Implementing GISHydro Installation, Customized Enhancements, and Support

(SP 907C4H)

Final Report

Submitted to
MARYLAND DEPARTMENT OF TRANSPORTATION
STATE HIGHWAY ADMINISTRATION

By

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February 28, 2002
(revised March 27, 2002)

Introduction

On May 15, 2000 a revised scope of work was proposed and accepted for this project. That scope of work outlined the following 5 tasks to be performed under this during this project period these tasks were:

1. Develop an Ultimate Land Use Procedure
2. Develop better Watershed Analysis Reporting Features
3. Develop a Segmental Velocity Method Time of Concentration Calculator
4. Develop a GISHydro Website
5. Produce a Final Report/Documentation for the Project

This document describes the completion of Tasks 1 through 4 and represents of itself the completion of Task 5. The following sections will give thorough details of how each of the above Tasks 1 through 4 were approached and resolved.

Task 1: Development of an Ultimate Land Use Procedure

The State of Maryland needs to develop a GIS coverage of "Ultimate Development" to aid in the estimation of the hydrologic consequences of this land use condition. We have obtained from the Maryland Department of Planning (MDP) GIS coverage of current zoning information for all counties in the state. (These data do not include zoning information in Baltimore city.) Each county has a different naming scheme for their coverages, however almost every zoning category can be reduced to a number representing the number of dwelling units per acre (DUPA). Another data product that we have is the most recent MDP Generalized Land Use/Land Cover (LULC) information for 1997 conditions. Using the zoning and land use/land cover data we need to develop a coverage that substitutes the equivalent land use at all locations that would be realized given the zoning information.

Maryland Department of Planning Urban LULC Categories

In their most recent (1997) LULC coverage, the MDP defines the following urban land use categories:

11. **Low-density residential** - Detached single-family/duplex dwelling units, yards and associated areas. Areas of more than 90 percent single-family/duplex dwelling units, with lot sizes of less than five acres but at least one-half acre (.2 dwelling units/acre to 2 dwelling units/acre).

12. **Medium-density residential** - Detached single-family/duplex, attached single-unit row housing, yards, and associated areas. Areas of more than 90 percent single-family/duplex units and attached single-unit row housing, with lot sizes of less than one-half acre but at least one-eighth acre (2 dwelling units/acre to 8 dwelling units/acre).

13. **High-density residential** - Attached single-unit row housing, garden apartments, high-rise apartments/condominiums, mobile home and trailer parks. Areas of more than 90 percent high-density residential units, with more than 8 dwelling units per acre.

14. **Commercial** - Retail and wholesale services. Areas used primarily for the sale of products and services, including associated yards and parking areas.

15. **Industrial** - Manufacturing and industrial parks, including associated warehouses, storage yards, research laboratories, and parking areas.

16. **Institutional** - Elementary and secondary schools, middle schools, junior and senior high schools, public and private colleges and universities, military installations (built-up areas only, including buildings and storage, training, and similar areas), churches, medical and health facilities, correctional facilities, and government offices and facilities that are clearly separable from the surrounding land cover.

17. **Extractive** - Surface mining operations, including sand and gravel pits, quarries, coal surface mines, and deep coal mines. Status of activity (active vs. abandoned) is not distinguished.

18. **Open urban land** - Urban areas whose use does not require structures, or urban areas where non-conforming uses characterized by open land have become isolated. Included are golf courses, parks, recreation areas (except areas associated with schools or other institutions), cemeteries, and entrapped agricultural and undeveloped land within urban areas.

In addition, we have created six new residential land use definitions based on the densities defined in the NRCS TR-55 manual. These codes are as follows:

111. **Residential** – residential zoning with lot sizes of at least 2.00 acres in area.
112. **Residential** – residential zoning with lot sizes of at least 1.00 acres but less than 2.00 acres.
113. **Residential** – residential zoning with lot sizes of at least 0.50 acres but less than 1.00 acres.
114. **Residential** – residential zoning with lot sizes of at least 0.33 acres but less than 0.50 acres.
115. **Residential** – residential zoning with lot sizes of at least 0.25 acres but less than 0.33 acres.
116. **Residential** – residential zoning with lot sizes less than 0.25 acres in area.

Wherever possible, we have attempted to use the NRCS-based categories 111 through 116 instead of 11 through 13 provided by MDP. The other (non-urban) land use categories defined by the MDP are:

21. Cropland
22. Pasture
23. Orchards
24. Feeding Operations
25. Row Crops
41. Deciduous Forest
42. Evergreen Forest
43. Mixed Forest
44. Brush
50. Water
60. Wetlands
71. Beaches
72. Bare Exposed Rock
73. Bare Ground
80. Transportation
241. Feeding Operations
242. Agricultural Buildings

These other categories do appear in the derived ultimate land use coverage, however their appearance is generally not due to land actually being zoned in these categories, but

rather due to unknown or poorly defined zoning categories that are then assigned the current land use (see Example below for Location 2).

Example

Location 1: A location in southeastern Montgomery County is zoned as "R60". This category corresponds to single-family, residential housing with a minimum lot size of 6000 ft^2. The "realized density" in this zoning category is 4.2 DUPA. Taking the reciprocal of 4.2 gives the "realized lot size" of 0.23 acres. Examining the MDP land use classification system, we find that this location is rated as category "12" which corresponds to medium density residential housing. According to MDP documents, this category corresponds to residential housing densities ranging from 2 to 8 DUPA. However, the additional zoning categories 111 through 116 indicate a land use category of 116 is appropriate. In this case, 116 is selected.

Location 2: Much of northern and western Montgomery County is zoned as "RDT". This category is named "Rural Density Transfer" and has an associated 0.04 DUPA or a lot size of 25 acres associated with it. This lot size is much greater than the largest lots considered in MDP's LULC category "11" or the NRCS-based category "111". Further examination of the extent of the RDT zoning reveals that a very large percentage of northern and western Montgomery County is zoned as RDT. Imposing land use categories "11" or "111" would not do a good job of accurately representing ultimate land use in these areas where currently agricultural and forested land use prevail. It is particularly the forest land that would no longer be represented that would be the largest source of inaccuracy in assigning either land use code "11" or "111". In fact, if the zoning data are taken literally, the ultimate land use in the county would include no forest land whatsoever. Our solution in this case is to invent a new code, "-1", which is used to represent the great uncertainty in what the realization of ultimate land use would look like in such a zoned area. Our algorithm (described below) will interpret the "-1" zoning as an indication that the current (1997) land use be assigned as the ultimate land use. The "-1" code will be used throughout the state whenever the zoned land use represents a classification that is not well defined (such as in this case with the "RDT" classification), or where the hydrologic meaning of the classification is poorly defined (such as in the case of "Historical" or "Unknown" zoning classifications).

Other Zoning Interpretation Rules

1) **Protected Areas:** Often zoning does not seem to account for protected areas such as county and state parks. I downloaded the TIGER "Landmark Areas" coverage and tagged all "Park" polygons. I use these areas to override the zonings indicated by the individual counties and instead use the 1997 MDP LULC data as in the Location 2 example above.
2) **Riparian Buffers:** Imposing the supplied zoning as a land use has the effect of eliminating essentially all forest cover from the most counties. It seems unlikely this will truly be the case, the most obvious forest cover to remain would be buffer zones (perhaps 100-200 feet wide at least) adjacent to streams and rivers.

See Moglen (2000) for more information on how MDP representations of generalized land use show that this kind of process is already taking place in some counties (e.g. Montgomery). In the ultimate development coverage generated here we have retained a 100 foot forested buffer adjacent to all streams identified in the 1:100,000 National Hydrography Dataset (NHD). Any land which is currently not in an urbanized category but is zoned to become urbanized is assumed to retain 100 foot forest buffers on both sides of any NHD stream that intersects such zoned land.

