NRCS GEO-HYDRO – HYDROLOGIC MODEL GIS INTERFACE

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Abstract

The NRCS Geo-Hydro system will develop input for the Natural Resources Conservation Service (NRCS) WinTR-20 hydrologic model from GIS data. Required GIS layers which need to be developed by the user for import to the interface include elevation, land use, and hydrologic soil group. A stream location layer is optional but recommended. The user may also import any other layers which would be useful in locating a watershed such as political boundaries, roads, etc. These data are available for much of the United States through the NRCS Geospatial Data Gateway and other sources.

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

NRCS Geo-Hydro is based upon the ArcView GIS program from Environmental Systems Research Institute (ESRI). The following software requirements are necessary to operate NRCS Geo-Hydro: ArcView GIS Version 3.2 or 3.3, ArcView Spatial Analyst Extension version 1.1 or greater, NRCS Geo-Hydro ArcView project and databases. Even though the system is point-and-click, basic familiarity with GIS operations and hydrologic analysis is recommended. NRCS Geo-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 which 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. NRCS Geo-Hydro and WinTR-20 systems have comprehensive user guides, training material, example data, and other technical documentation. Development of an equivalent interface in ArcGIS 9 is underway.

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. The NRCS WinTR-20 hydrologic model (USDA-NRCS, 2005) requires analysis of geographic data to derive much of the input data. NRCS Geo-Hydro is an interface which will now automatically develop a large part of the required data. This greatly improves the efficiency of hydrologic modeling when compared to previous manual procedures.

NRCS Geo-Hydro is available at www.wcc.nrcs.usda.gov/hydro/nrcs-geo-hydro.html. 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 Geo-Hydro is an ArcView project file

(with .prj extension in the file name). The menus and tools are driven by ArcView Avenue scripts.

Use of NRCS Geo-Hydro has three parts. These are: prepare the data, use NRCS Geo-Hydro to get a first WinTR-20 run, and use WinTR-20 Controller/Editor to make refinements, calibrate, run alternatives, etc. NRCS Geo-Hydro is designed to follow the general steps in conducting a watershed hydrologic analysis. These are:

A. Locate the design point/watershed outlet based on stream network.
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; the NRCS Lag Equation (USDA-NRCS, 1972) or Velocity Method (USDA-NRCS, 1986).
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.

BACKGROUND

NRCS Geo-Hydro is based on GISHydro2000 (Moglen, 2005). GISHydro2000 is operable anywhere within the state of Maryland (all GIS data are included in the system). The NRCS wanted to develop an interface which could be used anywhere the GIS data are available.

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 Geo-Hydro. Though GIS data are available from many sources, the NRCS Geospatial Data Gateway (USDA-NRCS, 2003) is the featured data source. The United States Geological Survey Digital Elevation Model (USGS, 2003), land use, detailed soil SSURGO (USDA-NRCS, 2004), general soil STATSGO (USDA-NRCS, 1995), and TIGER data (US Census Bureau, 2002) are available. The National Hydrography Dataset (NHD) is available from a USGS web site (USGS, 2005) and the NRCS 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 all grid layers 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 CN to 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 (USDA-NRCS, 1986) 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 original soil data layers (SSURGO and STATSGO) 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. ArcGIS (8.x or 9) with the Spatial Analyst extension and Arc View 3.x with Spatial Analyst and XTools extensions are recommended for data preparation. Since the resolution of 98.425 feet is used, channel depth and width are difficult to determine from the DEM. 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 which describes how the relationships may be derived from measurements of channel depth and width.

INTERFACE OPERATION

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

The first steps are to open the NRCS Geo-Hydro ArcView project 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 which 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.

Watershed Tool 

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 

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 pixel of each stream. An upper limit of 30 streams may be added using this tool.

Add Outlets Tool 

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. 

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 box will contain data developed from the DEM, a cross section rating table, and default values upon which the rating table is based. 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 1). If a cross section is not satisfactory, it may be re-drawn at another location.

