.**

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

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

11 Computing a Composite Curve Number

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

11.1 Land Use Table

Now users need to create a land use table with IDs and CNs for each type of land use on their 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. In the *Open* dialog, 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, users 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 by clicking *File* **| Save** and close the editor by clicking the x at the top of the *Notepad* window.

11.2 Computing Composite Curve Numbers

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

1. Select *Calculators* **| Compute GIS Attributes.** This will open a *Compute GIS Attributes* dialog.
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".

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

Whether users have manually created tables or read them in from files, they 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. In the *Open* dialog, find and open the mapping table "landuse.tbl".

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

10. Select **OK** to compute the composite CNs. If needed, select **OK** to open the Notebook or another text editor, then save and close the word processor as users did in step 5 of section 11.1.

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.

12 More TR-55

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

13 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 users have also learned about the TR-55 interface.