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STATE HIGHWAY ADMINISTRATION

RESEARCH REPORT

CONTINUED ENHANCEMENTS TO GISHYDRO2000

UNIVERSITY OF MARYLAND

FINAL REPORT

May 2004

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16. Abstract GISHydro2000 is a GIS-based program that automates the analysis of any stream within or draining into the State of Maryland. This document describes the activities conducted over a roughly 2-year period from Spring 2002 to Spring 2004 in the continued development and maintenance of this program. In particular this document gives an overview of the six specific tasks outlined for completion during this project and describes the use of three dialog boxes/tools developed during this project. These dialogs/tools perform the following: 1) allows the engineer to update any arbitrary region to a new land use definition; 2) allows the engineer to develop explicit pixel-by-pixel reporting on the time of concentration calculation for the velocity method, and; 3) allows the engineer to define hydrologic condition on a land use category-by-category basis. Other tasks completed during this project period include converting the entire spatial database to the Maryland Stateplane coordinate system in horizontal units of meters (was previously feet), adding a new, year 2000, land use dataset, and refreshing the ultimate zoning dataset to be consistent with this year 2000 land use.			
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Research Summary

Problem

This research project involved the continued development and evolution of the GISHydro2000 program. This program automates the hydrologic analysis of any watershed within the State of Maryland or draining into the state (except for the Susquehanna and Potomac Rivers). It is important to continually develop, maintain, and update this program as new data become available, new techniques or reporting are desired, and for compatibility with other GIS products produced or used by the State of Maryland.

Objectives

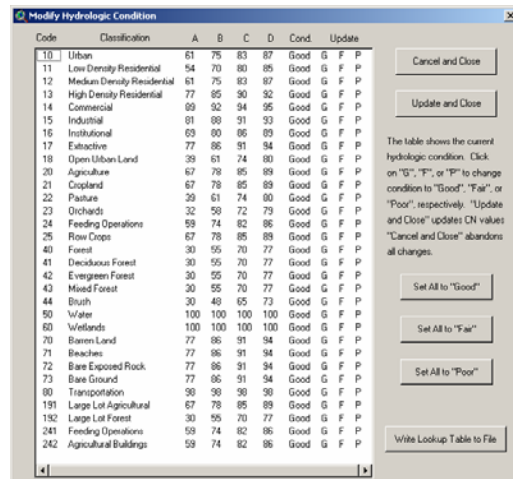
1. Build menu choices that execute new peak flow estimation equations.
2. Rebuild database to be in the Maryland Stateplane, NAD '83, in meters.
3. Incorporate the Maryland Department of Planning (MDP) 2000 land use coverage.
4. Refresh ultimate development coverage.
5. Build GIS-based tool to revise land use coverages.
6. Address miscellaneous MDSHA needs as they arise during the project period.

The main deliverable of this project is a revised version of GISHydro2000 – delivered as a self-installing executable program.

Description

Different tasks in this project were approached in different ways. Tasks 1 and 5 involved programming within the GIS interface to provide MDSHA engineers tools and menu choices to perform the desired analyses or modifications to data. Tasks 2, 3, and 4 primarily involved obtaining data from the MDP and using the GIS to project all existing data within the GISHydro2000 database to the Maryland Stateplane coordinate system in horizontal units of meters.

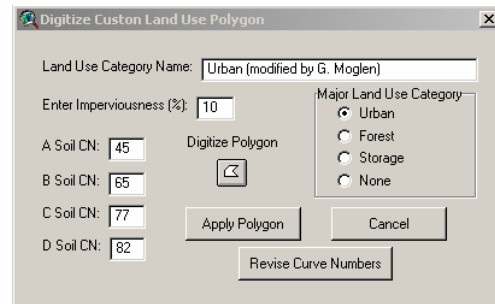
Since Task 6 was purposely designed to be open-ended, this task was approached by continually soliciting advice and direction directly from MDSHA personnel and from members of the Hydrology Panel (of which the PI is a member). This task resulted in several new features being added to the GISHydro2000 program, principal among them were tools for increased interaction and reporting of the Time of Concentration calculations for the velocity method and a new tool to modify the hydrologic condition associated with a given land use category on a category-by-category basis. This tool is pictured at right and described completely in Appendix C.