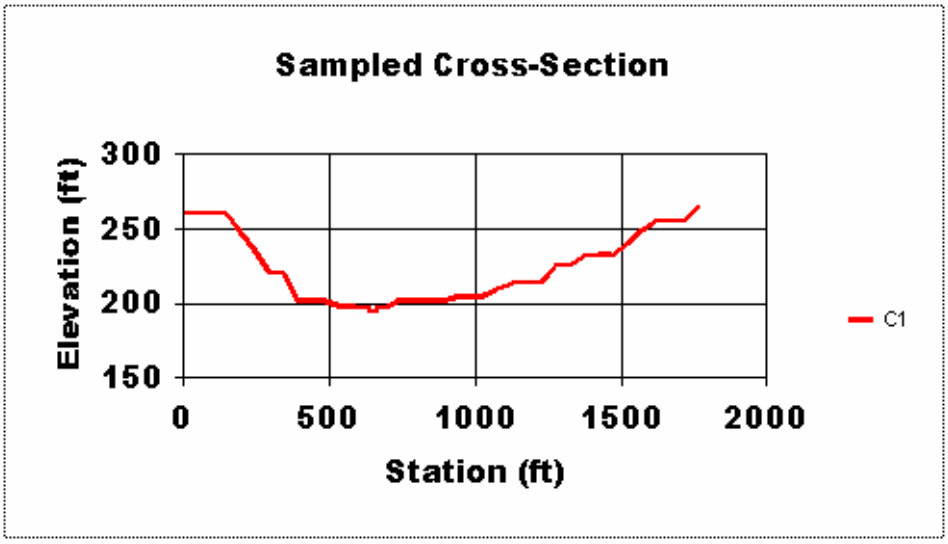

Figure 1 Example Cross Section Plot

Figure 2 (see next page) 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. The watershed outlet is located at the south edge of sub-area 6.

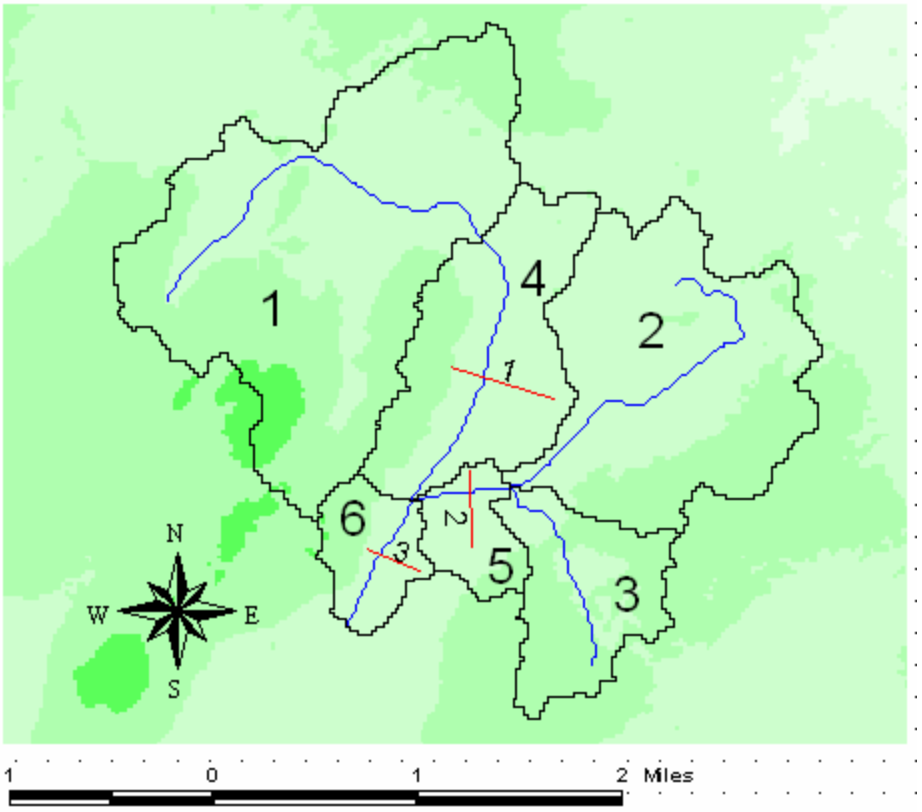

Figure 2 Example watershed map

CONTROL PANEL

The Control Panel dialog box allows the user to select 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 24-hour rainfall values and design storm type are placed in the appropriate data boxes. These may be edited. The user may then select storm events for which simulations are desired.