3) **Water and Wetlands:** (MDP LULC = 50 and 60). These areas should not be expected to change so LULC = 50 or 60 are imposed to remain so in the future.
4) **Decreased Density:** We test for any area that drops its residential density as a function of the new assigned zoning density. If the zoned density represents a drop from the observed 1997 density then the land use from 1997 is imposed.
5) **Undefined Areas:** Some counties have small areas that do not contain any zoning attribute. If such a case is encountered, these areas are handled as "unknown" and are assigned the current land use as in the Example at Location 2.

The mapping from individual county zoning codes to ultimate development is provided in Appendix A. The Avenue script to apply the zoning interpretation rules above is supplied for reference in Appendix B.

The entire ultimate land use data set was developed as a single seamless GIS coverage. It was then "cut" into rectangular sections corresponding to the USGS 7.5 minute quad sheets with each quadrangle assigned a filename identical to the USGS quadrangle name and given the filename extension ".ult". (For example, kensington.ult.) The complete set of these ".ult" files were then compressed into a single "zip" file which is located in the path:

drive:\umdgis\luult\luult_grids.zip

Such zip files are analogous to the zip files already part of the GISHydro2000 database for other land use, topography, or soils coverages. These files are then accessible via the GISHydro2000 "Select Quads" dialog as the land use type "Ultimate Landuse".

Task 2: Development of Better Watershed Analysis Reporting Features

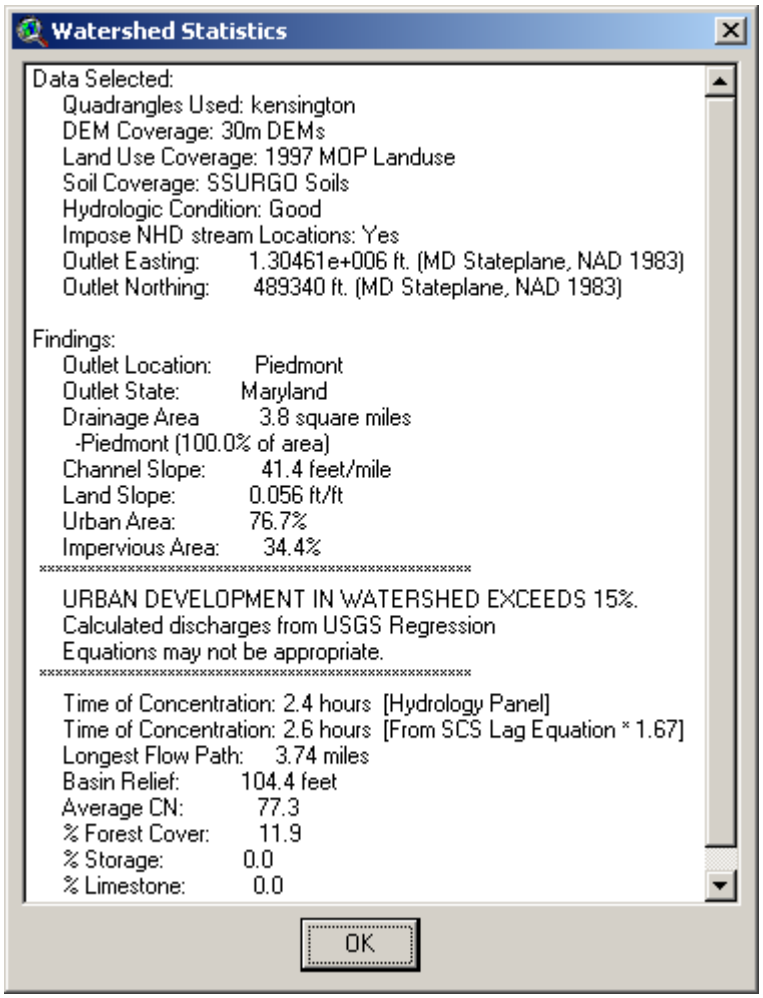
Reporting was enhanced in two ways: Increased reporting associated with the "Hydro: Basin Statistics" menu choice and new reporting associated with the "CRWR-PrePro: Write Sub-Area Land Use Distribution

Hydro: Basin Statistics

The dialogue box shown below illustrates a sample result from selecting this menu choice.

Data Selected: All information included under the "Data Selected" area is new. This reported information completely defines the information selected by a GISHydro user including the quadrangles selected, the specific types of DEM's, land use, and soils chosen, and also options such as the "Hydrologic Condition" (Good or Fair) and the

"Burn Streams" (Yes or No) choice. Finally, the reported information includes the precise location of the selected outlet in Maryland Stateplane Coordinates.



Findings: Several of the entries located under the "Findings" area are new. These entries are:

Land Slope: this quantity is defined as the average of the local slope calculated for each 100 foot pixel within the entire watershed. Local slope is calculated by taking the difference in elevation between each upstream and downstream pixel and the flow length between these pixels (either 100 feet or $100\sqrt{2}$). This quantity is needed to correctly apply the SCS Lag equation.

Urban Area: the Watershed Statistics box now distinguishes between Urban Area and Impervious Area. Urban area is any land use classified as residential, commercial, or industrial within any of the land use datasets GISHydro2000 makes available. This is in contrast to "Impervious Area" (reported as a separate entry) that reports a strict accounting of impervious cover such as pavement or rooftops. Notice that, in general, urban area is not entirely impervious and so urban area is generally a greater percentage of the area within the watershed. The "Urban Development" warning is keyed to the Urban Area rather than Impervious Area as used to be the case.

Time of Concentration: the time of concentration is reported two different ways: using the SCS Lag Equation (multiplied by 1.67 to convert the lag into a time of concentration) and also using the regression equation developed by Will Thomas as part of his work for the Hydrology Panel report.

CRWR-PrePro: Write Sub-Area Land Use Distribution

This menu choice produces individualized land use and curve number statistics for each sub-area identified in the sub-divided watershed. The output from this menu choice goes directly to a text file. For illustrative purposes this output is shown in Table 1 below for just a single sub-watershed.

Table 1. Sample output from "Write Sub-Area Land Use Distribution" menu choice.

Landuse and Soil Distributions for: Sub-Area 1

Distribution of Landuse by Soil Group

Streams located in this sub-area:
Sligo Creek,

Land Use	Acres on Indicated Soil Group A-Soil	B-Soil	C-Soil	D-Soil
Medium Density Residential	0	588.61	5.28	9.64
High Density Residential	0	75.3	3.9	6.43
Commercial	0	6.66	1.15	16.07
Institutional	0	76.22	3.21	7.35
Open Urban Land	0	15.84	1.61	0.69
Deciduous Forest	0	105.83	18.14	75.76
Total Area:	0	868.46	33.29	115.93

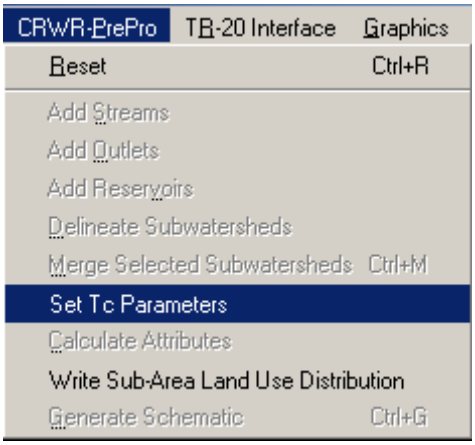
Distribution of Land Use and Curve Numbers Used

