NRCS Hydro
A GIS-Based Hydrologic Modeling Tool

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Abstract

The NRCS Hydro have developed input file (from GIS data) for the Natural Resources Conservation Service **WinTR-20** hydrologic model. Required GIS layers include Digital Elevation, soil data, land use, and stream data.

The WinTR-20 computer program is used in NRCS to estimate peak discharge and runoff volume from watersheds for use in designing water control structures and in determining impacts of changing land use on the hydrologic system.

NRCS Hydro automates the process used in a typical watershed hydrologic analysis. The major procedures include:

1. Delineate the watershed boundary.
2. Subdivide the watershed into sub-areas based on watershed heterogeneity and locations where peak discharges and/or hydrographs are desired within the watershed.
3. Estimate hydrologic parameters for each sub-area. Estimate length and cross section rating tables for channel routing reaches.

Steps in these procedures have been automated to take advantage of geographic and hydrologic data and efficient GIS processing capabilities.

Introduction

Vast amounts of GIS data are being made available for public use in the United States. Standard data needed for hydrologic modeling are now available. NRCS Hydro is an ArcView Geographic Information System (GIS) interface for the Natural

Resources Conservation Service (NRCS) **WinTR-20** hydrologic model developed by National Water and Climate Center (NWCC) and the National Cartographic and Geospatial Center (NCGC). The NRCS WinTR-20 computer program is used to estimate watershed peak discharge and surface water runoff associated with single storm events for use in designing water control structures and in determining impacts of changing land use on the hydrologic system. WinTR-20 is a version of the NRCS TR-20 model that operates in the Windows environment.

NRCS Hydro is based upon the ArcView GIS program from Environmental Systems Research Institute (ESRI). The following software requirements are necessary to operate NRCS Hydro: ArcView GIS Version 3.2 or 3.3, ArcView Spatial Analyst Extension version 1.1 or greater, NRCS Hydro ArcView project file and databases. Even though the system is point-and-click, basic familiarity with GIS operations and hydrologic analysis are recommended.

Use of NRCS Hydro has three parts. These are: prepare the data, use NRCS Hydro to get a first WinTR-20 run, and use WinTR-20 Controller/Editor to make refinements, calibrate, run alternatives, etc.

NRCS Hydro is designed to follow the general steps in conducting a watershed hydrologic analysis. These are:

A. Locate the design point based on stream/road crossing.
B. Determine the extent of the watershed draining to the outlet point. Delineate the watershed boundary. Determine rainfall frequency data for the watershed location.
C. Subdivide the watershed into sub-areas based on watershed heterogeneity and locations where peak discharges and/or hydrographs are desired within the watershed.
D. Select method for calculating the Time of Concentration (NRCS Lag Equation or Velocity Method).
E. Enter hydraulic geometry channel depth and width coefficients (or use default values).
F. Estimate hydrologic parameters such as area, runoff curve number, and time of concentration for each sub-area. Estimate length and cross section rating tables for channel routing reaches.
G. Assemble model input and develop WinTR-20 model schematic.
H. Format model input for WinTR-20, execute the model, and view results.

NRCS Hydro is available for no charge over the internet. The web site address is www.wcc.nrcs.usda.gov/hydro/nrcs-hydro.html. NRCS Hydro and WinTR-20 systems have comprehensive user guides, training material, example data, and other technical documentation. A fact sheet, user guide, or entire package may be downloaded. The User Guide has detailed instructions on setup and installation. Two directories need to be placed on the C: drive and a system environment variable

needs to be set. NRCS Hydro is an ArcView project file (with .prj extension in the file name). The menus and tools are ArcView Avenue scripts.

Background

NRCS Hydro is based on GIS Hydro 2000 which was developed by Dr. Glenn Moglen of the University of Maryland. GIS Hydro 2000 is operable anywhere within the state of Maryland (all GIS data are included in the system). NRCS wanted to develop an interface which could be used anywhere that GIS data are available.

Data Acquisition

GIS layers that need to be developed by the user for import into the interface include Digital Elevation Model (DEM), land use, and hydrologic soil group. A stream location layer such as available from the USGS National Hydrographic Dataset (NHD) is optional but recommended. The user may also import any other layers that would be useful in locating a watershed such as political boundaries, roads, etc. Some of these optional layers include Digital Line Graphs (DLG), TIGER (Topologically Integrated Geographic Encoding and Referencing system) data, Hydrologic Unit Code (HUC) maps, etc.   These data are available for much of the United States through the NRCS Geospatial Data Gateway and other sources.