EXECUTE WINTR-20

A menu selection allows the user to execute WinTR-20 which 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.

FURTHER ANALYSES USING WINTR-20 CONTROLLER/EDITOR

For more WinTR-20 options (such as changing dimensionless unit hydrograph, rainfall distribution, adding reservoirs, analyzing alternatives, 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 3) and other graphics.

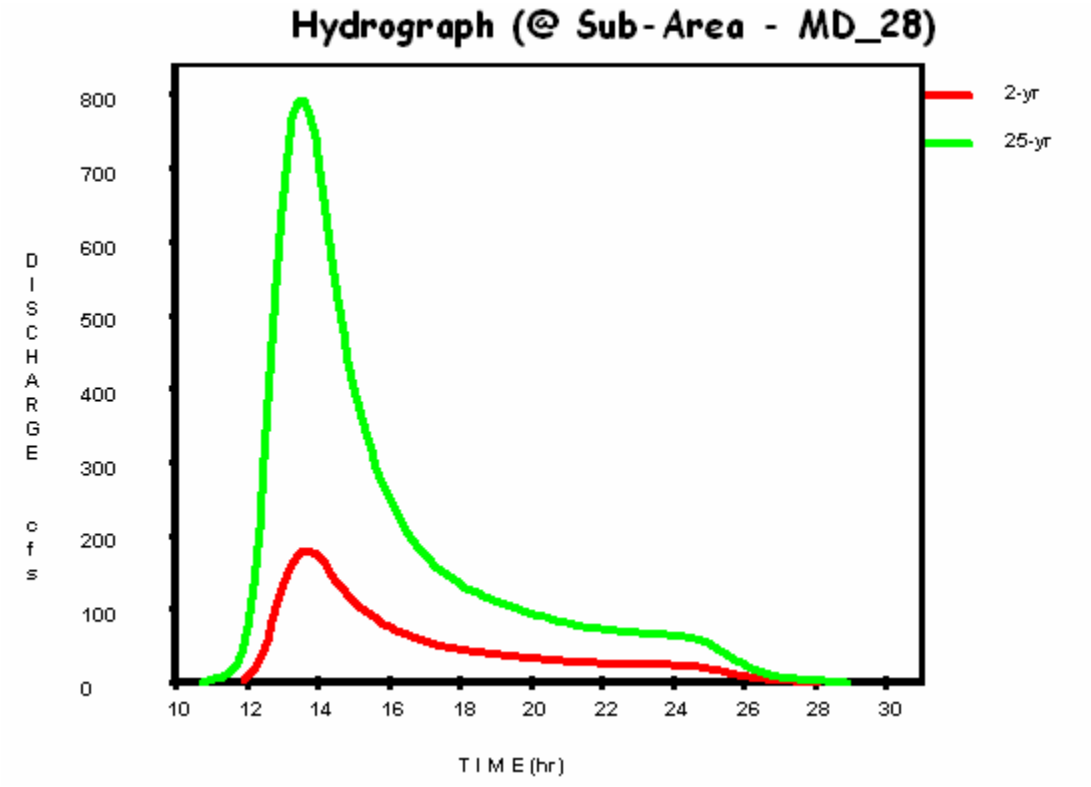

Figure 3 Example WinTR-20 Hydrograph Plot

ARC-GIS VERSION

NRCS Geo-Hydro is being developed to operate in ArcGIS 9. It is based on ESRI ArcHydro Tools. It is being designed to overcome the significant limitations in the ArcView version. The ArcGIS version will be an extension and operate with any resolution of topographic, land use, and soil GIS layers. Steps required to prepare GIS layers are streamlined. The same capabilities of the ArcView version will be included plus utilization of GIS rainfall layers and a tool to determine reservoir elevation versus storage data. Opening the WinTR-20 Controller/Editor will be a menu selection allowing the user to make modifications and complete multiple analyses.

SUMMARY

NRCS Geo-Hydro has proved to be very robust. It is a comprehensive system in that a hydrologic analysis may be completed by opening the software only once. 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 has a basic level of required GIS and hydrology expertise. Development of an equivalent interface in ArcGIS 9 is underway.

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