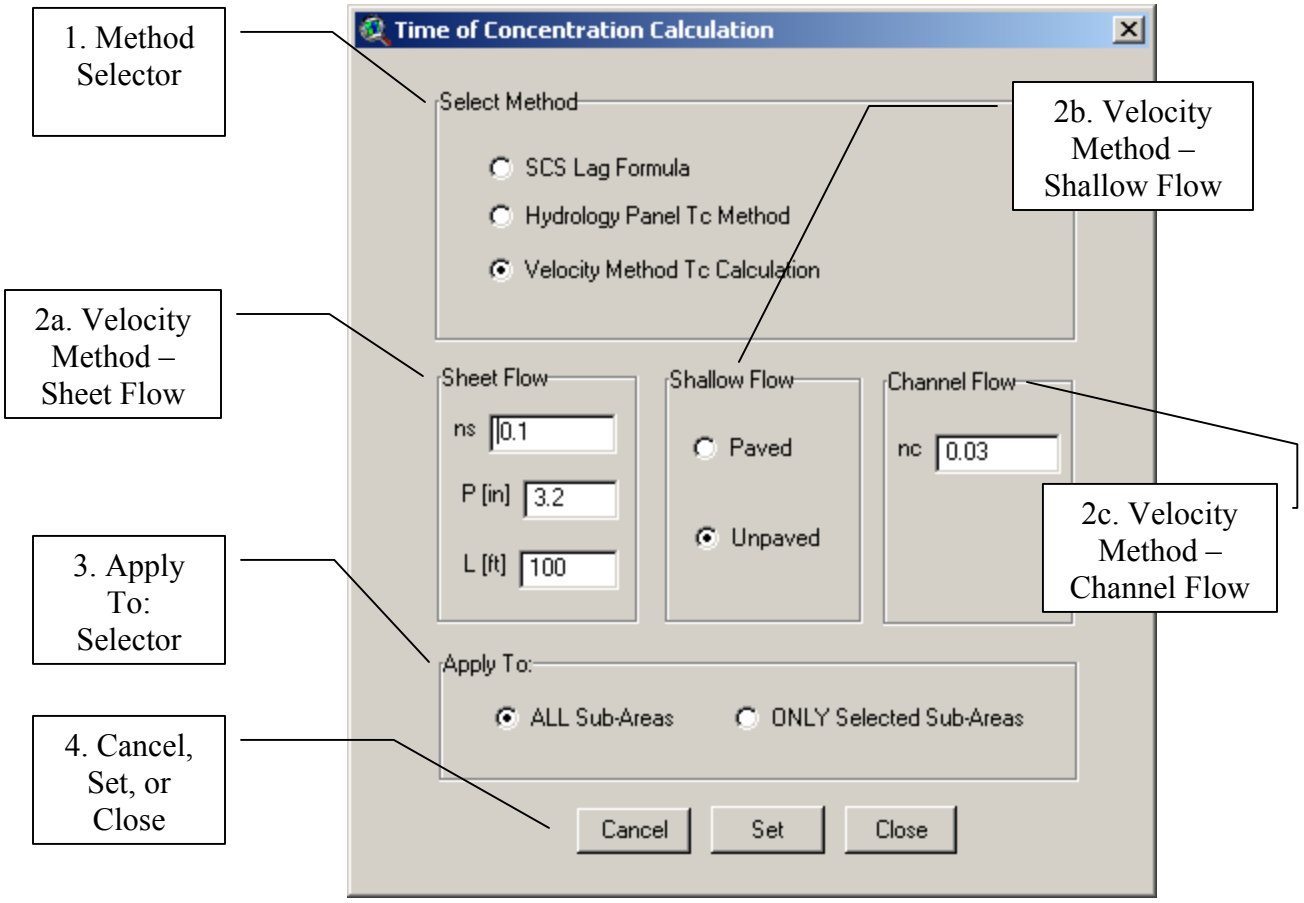
Land Use	Acres	Percent	A	B	C	D
Medium Density Residential	603.54	59.31	61	75	83	87
High Density Residential	85.63	8.41	77	85	90	92
Commercial	23.88	2.35	89	92	94	95
Institutional	86.78	8.53	81	88	91	93
Open Urban Land	18.14	1.78	39	61	74	80
Deciduous Forest	199.72	19.63	30	55	70	77

The output included in Table 1 is a listing of all National Hydrography Dataset (NHD) identified streams within the sub-area (in this case there is only one, "Sligo Creek", because of the small size of the sub-area), and the breakdown of land area within the sub-area by land use and soil type. Also reported are the exact curve numbers used in the analysis.

Task 3: Development of a Segmental Velocity Method Time of Concentration Calculator

This added functionality is accessed through the menu choice, "CRWR-PrePro: Set Tc Parameters" as shown at right. The resulting dialog box is shown on the following page:





1. **Method Selector:** The dialogue box allows the user to select from three methods for time of concentration calculation: the SCS Lag Formula, the Hydrology Panel Method (the method developed by Will Thomas for the Hydrology Panel report), and the Velocity Method (the segmental method defined by the NRCS (SCS, 1984). A single method can be applied universally across all sub-areas, or the user can use the GIS interface (using the  tool) to select individual sub-areas to which the selected method will be applied. If either the SCS lag method or the Hydrology Panel method are selected, no further input is required by the user. The Velocity Method requires more detailed input as described below.

2. **Velocity Method:** If the user selects the Velocity Method Tc Calculation choice then the overall time of concentration is calculated as the sum of three incremental travel times associated with sheet flow, shallow concentration flow, and channel flow as defined by the NRCS.
   - **a.** Sheet Flow: this flow type originates at all drainage divides and proceeds downhill a maximum of L feet until transitioning to shallow concentrated flow. The user needs to specify the Manning's roughness parameter, ns, the 2-year precipitation depth, P, in inches, and the length of flow, L (in feet), until shallow concentrated flow is encountered. Default values are shown in the provided sample dialogue box.

b. **Shallow Flow:** this type of flow begins at the downstream end of the sheet flow segment and continues until a true channel is encountered. The travel time is calculated using a kinematic velocity approach where the velocity, *v*, is calculated as the product of a surface coefficient, *k*, and the square root of the local slope, s_l:

$$v = k\sqrt{s_l}$$

The value of *k* is controlled by the paved or unpaved buttons in the indicated area of the dialogue box. The default is for an unpaved surface.

c. Channel Flow: this type of flow begins at the downstream end of the shallow concentrated flow segment and continues downstream until the outlet of the watershed is encountered. The upstream extent of the channel network is inferred from the 1:100,000 scale, NHD_Streams theme described more fully under the "**Additional Items**" section below. The user needs to specify the Manning's roughness parameter, nc, for the channel. The default value for nc is 0.03 as shown in the provided sample dialogue box. Channel geometry varies continuously as drainage area increases along the flow path and is determined using the regression equations for channel geometry developed by Dunne and Leopold (1977):

$$A_c = 24.5(DA)^{0.66}$$

$$w = 15.5(DA)^{0.38}$$

$$d = 1.57(DA)^{0.28}$$

where A_c is the cross-sectional area of the channel in square feet, *DA* is the drainage area in square miles, *w* is the channel width in feet, and *d* is the channel depth in feet. The wetted perimeter, P_w, is calculated assuming a rectangular shaped cross-section:

$$P_w = 2d + w$$

and then the channel velocity is estimated using Manning's equation:

$$v_c = \frac{1.49}{n_c}\left(\frac{A_c}{P_w}\right)^{2/3} s_l^{1/2}$$

The overall travel time is calculated as the incremental travel times spent in sheet, shallow concentrated, and channel flow.