Data Preparation

A Data Preparation Guide was written to guide the user through the process of obtaining GIS data and organizing it for use in NRCS Hydro. Though GIS data are available from many sources, the Geospatial Data Gateway (the web site is http://datagateway.nrcs.usda.gov .) is the featured data source for DEM (USGS National Elevation Dataset, NED), land use (USGS land use land cover), soil (NRCS Soil Survey Geographic database, SSURGO), and TIGER data (roads, political boundaries, etc). The National Hydrographic Dataset (NHD) is available from a USGS web site (http://nhd.usgs.gov) and Geospatial Data Gateway. The preparation of DEM, land use, NHD, and TIGER data is straightforward in that the data need only be projected to a common projection (UTM recommended) and converted to units of feet. The required cell size for DEM grid is 98.425 feet (equivalent to 30 meters). Each land use type needs to be assigned a set of runoff curve numbers (CN). A text file has been prepared to assign the standard USGS land uses for good, fair, and poor hydrologic condition for hydrologic soil groups A, B, C, and D. Standard NRCS CN values are included in NRCS TR-55 documentation. If other land use data are used, a similar set of tables needs to be developed. Preparing the hydrologic soil group (HSG) layer is somewhat more complicated. The soil data layers from SSURGO are shape files based on soil mapping unit. The hydrologic soil group is an attribute of the soil mapping unit (each soil mapping unit is assigned a particular hydrologic soil

group: A, B, C, or D). A shape file of the hydrologic soil group needs to be created then converted to a grid or raster layer. The required cell size for land use and hydrologic soil group grids is 98.425 feet (equivalent to 30 meters). ArcGIS (8.x or 9) with the Spatial Analyst extension or Arc View 3.x with Spatial Analyst and XTools extensions are recommended for data preparation. Hydraulic geometry relationships are used to estimate channel depth and width based on the drainage area at a particular location. Default values are included for various locations in the United States. If these defaults are not appropriate for the watershed being analyzed, a guide was prepared that describes how the relationships may be derived from measurements of channel depth and width.

Interface Operation

NRCS Hydro is organized to automate the process used in a typical watershed hydrologic analysis. Its operation is grouped into a series of menus, buttons, and tools that are designed to be used in a sequential manner. Further refining or use of advanced **WinTR-20** options may then be accomplished through the use of the **WinTR-20** Controller/Editor.

Once data are prepared, elementary knowledge of ArcView is required. The User Guide has complete descriptions of all ArcView operations used as well as example applications.

The first steps are to open the NRCS Hydro ArcView project file and add DEM, land use, hydrologic soil group, NHD, and optional themes. If the area covered by GIS data is much larger than the watershed to be analyzed, a rectangular area may be cut out for more efficient operation. The next step is to process the DEM (fill sinks, flow direction, flow accumulation), develop a curve number theme from land use and HSG layers, and develop a stream location grid theme based on the NHD streams and DEM flow accumulation.

A table of rainfall frequency (2-year to 100-year 24 hour values) may be accessed to automatically add these to the analysis. The user need only select state and county from the database that includes data for 38 states. Two methods are available for calculation of time of concentration (TC). They are the NRCS lag equation (TC based on longest flow path, sub-area CN, and average sub-area slope) and NRCS velocity method (TC based on sum of sheet flow, shallow concentrated flow, and channel flow travel times). A menu selection allows the user to accept default channel geometry coefficients or enter alternative values.

Interface Menus and Tool buttons

The NRCS Hydro interface is a set functions or utilities; it is grouped by functions into three menus and five tool buttons.

Three menus are:

- Hydro Pre-Processing: Functions mostly used once in order to prepare all the GIS data required by the project. They are dealing with Pre-Process DEM, land use and soil data.
- Watershed Processing: Functions used to assemble input file for the WinTR-20 model. They are dealing with subwatershed delineation, and watershed characteristic determination.
- Win TR-20 Interface: They are Control Panel and then Execute the WinTR-20 model.

Control Panel

The Control Panel dialog box allows the user to select an input and output file name and various input and output options. The Antecedent Runoff Condition (ARC) may be selected at condition 1 (dry), 2, (normal), or 3 (wet) prior to the storm. If the user Loads NRCS Storm Data, the design storm type is placed in the Design Storm Type data box. If the Load NRCS Storm Data option was selected earlier, the 24-hour rainfall frequency data appear in the rainfall data box (otherwise default rainfall values appear). These may be edited. The user may then select storm events for which simulations are desired.