Code	Classification	A	B	C	D	Cond.	Update
10	Urban	61	75	83	87	Good	G F P
11	Low Density Residential	54	70	80	85	Good	G F P
12	Medium Density Residential	61	75	83	87	Good	G F P
13	High Density Residential	77	85	90	92	Good	G F P
14	Commercial	89	92	94	95	Good	G F P
15	Industrial	81	88	91	93	Good	G F P
16	Institutional	69	80	86	89	Good	G F P
17	Extractive	77	86	91	94	Good	G F P
18	Open Urban Land	39	61	74	80	Good	G F P
20	Agriculture	67	78	85	89	Good	G F P
21	Cropland	67	78	85	89	Good	G F P
22	Pasture	29	61	74	80	Good	G F P
23	Orchards	32	59	72	79	Good	G F P
24	Feeding Operations	59	74	82	86	Good	G F P
25	Row Crops	67	78	85	89	Good	G F P
40	Forest	30	55	70	77	Good	G F P
41	Deciduous Forest	30	55	70	77	Good	G F P
42	Evergreen Forest	30	55	70	77	Good	G F P
43	Mixed Forest	30	55	70	77	Good	G F P
44	Barren	30	49	65	73	Good	G F P
50	Water	100	100	100	100	Good	G F P
60	Wetlands	100	100	100	100	Good	G F P
70	Barren Land	77	86	91	94	Good	G F P
71	Beaches	77	86	91	94	Good	G F P
72	Bare Exposed Rock	77	86	91	94	Good	G F P
73	Bare Ground	77	86	91	94	Good	G F P
80	Transportation	98	98	98	98	Good	G F P
191	Large Lot Agricultural	67	78	85	89	Good	G F P
192	Large Lot Forest	30	55	70	77	Good	G F P
241	Feeding Operations	59	74	82	86	Good	G F P
242	Agricultural Buildings	59	74	82	86	Good	G F P

Results

This project attained all tasks outlined above in the objectives section. Interim versions of the GISHydro2000 program were posted at the GISHydro website and updated numerous times over the course of the project. A final version of the GISHydro2000 software was developed and posted on May 14, 2004. Aside from the conversion to horizontal metric units, one of the main tools developed during this project was the tool to modify land use with complete flexibility on the part of the engineer to digitize the relevant land area, define the land use type, and specify the appropriate curve numbers. A small screenshot of the dialog box for this tool is shown at right and described completely in Appendix A.



Report Information

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Introduction

This project outlined six tasks that were to be performed:

1. Build menu choices in GISHydro that execute the five peak flow estimating equations for the State of Maryland. Three of these are the equations that have been developed under separate contract by Moglen, Thomas, and Miller. These include: Fixed Region (Bulletin 17) estimates, Region of Influence estimates, and L-Moments Method estimates. The remaining two equations are the current United State Geological Survey (USGS) peak flow regression equations (Dillow, 1996) and the former USGS peak flow regression equations (Carpenter, 1980). (30%)
2. Rebuild entire GISHydro2000 database to be consistent with the current accepted coordinate system, projection, and units recognized by the State of Maryland (Maryland Stateplane Coordinate System, North American Datum (NAD) 1983, meters) (20%)
3. Incorporate the Maryland Department of Planning (MDP) 2000 Land Use data set (5%).
4. Refresh ultimate development coverage to be consistent with MDP 2000 Land Use (5%)
5. Build GIS-based tool so that MDSHA engineers can revise Ultimate Zoning Coverage as needed. (15%)
6. Address miscellaneous MDSHA needs as they arise during the project period. Provide formal and informal training and feedback to MDSHA personnel on the use of GISHydro2000. Write documentation for all new features, tools, and datasets developed during the project period. (25%)

This document describes the completion of Tasks 1 through 6. The following sections will give thorough details of how each of the above Tasks 1 through 6 were approached and resolved.

Task 1: Build menu choices in GISHydro that execute new peak flow estimation equations.