3. Apply To: Selector: As mentioned earlier under "1. Method Selector", the method and (if applicable) the parameters for the velocity method can be applied universally across all sub-areas, or across only selected sub-areas. The "Apply To" control conveys this information to GISHydro2000. If the information supplied in the "Time of Concentration Calculation" dialogue box is intended to be applied only to selected sub-areas, the user must use the select tool,  , to select these sub-areas from the "subsheds.shp" theme ***before*** using the "Set" button described in "4. Cancel, Set, or Close" below.

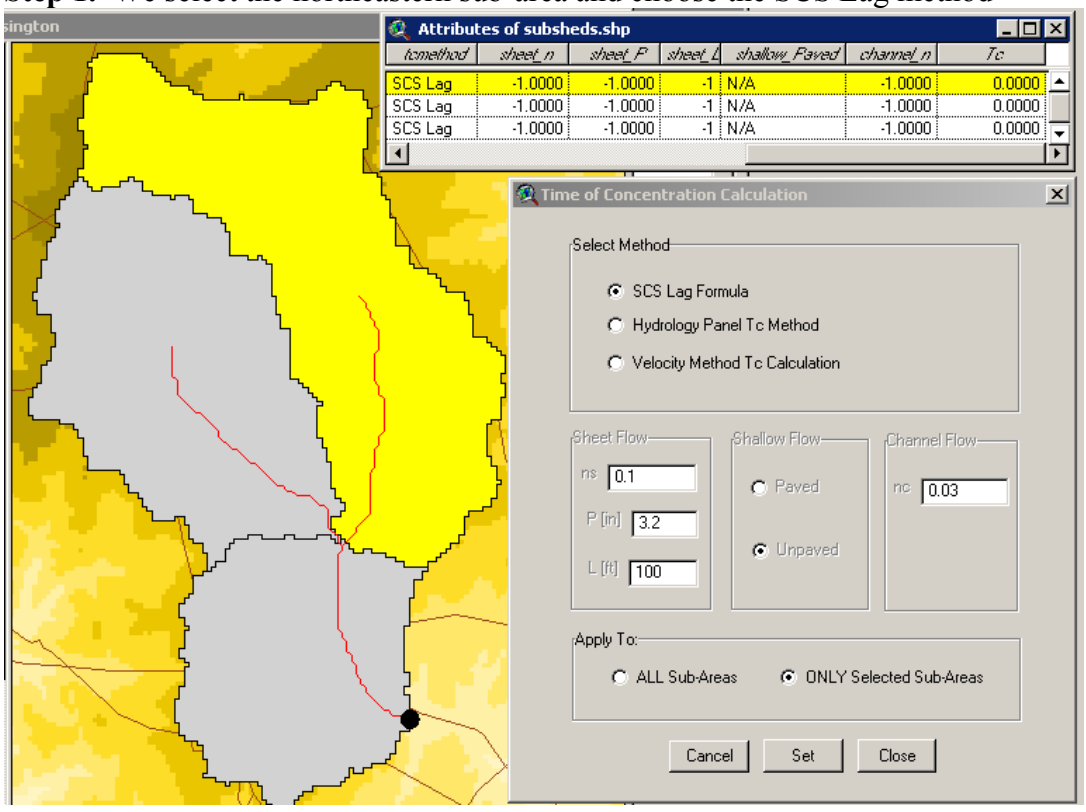
4. **Cancel, Set, or Close:** These three buttons control what is done with the information supplied in the dialogue box.

    a. "Cancel" closes the dialog box without making any further changes to procedures to be used to calculate the time of concentration for any sub-areas.
    b. "Set" applies the current parameters indicated in the dialogue box but keeps the dialogue box open. The user would use the "Set" button multiple times if applying different parameters across different selected sub-areas.
    c. "Close" applies the current settings and closes the dialogue box. The user would use this button when satisfied that all sub-areas are appropriately parameterized.

Example:

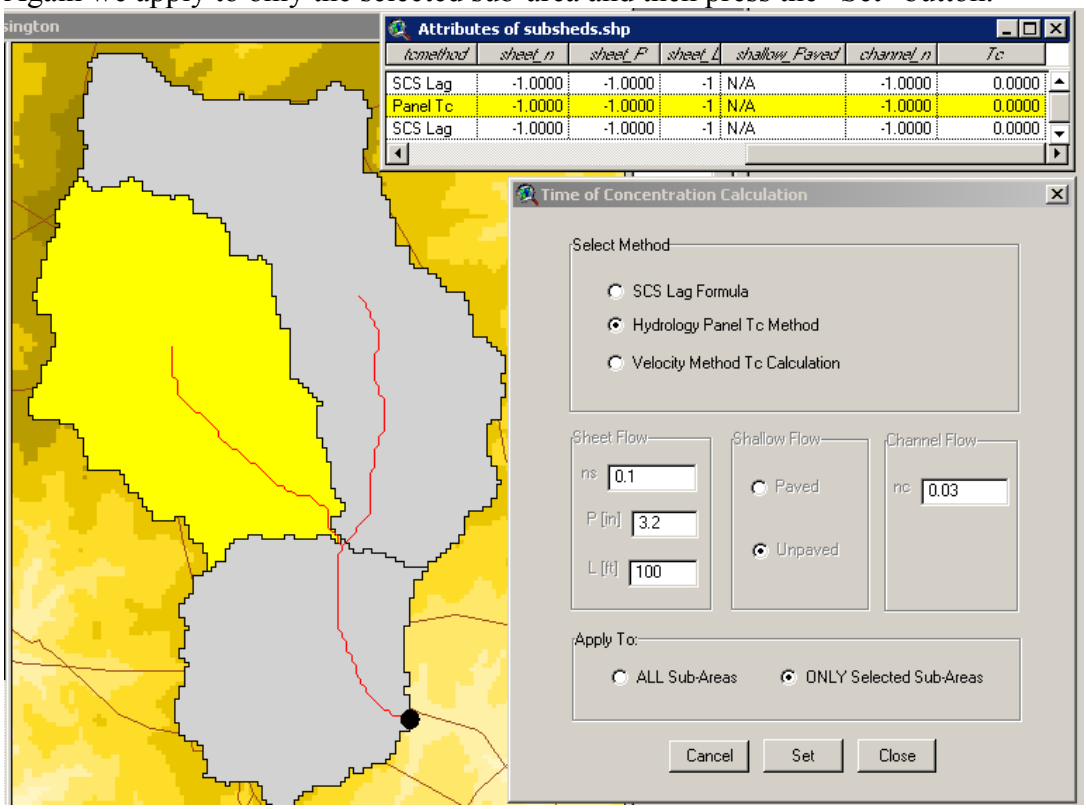
The example below shows the unique parameterization of three sub-areas in the small Sligo Creek watershed used earlier in this report. To illustrate all permutations of this process, let's apply the SCS Lag method to the northeastern sub-area, the Hydrology Panel method to the northwestern sub-area, and the Velocity method to the southern sub-area (with sheet Manning's roughness, ns=0.15, P=3.3 inches, L=100 feet, "paved" shallow flow, and a channel Manning's roughness, nc=0.04).