Execute WinTR-20

The Execute WinTR-20 menu item allows the user to execute **WinTR-20** model that will generate the output file for evaluation. If there are errors, the error file is opened. WinTR-20 sub-area number and reach number may be shown on the watershed map which then allows correlation of output with locations within the watershed.
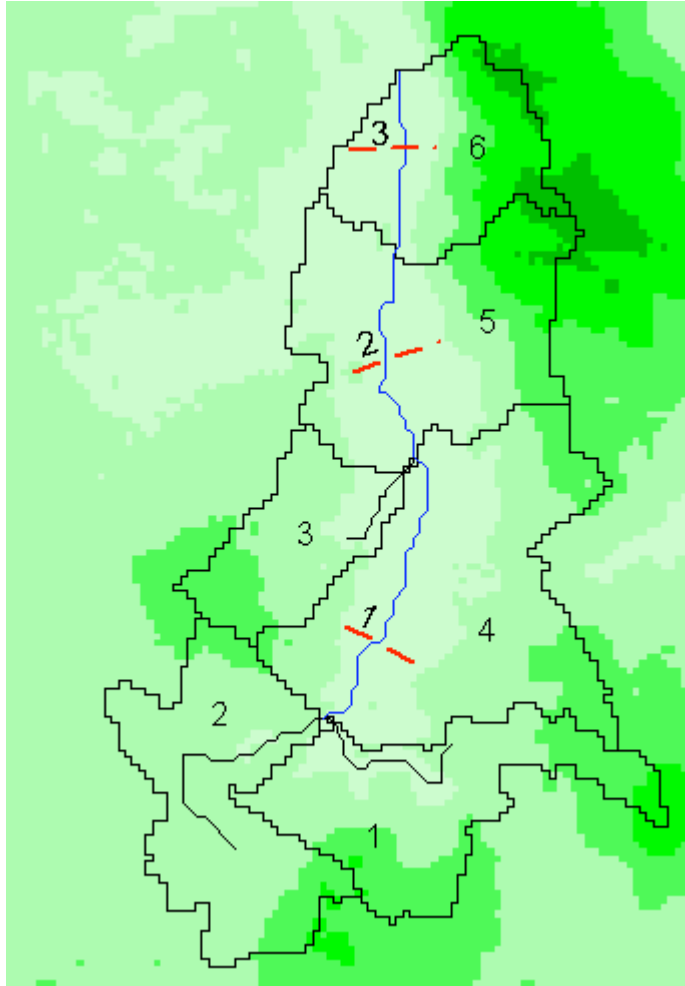
Figure 1.   Example watershed map

Figure 1 shows an example of a watershed boundary map overlaying a DEM.
WinTR-20 sub-area numbers (1 to 6) and reach numbers (1 to 3) associated with
each cross section location are displayed.

Watershed Tool   W

The Watershed Tool is used to delineate the watershed draining to a user-defined
outlet point. It is necessary that the outlet be placed directly on the raster channel
network. The watershed may be divided into sub-areas using the Add Streams and
Add Outlets Tools.

Add Streams Tool   S

Use the Add Streams Tool to select which streams will be used to define the WinTR-
20 model stream network. Each stream junction will define where sub-areas are to be
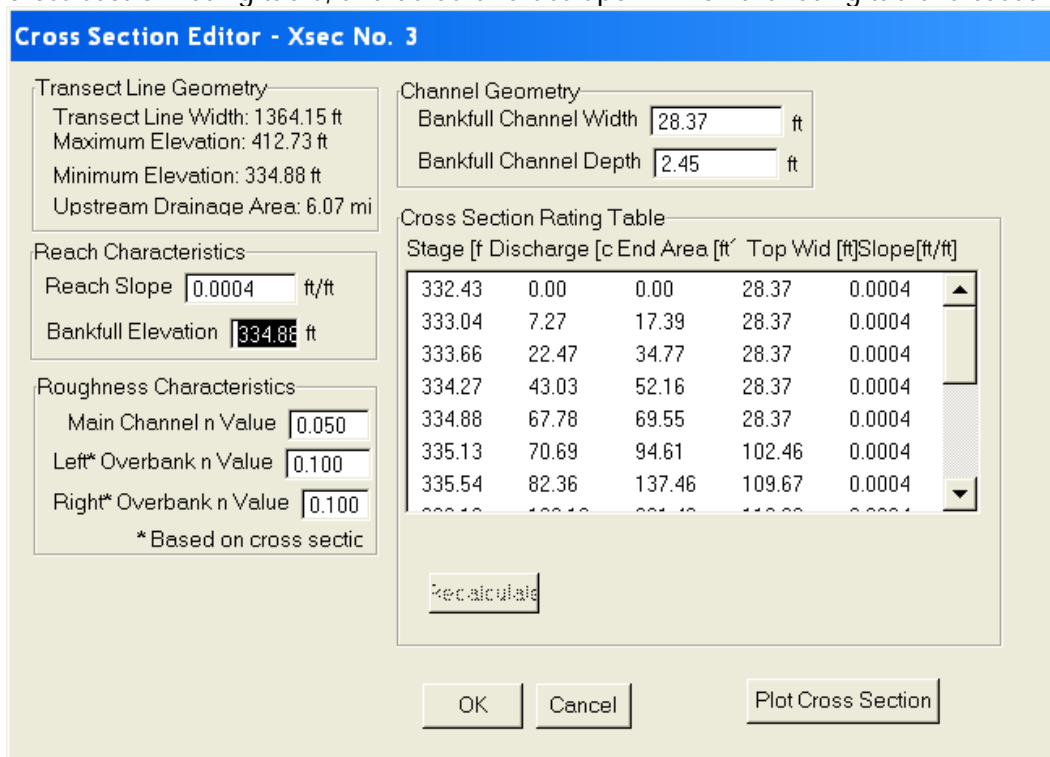
defined. Select the tool from the toolbar and click on the upstream raster of each stream. An upper limit of 30 streams may be added using this tool.