GISHydro2000 now produces a table showing the estimate and 1 standard error upper-bound for five methods: Carpenter, Dillow, Fixed Region, L-Moment, and Region of Influence. The latter three methods were the result of the recent project completed by PI's Moglen, Thomas, and Miller for MSHA. This table is produced by choosing the "Hydro: Compare Discharges" menu choice after a watershed has been delineated and basin statistics have been calculated. A sample table is shown below in Figure 1. This table provides the discharges for the 1.25-, 1.5-, 1.75-, 2, 5-, 10-, 25-, 50-, 100-, 200-, and 500-year return periods. A value of "-999" in any entry indicates that no value is calculated for the indicated return period and method. Please note that the Fixed Region method corresponds to the new set of regression equations that are being recommended

Return Period	Carpenter	Carpenter+1SE	Dilow	Dilow+1SE	Thomas	Thomas+1SE	L-Moment	L-Moment+1SE	ROI	ROI+1SE
1.25 Year	-999.0	-999.0	-999.0	-999.0	445.0	631.0	-999.0	-999.0	-999.0	-999.0
1.50 Year	-999.0	-999.0	-999.0	-999.0	603.0	825.0	-999.0	-999.0	-999.0	-999.0
1.75 Year	-999.0	-999.0	-999.0	-999.0	695.0	942.0	-999.0	-999.0	-999.0	-999.0
2 Year	359.0	523.0	495.0	680.0	758.0	1020.0	411.0	582.0	771.0	1140.0
5 Year	614.0	901.0	934.0	1260.0	1380.0	1770.0	799.0	1100.0	1370.0	2040.0
10 Year	840.0	1260.0	1340.0	1830.0	1930.0	2440.0	1170.0	1620.0	1900.0	2880.0
25 Year	1210.0	1900.0	1990.0	2810.0	2820.0	3560.0	1810.0	2550.0	2710.0	4270.0
50 Year	1560.0	2530.0	2570.0	3780.0	3660.0	4680.0	2460.0	3560.0	3330.0	5420.0
100 Year	1980.0	3340.0	3260.0	5030.0	4650.0	6080.0	3290.0	4910.0	4280.0	7200.0
200 Year	-999.0	-999.0	-999.0	-999.0	5830.0	7860.0	-999.0	-999.0	5260.0	9190.0
500 Year	-999.0	-999.0	5350.0	9330.0	7760.0	11000.0	6320.0	10200.0	6830.0	12500.0

Figure 1. Sample discharge comparison table produced by “Hydro: Compare Discharges” menu choice.

by the Hydrology Panel for use in the State of Maryland. A separate menu choice, “Hydro: Calculate Thomas Discharges” produces the message box shown in Figure 2. The engineer also has the option to output the contents of this message box to a text file for later reporting.

Task 2: Rebuild entire GISHydro2000 database to be in the Maryland Stateplane coordinate system, NAD '83, in units of meters.

All of the topography, land use, soils, and supporting datasets were projected to this new coordinate system. The underlying pixel resolution of the former GISHydro2000 database had been 100 feet. The new pixel resolution is 30 meters. Although all data are now stored in the metric system units, GISHydro2000 internally performs all necessary computations and conversions to feet so that the imbedded

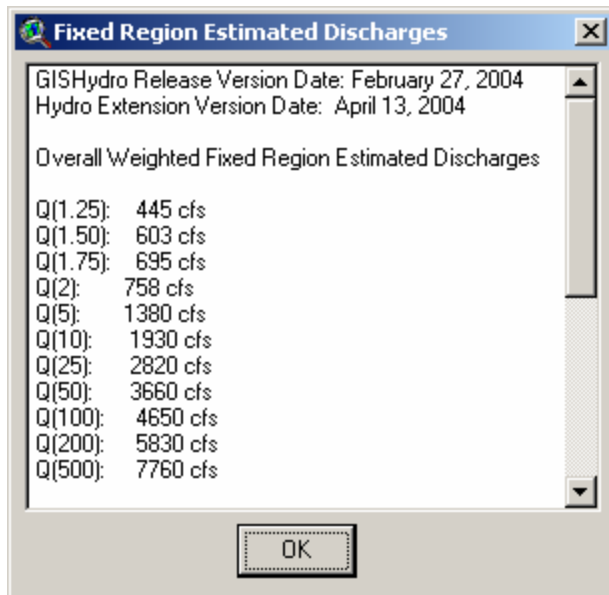


Figure 2. Output from “Hydro: Calculate Thomas Discharges” menu choice.

regression equations and interface to TR-20 (SCS, 1984) are not compromised. An user who is unconcerned about whether the data are in feet or meters should not notice any appreciable change in GISHydro2000 performance, nor should calculations differ in any systematic way.