Step 1. We select the northeastern sub-area and choose the SCS Lag method



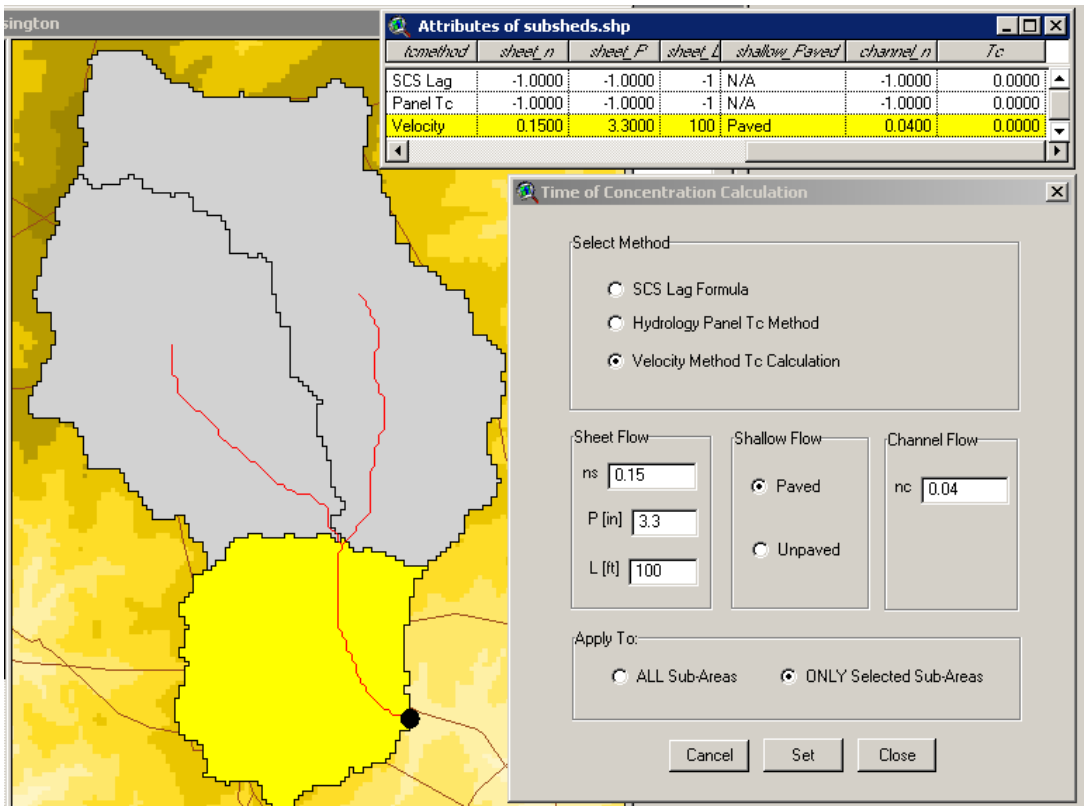
We also select the "Apply To" "ONLY Selected Sub-Areas" since we are only using the SCS Lag method for this sub-area. We then press the "Set" button. Notice that this becomes the default method for all sub-areas as indicated by the "Attributes of subsheds.shp" table shown in the upper right-hand corner of the figure.

Step 2. We select the northwestern sub-area and choose the Hydrology Panel method. Again we apply to only the selected sub-area and then press the "Set" button.



Notice that the middle record of the "Attributes of subsheds.shp" is updated to reflect that the "Panel Tc" is indicated in the "tcmethod" field.

Step 3. Finally we select the southern sub-area and choose the Velocity method. Since the parameters indicated in the example are different from the defaults we must change the information in the dialogue box so that ns=0.15, P=3.3 inches, L=100 feet, "paved" shallow flow is selected, and nc=0.04). We make sure this applies only to the selected sub-area and then we press either the "Set" or "Close" button. ("Set" is shown below.)



Step 4. Satisfied that the time of concentration calculation attributes have been correctly specified we can then press the "Close" or "Cancel" buttons to close the dialogue box.

Step 5. We then choose the "Calculate Attributes" menu choice from the "CRWR Pre-Pro" menu. After some calculations, GISHydro2000 will respond that the "Attribute Calculations are Complete".

In this case, the resulting "Attributes of subsheds.shp" table is shown below.

Attributes of subsheds.shp

tcmethod	sheet_n	sheet_P	sheet_L	shallow_Paved	channel_n	Tc
SCS Lag	-1.0000	-1.0000	-1	N/A	-1.0000	2.2794
Panel Tc	-1.0000	-1.0000	-1	N/A	-1.0000	1.1869
Velocity	0.1500	3.3000	100	Paved	0.0400	0.9544

This table now reflects both the parameters contributing to the time of concentration calculation, and the actual computed *Tc* value in hours. Thus, the time of concentration for the northeastern sub-area is about 2.28 hours, the northwestern sub-area is about 1.19 hours, and the southern sub-area is about 0.95 hours. If it was desired to update these values in this table itself, the engineer may select "Table: Start Editing" and then use the  tool to modify any entries in this table that are undesirable.

Task 4: Development of a GISHydro Website

Our original intent with the development of this website was to build a interface that would be accessible through a normal browser that would function much like the GISHydro2000 software does within the ArcView GIS software. Mr. Michael Casey, who worked on previous GISHydro projects and also worked on this project earlier on, received formal training (under funding from this project) in the development of such a web-based interface. Unfortunately, the functionality that we wanted to create was too complicated for some of the things we wanted to perform and too slow for things we were able to accomplish. This is not an indictment of the idea of creating such an interface, but it seems that both current available software and computer capabilities are insufficient for our needs at this time.

To make effective use of the server supplied by MDSHA, we have established a website at:

`http://www.gishydro.umd.edu`

where anyone is able to log in, and download the GISHydro2000 software. To date, this site has had 635 people register for access to download the software. This has become a very effective means for the PI to make this software available to both agencies around the State of Maryland and to consultants within the state working on MDSHA projects. The site has even spawned international interest with registrants from at least 37 other countries including: Australia, Belgium, Canada, China, Colombia, Germany, Greece, India, Indonesia, Israel, Italy, Japan, Mexico, the Netherlands, Peru, Poland, Portugal, Russia, Spain, and Turkey. The continuing usefulness and popularity of the site is indicated by the existence of over 50 new registrants to the site during the first two months of 2002.

Additional Items Accomplished/Recognition during Project Period

- **Added Data Sets:**
  - **SSURGO Soils Data** - this is the highest resolution soils data available from the NRCS. All these data appear in the zip file located at: \umdgis\ssurgo\ssurgo_soils.zip.
    - Washington County, MD
    - Washington, DC
    - Frederick County, MD
    - Harford County, MD (Aberdeen Only)
    - Bedford County, PA (north of Allegany county)
    - Franklin County, PA (north of Frederick and Washington counties)
    - Fulton County, PA (north of Allegany and Washington counties)
    - Lancaster County, PA (north of Harford and Cecil counties)
  - **National Hydrography Dataset –** this is a 1:100,000 digitized coverage of streams available throughout the U.S. supplied by the USGS. This theme is now automatically included in the "Maryland View" of GISHydro2000 and can be used with the "Burn Streams" option to impose streams interpreted by the DEM topography to be consistent with the

known (digitized) streams. This theme supersedes the "RF3" coverage of similar information. It is superior because of the higher level of quality checking and because it includes stream name attributes which aids in the reporting of streams (see new reporting features in earlier section). This theme was also used throughout the state to infer the location of future stream buffer areas in development of the ultimate land use coverage. Details of this use are explained earlier under "Task 1: Riparian Buffers". This dataset appears in the GIS shapefile located at: \umdgis\maryland\nhd_streams (.shp, .shx, and .dbf)

- **Thiessen Polygon Coverage of 2-yr, 24hr precipitation for NOAA Rainfall Atlas –** these data were obtained directly from the National Weather Service as part of their project to renew the rainfall atlas in the Ohio river basin. We have applied a theissen polygon routine to these point data and the result appears in the "Area of Interest" view for all selected quadrangles. These data can be useful in defining rainfall parameters for TR-20 and are also being used in the PI's parallel "Peak Flow Estimation" project. All these data appear in the zip file located at: \umdgis\prec\prec2yr.zip.