Add Outlets Tool   [O]

Use the Add Outlets Tool to indicate additional sub-area outlet points on the channel network which are not at stream confluences. Select the tool from the toolbar and click on the desired points on the raster channel network.

Add Cross Section Tool.   [X.]

Use the Add Cross Section Tool to indicate cross section transect lines for stream segments to be used as channel routing reaches. Click on the Add Cross Sections tool and draw a transect line perpendicular to a stream segment. The **Cross Section Editor** dialog window (see figure 2) will contain data developed from the DEM, a cross section rating table, and default values upon which the rating table is based.

Cross Section Editor - Xsec No. 3

Transect Line Geometry
Transect Line Width: 1364.15 ft
Maximum Elevation: 412.73 ft
Minimum Elevation: 334.88 ft
Upstream Drainage Area: 6.07 mi

Reach Characteristics
Reach Slope 0.0004 ft/ft
Bankfull Elevation 334.88 ft

Roughness Characteristics
Main Channel n Value 0.050
Left* Overbank n Value 0.100
Right* Overbank n Value 0.100
* Based on cross sectic

Channel Geometry
Bankfull Channel Width 28.37 ft
Bankfull Channel Depth 2.45 ft

Cross Section Rating Table

Stage [f	Discharge [c	End Area [ft´	Top Wid [ft]	Slope[ft/ft]
332.43	0.00	0.00	28.37	0.0004
333.04	7.27	17.39	28.37	0.0004
333.66	22.47	34.77	28.37	0.0004
334.27	43.03	52.16	28.37	0.0004
334.88	67.78	69.55	28.37	0.0004
335.13	70.69	94.61	102.46	0.0004
335.54	82.36	137.46	109.67	0.0004

Recalculate

OK   Cancel   Plot Cross Section

Figure 2.   Example Cross Section Editor dialog window

 The user may revise the slope, channel width, channel depth, and Manning n if these values do not represent the characteristics of the location. The cross section rating table includes a relationship of elevation, discharge, flow area, top width, and slope for that transect location. A plot of the cross section transect developed from the DEM may be viewed by clicking the Plot button (see Figure 3). If a cross section is not satisfactory, it may be re-drawn at another location.
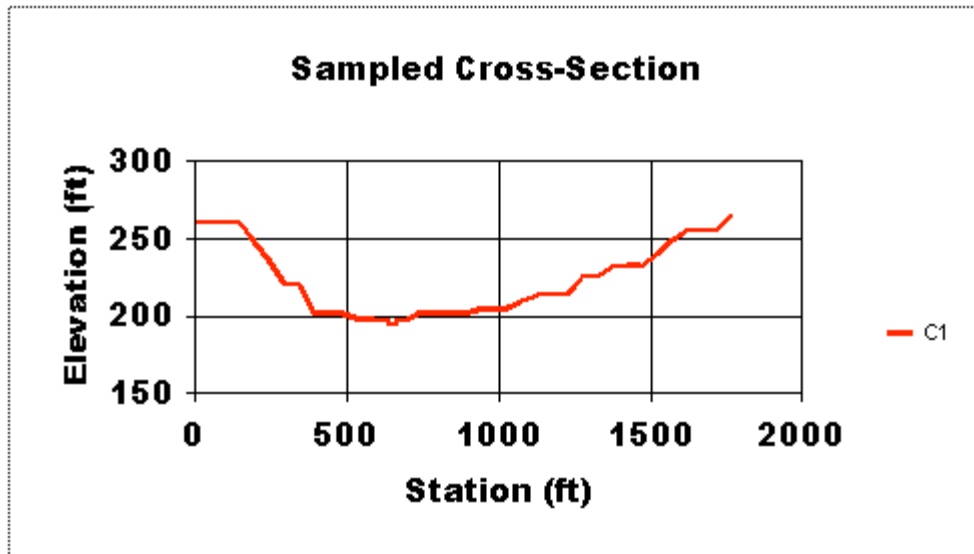
Figure 3.   Example Cross Section Plot

Edit Cross Section Tool   [XE]

This allows re-open the **Cross Section Editor** dialog Window after a cross section has been drawn and accepted, and revise any information (such as Manning n, channel width, etc).