One change to GISHydro2000’s database has been the addition of the National Elevation Dataset (NED) DEM’s as the default topographic dataset. This dataset should be very comparable to the 30m DEM’s that were the previous default. However, the NED is considered the best quality topographic dataset available and has been added as the default. The 30m DEM’s dataset is still an available

choice. For historical reasons, we still include the 90m DEM's although we do not recommend their except for comparison purposes. The MAIA (Mid-Atlantic Integrate Assessment) DEM's have been removed as they were from a blend of varying resolutions and their use was not recommended.

Task 3: Incorporate the Maryland Department of Planning (MDP) 2000 Land Use data set.

This is now one of the land use layer choices listed in the "Select Quads" dialogue box. This land use layer was compiled and posted on October 24, 2002.

Task 4: Refresh ultimate development coverage to be consistent with MDP 2000 Land Use.

This was completed and has been available since October 24, 2002. (The Beltsville and Laurel_MD quads were revised and updated slightly on July 17, 2003 to reflect zoning changes in the vicinity of the ICC study.

Task 5: Build GIS-based tool so that MDSHA engineers can revise Ultimate Zoning Coverage as needed.

This task was actually implemented a bit more generally so that MSHA engineers can revise *any* land use coverage as needed. This dialogue was created and posted April 3, 2003 and updated slightly a week later. The description/user's manual for this dialogue appears as Appendix A of this report.

Task 6: Address miscellaneous MDSHA needs as they arise during the project period. Provide formal and informal training and feedback to MDSHA personnel on the use of GISHydro2000.

Many miscellaneous tasks appeared over the approximate two years of this project's lifetime. I am attaching a partial listing here. Two significant tasks that were performed included the development of a more flexible and more rigorously reported time of concentration method (see Appendix B), and a dialogue for modifying the hydrologic condition by land use category, rather than having to accept the same hydrologic condition for all land use categories (see Appendix C). The following is the partial listing I have maintained over the project lifetime:

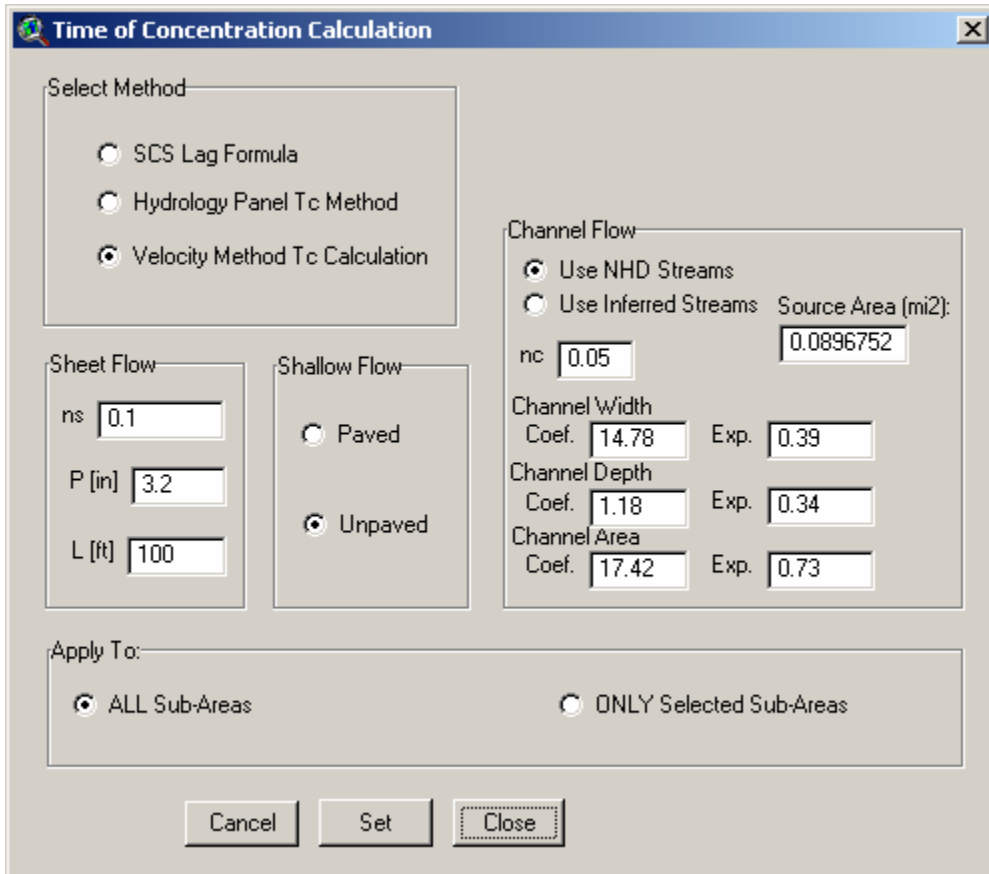
1. Modified all land use legends in GISHydro2000 to have a consistent set of color themes (reds for urban, yellows for agriculture, greens for forest, blues for water/wetlands, and browns for miscellaneous categories).
2. I have sent a CD to Ms. Randah Kamel providing the zoning data and zoning lookup tables for all counties in Maryland. These data were not integrated into GISHydro2000 itself because of the prior agreements between myself, MSHA, and the Maryland Department of Planning concerning how these data would be used/distributed.
3. I located a bug in GISHydro2000 that led to incorrect calculations of impervious area for ultimate land use. The bug was fixed and the software to overcome this bug was posted on the GISHydro web site.
4. I have created a new GISHydro2000 install program and posted it at the GISHydro web site for general distribution just today. This new install includes