- **Appearance in *TR News*, "Research Pays Off" column:** The GISHydro2000 program was featured in the September-October issue of the *TR News* in their "Research Pays Off" column. A copy of this column appears in Appendix C and can also be found at:

  `http://trb.org/trb/publications/trnews/rpo/rpo.trn210.pdf`

  The citation for this column appears below:

  Moglen, G.E. and A. Kosicki, 2000. "GISHydro2000: Performing Automated Hydrologic Analyses in Maryland." *TR News*, 210: 18-19. Transportation Research Board, National Academy of Sciences. Washington, DC.

- **Award winner at Towson GIS2001.** In May, 2001 the GISHydro2000 software and the PI received the Outstanding GIS Award "…in recognition of my contributions to GIS in Maryland" from the 14th Annual Towson University GIS Conference for the State of Maryland, 2001.
- **Presentations of GISHydro2000 program:** Three presentations of the GISHydro2000 program were given at the Annual Geographic Information Sciences Conference in Maryland, to the Federal Highway Administration, and AASHTO officials during the funding period as listed below:
  - **Moglen, G.E.,** "GISHydro2000: Using GIS to Automate Hydrologic Analyses in Maryland", Presented at 13th Annual Geographic Information Sciences Conference, Baltimore, MD. May 2, 2000.
  - **Moglen, G.E.**, "GISHydro2000: Using GIS to Automate Hydrologic Analyses in Maryland", Presented at Federal Highway Administration

Eastern/Southern Resource Center Hydraulic Engineering Conference, Orlando, FL, July 20, 2000.

- **Moglen, G.E.**, "GISHydro2000 – A Customized GIS-Based Tool for Hydrologic Analyses in Maryland." Presented at Task Force on Hydrology and Hydraulics, American Association of State Highway and Transportation Officials (AASHTO), Baltimore, MD, October 4, 2001.

Summary

This report describes the datasets and codes developed, new features added, and activities of the PI relative to this project over the funding period. Each of the tasks identified in the approved scope of work was addressed with success in the development of an ultimate land use coverage, enhanced reporting features, and the development of a segmental method time of concentration calculator. Somewhat limited success was achieved in the development of a web-based version of GISHydro. However, even with regards to this item this project did successfully establish a web site for the free, centralized dissemination of the GISHydro2000 software to those needing access to (or simply interested in) this program from around the State of Maryland and throughout the world. We hope that future advances in GIS-based server-software may yet allow us to develop the application originally scoped out for this project.

References

Dunne, T. and L.B. Leopold, 1978. Water in Environmental Planning. W.H. Freeman and Co. 818p.

Moglen, G.E., 2000. "Urbanization, Stream Buffers, and Stewardship in Maryland." *Watershed Protection Techniques*, 3(2): 676-680. (reprinted in: *The Practice of Watershed Protection*, 2000. T.R. Schueler and H.K. Holland, (eds.), The Center for Watershed Protection, Ellicott City, Maryland.)

Soil Conservation Service, 1984. *Computer Program for Project Formulation*, Technical. Release 20, Washington, DC.

Appendix A: Zoning to Ultimate Land Use Conversion Tables

The following pages present the zoning codes for each county in Maryland as obtained from the Maryland Department of Planning in Spring 2001. These tables include two fields: "Zoning" and "MDPcat". The "Zoning" field identifies an exhaustive list of zoning categories appearing in the GIS-based zoning theme for each individual county. The associated entry in the "MDPcat" identifies the corresponding land use category as it would be assigned in the MDP scheme. Several residential categories (111-116) were created to convey higher resolution in lot sizes according to zoning information compared to MDP's "low", "medium", and "high" resolution as described earlier in this report.

Allegany County

Zoning	Mdpcat
R	111
B-1	14
B-2	14
I	15
G-1	111
G-2	111
A	-1
C	-1
Mun	-1

Anne Arundel County

Zoning	MDPcat
C1	14
C2	14
C3	14
C4	14
DD	14
MA	-1
MA1	16
MA2	14
MA3	14
MB	14
MC	14
OS	-1
R1	112
R10	116
R15	116
R2	113
R22	16
R5	116
R44	116
RA	-1
RLD	111
W1	15
W2	15

W3	15
WAT	50
TC	16
A-B1	14
A-B1A	14
A-B2	14
A-B3	14
A-BR	14
A-C1	-1
A-C1A	-1
A-C2	-1
A-C2A	-1
A-C2P	-1
A-I1	15
A-I2	15
A-MIL	16
A-MX	14
A-OS	-1
A-P	14
A-PM	14
A-PM2	14
A-PT	14
A-R1	116
A-R1A	113
A-R1B	115
A-R2	116
A-R3	116
A-R4	112
A-R5	116
A-W2	50
A-W3	50
A-WMC	14
A-WMM	14
A-WME	14
A-WMI	14
A-BCE	14

Baltimore City

Zoning	MDPcat
all	-1

(No zoning data were available for Baltimore City hence current land use was assigned for ultimate land use.)

Baltimore County

Zoning	MDPcat
RC	-1
RC 2	-1
RC 3	111
RC 4	111
RC 5	112
RC 5 CR	112

RC 20	-1
RC 50	-1
RCC	14
DR 1	112
DR 1 H	112
DR 2	113
DR 2 H	113
DR 3.5	115
DR 3.5 H	115
DR 3.5 H1	115
DR 5.5	116
DR 10.5	116
DR 10.5 H	116
DR 16	116
RAE 1	116
RAE 2	116
RO	116
ROA	116
RO CR	116
OR 1	116
OR 2	116
O 3	14
O T	14
SE	-1
BMM	-1
BMB	-1
BMYC	-1
CB	14
BLR	14
BL	14
BL AS	14
BL CCC	14
BL CR	14
BL CS1	14
BL CS2	14
BL CT	14
BL H	14
BM	14
BM AS	14
BM CCC	14
BM CNS	14
BM CR	14
BM CT	14
BM IM	15
BR	14
BR AS	14
BR CCC	14
BR CR	14
BR IM	15
MR	15
MR IM	15
MLR	15
MLR IM	15
ML	15

ML AS	14
ML IM	15
MH	14
MH AS	14
MH IM	15

Calvert County

Zoning	MDPcat
ECT	-1
I-1	15
MC	14
R-1	113
R-2	112
RC	14
RUR	-1
TC	14

Caroline County

Zoning	MDPcat
C1	14
C2	14
HC	14
I2	15
IM	113
MH	116
R	-1
R1	113
R2	115
R3	116

Carroll County

Zoning	MDPcat
A	-1
BG	14
BL	14
C	-1
IG	15
IR	15
MUN	-1
R10	116
R20	114
R40	112
R7.5	116
WATER	50

Cecil County

Zoning	MDPcat
NAR	-1

SAR	-1
RR	111
SR	113
DR	115
TR	115
VR	115
RM	116
MH	116
BL	14
BG	14
BI	14
MB	14
M1	15
M2	15
OS	18
MEA	-1
MEB	-1
BMU	-1
MUN	-1

Charles County

Zoning	MDPcat
AC	-1
RC	-1
RR	112
RV	113
RL	114
RM	115
RH	116
RO	116
CN	14
CC	14
CB	14
CV	14
BP	14
IG	15
IH	15
PRD	116
PUD	14
WPC	-1
PEP	14
MX	116
PMH	116
C-H	14
CG-1	14
CG-2	14
CMX	14
F-P	-1
I	15
MUD	116
OS	-1
P-L	-1
R-1	114

R-2	116
R-3	116
R-5	116
R-10	116
R-21	114
L-I	-1
N/A	-1
C-B	14
R-8	111
USMIL	-1

Dorchester County

Zoning	MDPcat
AR	-1
MAR	-1
R1	112
R2	113
R3	116
B	14
B1	14
B2	14
B3	14
I1	15
I2	15
C	-1
H	-1
AP	-1
FP	-1
MUN	-1
Wa	50