Make Further Analyses using WinTR-20 Controller/Editor

For more WinTR-20 options (such as changing dimensionless unit hydrograph, rainfall distribution, adding reservoirs, etc.) the input data developed from GIS may be imported into the WinTR-20 interface. Use of the WinTR-20 interface allows for display of hydrograph plots (see Figure 4) and other graphics.
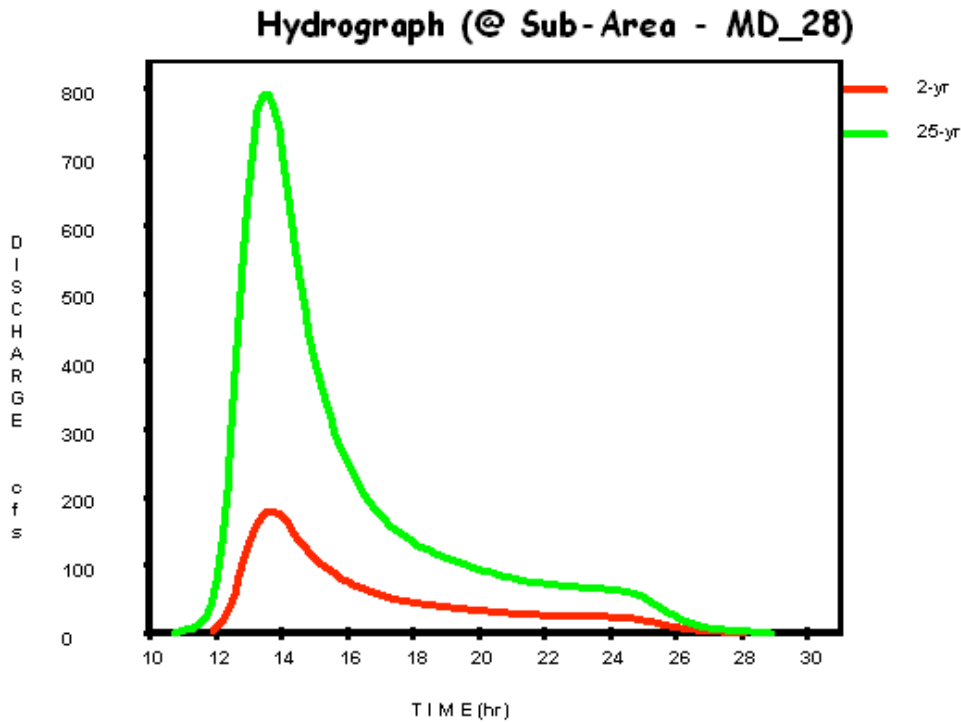
Figure 4.   Example WinTR-20 Hydrograph Plot

Summary

NRCS Hydro has proved to be very robust. Naturally, output quality will be directly related to input quality. Some major limitations in the use of the interface are in areas of flat terrain, karst topography, glacial potholes, alluvial fans, and man-made or natural levees. A dendritic drainage pattern is developed from the DEM and stream layer; no diversions or islands are determined. It is a simplified system yet completes the standard NRCS hydrologic modeling steps. It has been designed for use by practicing engineers and required a basic level of GIS and hydrology expertise. Development of an equivalent interface in ArcGIS 9 is underway. It is being designed to utilize detailed topographic data such as LIDAR (Light Detection And Ranging) data.

References

Moglen, G., (2004), GIS Hydro 2000. Web site: www.gishydro.umd.edu

USDA-NRCS (1986). Technical Release 55: Urban Hydrology for Small Watersheds, Second Edition, U.S. Government Printing Office.

USDA-NRCS (2004), WinTR-20, Watershed Hydrologic Model. Web site: www.wcc.nrcs.usda.gov/hydro/hydro-tools-models.html

USDA-NRCS (2004), Hydrology, National Engineering Handbook, Part 630. Web site: www.wcc.nrcs.usda.gov/hydro/hydro-techref-neh.html