Frederick County

Zoning	MDPcat
C	-1
A	-1
R1	112
R3	114
R5	116
R8	116
R12	116
R16	116
PUD	115
MH	116
VC	14
GC	14
HS	15
LI	15
GI	15
ORI	15
MM	17
MXD	-1

MUN	-1
MUNFRE	-1

Garrett County

zoning	MDPcat
RD	115
LR	112
TR	116
TC	116
C	14
MUN	-1
Unc	-1
WATER	50
Wa	50

Harford County

Zoning	MDPcat
AG	-1
R1	113
R2	115
R3	116
R4	116
R	112
RR	111
VR	114
RO	116
VB	116
B1	14
B2	14
B3	14
CI	15
LI	15
GI	15
G1	15
ORI	15
MUN	-1
NONE	-1
Wa	50

Howard County

Zoning	MDPcat
B1	14
B2	14
BR	14
HC	-1
HO	14
M1	15
M1MXD3	15
M2	15
NT	114

PEC	14
PGCC	113
POR	14
PORMXD6	14
R12	114
R20	113
R20MXD3	113
RA15	116
RCDEO	-1
RED	113
RMH	116
RRDEO	111
RRMXD3	111
RSA8	116
RSC	115
RVH	116
SC	14
SW	-1
WATER	50
unknown	-1

Kent County

Zoning	MDPcat
A	-1
RC	-1
RR	113
CAR	-1
V	115
LM	14
CC	14
I	15
PI	15
ICA	-1
MUN	-1
x	-1

Montgomery County

Zoning	MDPcat
C	-1
C1	14
C2	14
C3	14
C4	14
C5	14
CBD1	14
CBD2	14
CBD3	14
CINN	112
CITY	14
CO	14
HIST	-1

I	15
I1	15
I2	15
I3	15
I4	15
MXPD	116
OM	14
PCC	-1
PD13	116
PD2	113
PD3	114
PD4	115
PD5	116
PD7	116
PD9	116
PNZ	116
PRC	115
R	111
R10	116
R12_5	116
R150	113
R150-T	113
R20	116
R200	113
R200-P	113
R200-T	113
R30	116
R40	116
R6	116
R60	116
R60-TD	116
R80	114
R9	114
R90	114
R90-T	114
RC	111
RDT	-1
RE	112
RE-1	112
RE1	112
RE1-P	112
RE1-T	112
RE1-TD	112
RE2	111
RE2C	111
RE2C-T	116
RE2-T	116
RE2-TD	116
RH	116
RMH	116
RMH200	113
RMX1	112
RMX1-T	112
RMX2	113

RMX3-T	116
RMX-TD	112
RT	116
RT12_5	116
RT8_0	-1
RT80	116
RURAL	111
TOWN	116
TS	116
Wa	50

Prince George's County

Zoning	MDPcat
ROS	-1
OS	-1
RA	111
RE	112
RR	113
R80	115
R55	116
R35	116
RT	116
R20	116
R30	116
R30C	116
R18	116
R18C	116
RH	116
R10	116
R10A	116
MXT	14
MXC	14
MUTC	14
RPC	116
RMH	116
RL	113
RS	114
RM	116
RU	116
LAC	14
MAC	14
EIA	16
VL	113
VM	113
CO	14
CA	14
C1	14
C2	14
CC	14
CG	14
CSC	14
CH	14
CM	14

CW	14
CRC	14
I1	15
I2	15
I3	15
I4	15
ULI	15
TDO	-1
IDO	-1
LDO	115
RCO	111
L-ICS	15
L-IRPT	15
L-PDA	-1
L-PUD	-1
L-R5	12
L-ROS	18
L-CSH	-1
L-CV	14
L-OBE	14
L-CN	14
L-OB	14
L-IG	15

Queen Anne's County

Zoning	MDPcat
AG	-1
CS	113
E	113
SE	116
SR	116
SC	14
SI	15
LIHS	15
NC1	113
NC2	112
NC5	111
NC8	116
NC15	116
NC20	115
UR	116
UC	14
VC	14
WVC	14
TC	14
MUN	-1
CMPD	-1
GPRN	-1
SMPD	-1
SHVC	14
GNC	14
GVC	14
AD	-1

UNC	-1

Somerset County

Zoning	MDPcat
A	-1
AP	14
C1	14
C2	14
C3	14
CO1	-1
CO2	-1
I1	15
I2	15
MRC	116
MUN	-1
R1	111
R2	111
R3	112

St. Mary's County

Zoning	MDPcat
CC	14
DMX	10
CMX	14
TMX	112
VMX	114
RL	115
RH	111
RMX	113
I	15
OBP	14
CML	14
CMG	14
RNC	-1
RCL	14
RSC	14
RC	14
RPD	-1
RCA	-1
LDA	116
IDA	10
BMA	-1
WDF	14
RR	116
PUD	112
IS	113
H	-1
AG	-1
APZ1	-1
APZ2	-1
CZ	-1

CM	14
POND	50
none	-1

Talbot County

Zoning	MDPcat
RAC	-1
RC	-1
RR	111
VC	115
TR	115
LC	14
GC	14
LI	15
MUN	-1

Washington County

Zoning	Mdpcat
C	-1
C-HP	-1
C-IM	-1
A	-1
A-HP	-1
A-PUD	-1
RR	113
RS	115
RS-PUD	115
RU	116
RM	116
BT	14
BL	14
BG	14
IT	15
IR	15
IG	15
IM	15
PI	15
PUD	116
PB	14
HI	15
HI-1	14
HI-2	116
HP	-1
AO	-1
AP-1	-1
BO-MUN	-1
CS-MUN	-1
FU-MUN	-1
HG-MUN	-1
HN-MUN	-1

KE-MUN	-1
M-MUN	-1
SH-MUN	-1
SM-MUN	-1
WM-MUN	-1
AP	15
WATER	50

Wicomico County

Zoning	MDPcat
A1	-1
A2	111
C2	14
C3	14
D-MUN	115
F-MUN	115
H-MUN	115
HD1	-1
I1	15
I2	15
LB2	116
M-MUN	115
P-MUN	115
R15	116
R20	116
R21	116
R22	116
R8	116
SA-MUN	115
SH-MUN	115
W-MUN	115
x	-1

Worcester County

Zoning	MDPcat
A1	-1
B1	14
B2	14
C1	-1
E1	111
M1	15
M2	15
OC	-1
Poc	-1
R1	112
R2	115
R3	116
R4	116
R5	116
RO	116
SNH	-1

TwB	-1
V1	116
Wa	50

Appendix B: Avenue Script to impose convert zoning to ultimate land use

```
'Input Data that are needed:
'
' Themes
'
'    1) Current Land Use:    "Land Use"         (grid)
'    2) Zoned Land Use:      "Zoned Land Use"   (shapefile)
'    3) Parks:               "Mdparksstp.shp"   (shapefile)
'    4) County Outline:      "Poly"             (coverage called
"mdcountystp")
'    5) Streams:             "nhd_streams.shp"  (shapefile)
'
' Tables
'
'    6) CN Lookup Table:     "andlookupfair.txt" or "andlookupgood.text"
(text file)
'    7) Zoning Lookup Table  "zonelookup.txt"
(text file)
'
'Output Data
'
'    8) Ultimate Land Use:     "Ultimate Land Use" (grid)
'    9) Ultimate Curve Number: "Ultimate CN"       (grid)

deflookup = "$UMDGIS/mdinterface/andlookupfair.txt"
labels = {"County", "Current Land Use", "Zoned Land Use", "County
Boundaries", "Soils", "Streams", "Parks", "Zoning Lookup Table", "Curve
Number Lookup Table", "Ultimate Land Use", "Ultimate Curve Number"}
defaults = {"", "Land Use", "Zoned Land Use", "Mdcounties2000stpft.shp",
"Soils", "nhd_streams.shp", "mdparksstp.shp", "", deflookup, "Ultimate
Land Use", "Ultimate Curve Number"}
order = MsgBox.MultiInput("Enter Information", "Create Ultimate Land Use
and Curve Number", labels, defaults)

theview = av.finddoc("view1")
thecounty = order.get(0)
cttheme = theview.findtheme(order.get(3))
streams = theview.findtheme(order.get(5))
zoningtheme = theview.findtheme(order.get(2))
lu97 = theview.findtheme(order.get(1)).getgrid
parks = theview.findtheme(order.get(6))

cttab = cttheme.getftab
ctpolyfield = cttab.findfield("shape")
streamtab = streams.getftab
streampolyfield = streamtab.findfield("shape")
parktab = parks.getftab

zoningtheme.clearselection
zoningtab = zoningtheme.getftab
zoningcat = zoningtab.findfield("Zoning")

mappingtab = av.FindDoc(order.get(7)).GetVTab
mappingfield = mappingtab.findfield("Zoning")

zoningtab.Join(zoningcat, mappingtab, mappingfield)

nrec = zoningtab.getnumrecords
msgbox.info(nrec.asstring,"number of records")
MDPcat = zoningtab.findfield("Mdpcat")

all_cats_good = TRUE
for each i in 1..nrec
```

```
   a = zoningtab.returnvalue(zoningcat, i - 1)
   a = zoningtab.returnvalue(MDPcat, i - 1).asstring
   if (a.isnumber.not) then
      all_cats_good = FALSE
      badcat = zoningtab.returnvalue(zoningcat, i - 1)
      msgbox.info(badcat, "The missing category is:")
   end
end
if (all_cats_good) then
   msgbox.info("All Categories are Defined", "Good News")
end

statename = "Maryland"
thebitmap = cttab.GetSelection
success = cttab.Query("([County] = " + order.get(0).quote + ")",
thebitmap, #VTAB_SELTYPE_NEW)
cttab.updateselection

nselected = cttab.getnumselrecords
if (nselected <> 1) then
   msgbox.info("Must Select One County for Analysis", "Try Again")
else
   therect = cttheme.getselectedextent
   therect = therect.expandby(200)
   ae = theView.GetExtension(AnalysisEnvironment)
   ae.SetExtent(#ANALYSISENV_VALUE, therect)
   ae.SetCellSize(#ANALYSISENV_VALUE, 100)
   ae.Activate
   for each rec in cttab.getselection
      countypolygon = cttab.returnvalue(ctpolyfield, rec)
   end
   streams.SelectByPolygon (countyPolygon, #VTAB_SELTYPE_NEW)
   parks.SelectByPolygon (countyPolygon, #VTAB_SELTYPE_NEW)
   buffertab = FTab.MakeNew("d:\zoning\bufferareas.shp".AsFileName,
polygon)
   fld1 = Field.Make("Field1", #FIELD_CHAR, 15, 0)
   buffertab.AddFields({fld1})
   for each rec in streamtab.getselection
      theline = streamtab.returnvalue(streampolyfield, rec)
      thepoly = theline.returnbuffered(100)
      newrec = buffertab.AddRecord
      buffertab.setValue(buffertab.GetFields.Get(0), newrec, thepoly)
      buffertab.setValue(buffertab.GetFields.Get(1), newrec, "buffer")
   end
   buffertab.seteditable(FALSE)
   buffergrid = grid.MakeFromFTab(buffertab, prj.MakeNull, NIL, {100,
therect})
   buffergrid = 1.AsGrid - (buffergrid.IsNull)
end
ctmask = grid.makefromFtab(cttab, prj.MakeNull, NIL, {100, therect})
parkmask = grid.makefromFtab(parktab, prj.MakeNull, NIL, {100, therect})
parkmask = (1.AsGrid - (parkmask.IsNull)) * ctmask
buffergrid = buffergrid * ctmask

zonegrid = grid.makefromFtab(zoningtab, prj.MakeNull, mdpcat, {100,
therect})
zoningtab.UnJoinAll

'set zoned land use to be "-1" wherever null zoning exists within county
nullzone = zonegrid.IsNull
nullzone = nullzone * ctmask
zonegrid = nullzone.con(-1.AsGrid, zonegrid)

' Check for Inconsistent land use change
```

```
urban97 = lu97 < 20.AsGrid
ag97 = (lu97 >= 20.AsGrid) and (lu97 < 29.AsGrid)
for97 = (lu97 >= 40.AsGrid) and (lu97 < 50.AsGrid)
wat97 = (lu97 >= 50.AsGrid) and (lu97 < 70.AsGrid)
agult = (zonegrid >=20.AsGrid) and (zonegrid < 29.AsGrid)
forult = (zonegrid >=40.AsGrid) and (zonegrid < 50.AsGrid)
watgrid = (zonegrid >=50.AsGrid) and (zonegrid <70.AsGrid)
undevelopedgrid = agult + forult + watgrid

errorgrid = undevelopedgrid * urban97 ' pixels that are 1 represent
"undeveloping of landscape"
'modify zonegrid to be "-1" at identified errorgrid pixels
zonegrid = errorgrid.con(-1.AsGrid, zonegrid)

' locate parks - set zoned land use to be "-1"
zonegrid = parkmask.con(-1.AsGrid, zonegrid)

' locate 100 foot buffers - set zoned land use to be forest where it is
currently forest
forbuf = for97 * buffergrid
zonegrid = forbuf.con(lu97, zonegrid)

' Check for and modify pixels with lowering residential density
reshi97 = (lu97 = 13.AsGrid)
resmed97 = (lu97 = 12.AsGrid)
reslow97 = (lu97 = 11.AsGrid)
resmedult = (zonegrid = 12.AsGrid)
reslowult = (zonegrid = 11.AsGrid)
ressuperlowult = (zonegrid = 99.AsGrid)
resscsgrp1 = (zonegrid >= 114.AsGrid) and (zonegrid <= 116.AsGrid)
resscsgrp2 = (zonegrid >= 112.AsGrid) and (zonegrid <= 116.AsGrid)
zonegrid = (reslow97 * ressuperlowult).con(lu97, zonegrid)
zonegrid = (resmed97 * ressuperlowult).con(lu97, zonegrid)
zonegrid = (resmed97 * reslowult).con(lu97, zonegrid)
zonegrid = (reshi97 * ressuperlowult).con(lu97, zonegrid)
zonegrid = (reshi97 * reslowult).con(lu97, zonegrid)
zonegrid = (reshi97 * resmedult).con(lu97, zonegrid)

zonegrid = (resmed97 * resscsgrp1).con(lu97, zonegrid)
zonegrid = (reshi97 * resscsgrp2).con(lu97, zonegrid)

' Water and Wetlands Remain Water and Wetlands
zonegrid = (wat97.con(lu97, zonegrid)) * ctmask
nullgrid = (zonegrid.isnull) & (lu97 = 50.AsGrid)
zonegrid = nullgrid.con(50.AsGrid, zonegrid)

' Impose 1997 land use on unknown zoning categories

newgrid = (zonegrid = -1.AsGrid).con(lu97, zonegrid)

a = gtheme.make(newgrid)
a.setname(order.get(9))
theview.addtheme(a)
```

Appendix C: *TR News*: Research Pays Off (Issue 210, pages 18-19)

The following pages are a reprint of the article entitled "GISHydro2000: Performing Automated Hydrologic Analyses in Maryland." appearing in the "Research Pays Off" section of the *TR News*.