- the new coding for Task 1 above, and items 6.1 and 6.3 as well.
5. I have corrected a bug in the Region of Influence calculations that arose when the computed discharge was less than 100 ft³/s. This correction was part of the new posting on 10/24/2002.
 6. I have addressed questions from Ms. Randah Kamel concerning how rating curves are calculated. (This question arose the week of 10/28/2002.) I await further comment from SHA as to whether I should modify GISHydro2000 in light of Randah's concerns about the number of in-channel vs. the number of out-of-bank points in the rating curve.
 7. I have addressed questions from Ms. Randah Kamel concerning how channel cross-section information (x,y) data may be output to an external file for plotting outside of GISHydro2000. (This question arose the week of 10/28/2002.) I will build such a tool to make this exporting of information more straightforward however this tool is not part of the 10/24/2002 build.
 8. Ms. Randah Kamel indicated that it would be useful to output the (x, y) coordinates of the cross-sections that are "cut" by the engineer for each routing reach. An extra button has been added to the Cross Section Editor Dialog that says "Export Cross Section". Pressing this button exports the cross-section indicated by the engineer to a text file that can then be imported into third party software for graphical plotting or other analysis.
 9. Ms. Randah Kamel indicated that many SHA engineers had difficulty locating the Discharge Comparison Table which is created as the ultimate output of Task 1 described above. I have added a text file export dialogue that outputs tab-delimited text file to a user specified filename and location. This file can then be readily imported into, for instance, Excel, for further analysis or simply incorporated into a report document.
 10. New Ultimate Land Use was obtained from Prince Georges County and GISHydro2000 was updated to reflect these data on July 17, 2003
 11. A new method for estimating standard errors was adopted by the Hydrology Panel and was incorporated into new changes to the umdgishydro.avx file on July 31, 2003.
 12. I met with Andy Kosicki, Jeff Knaub, Kelly Brennan, and Regan Carver following the Hydrology Panel meeting on July 29, 2003. Several shortcomings to be fixed in the short term including the reporting of discharges to 3 significant figures and the use of CN rounded to the nearest integer value. These changes along with a new rasterization tool requested by Regan Carver were part of the GISHydro.apr file posted on August 4, 2003 and all subsequent postings.
 13. As a result of the December meeting of the Hydrology Panel, I revised GISHydro2000 to calculate and report the finalized (rural and urban) peak flow regression equations developed by Moglen and Thomas. This change was posted to the GISHydro2000 web page in December 2004.
 14. Andy Kosicki and Jennifer Sampson had some good questions about the calculation of the longest flowpath. I met with Andy and several of his engineers on December 23, 2003 to demonstrate revisions I had developed to the velocity method time of concentration calculator. GISHydro2000 now produces a table with an entry for each pixel along the longest flow path of all sub-areas within the

watershed. This table is keyed to a “longest flow path” theme that appears in the “Area of Interest” view. The table shows the incremental and cumulative travel times along with the type of flow (overland, mixed, swale, or channel) along with some other local quantities (e.g. drainage area, slope, flow length, etc). A small portion of a representative table is shown below:

Attributes Of Longest Path Sub 0													
Value	Count	Type	Mixed	Da	Slope	Width	Depth	Area	L_length	Tot_length	Vel	L_time	Tot_time
1	1	overland	No	1	0.0100	-1.00	-1.00	-1.00	100.0	100	0.18	0.156	0.156
2	1	swale	No	2	0.0100	-1.00	-1.00	-1.00	141.4	241	1.60	0.025	0.180
3	1	swale	No	5	0.0071	-1.00	-1.00	-1.00	100.0	341	1.35	0.021	0.201
4	1	swale	No	6	0.0100	-1.00	-1.00	-1.00	100.0	441	1.60	0.017	0.218
5	1	swale	No	7	0.0300	-1.00	-1.00	-1.00	141.4	583	2.77	0.014	0.233
6	1	swale	No	11	0.0300	-1.00	-1.00	-1.00	100.0	683	2.77	0.010	0.243
7	1	swale	No	32	0.0400	-1.00	-1.00	-1.00	141.4	824	3.20	0.012	0.255
8	1	swale	No	36	0.0500	-1.00	-1.00	-1.00	100.0	924	3.58	0.008	0.263
9	1	swale	No	65	0.0400	-1.00	-1.00	-1.00	141.4	1066	3.20	0.012	0.275
10	1	swale	No	86	0.0071	-1.00	-1.00	-1.00	100.0	1166	1.35	0.021	0.296
11	1	swale	No	88	0.0100	-1.00	-1.00	-1.00	141.4	1307	1.60	0.025	0.320
12	1	swale	No	119	0.0100	-1.00	-1.00	-1.00	100.0	1407	1.60	0.017	0.337
13	1	swale	No	122	0.0400	-1.00	-1.00	-1.00	100.0	1507	3.20	0.009	0.346
14	1	swale	No	124	0.0300	-1.00	-1.00	-1.00	100.0	1607	2.77	0.010	0.356
15	1	swale	No	139	0.0400	-1.00	-1.00	-1.00	141.4	1749	3.20	0.012	0.368

15. As a result of this meeting some additional modifications were identified (including the implementation of the channel geometry equations based on the Fish and Wildlife Service (McCandless and Everett, 2002; McCandless, 2003a, McCandless, 2003b) channel geometry studies in Maryland. The time of concentration dialog box was modified to allow for the engineer to specify channel extent either via the National Hydrography Dataset (NHD) data provided by the USGS at 1:100,000 mapping or via a minimum channel source area. The engineer is additionally presented with the default (area weighted) channel geometry equations from the FWS which can be modified if desired. A sample version of this dialog box is shown on the next page.
16. Two new GISHydro2000 installations were posted to the GISHydro web page, the first (early January) to reflect changes to the Time of Concentration calculation if using the velocity method. The second (mid-January) to fix a small bug in this time of concentration reporting.



17. On January 29, 2004 I discovered a remaining bug in the GISHydro2000 program. Although the FWS channel geometry equations were implemented for the time of concentration, I neglected to use these equations in the cross-section editor. I have fixed this oversight.
18. On February 26, 2004 I added Anne Arundel county to the SSURGO soils database.

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Appendix A

Use of Interactive Dialog Box for Modifying Land Use in GISHydro2000

Introduction

Part of the project the Maryland State Highway Administration project: “Continued Enhancements to GISHydro2000” (SP208B4J) is Task 5: “Build GIS-based tool so that MDSHA engineers can revise Ultimate Zoning Coverage as needed.” This document describes and illustrates the use of this tool. It should be noted that although the Task specifically identifies the “Ultimate Zoning Coverage”, the tool described in this document can be applied generally across all land use coverages contained within GISHydro2000.


Reasons for Using Tool

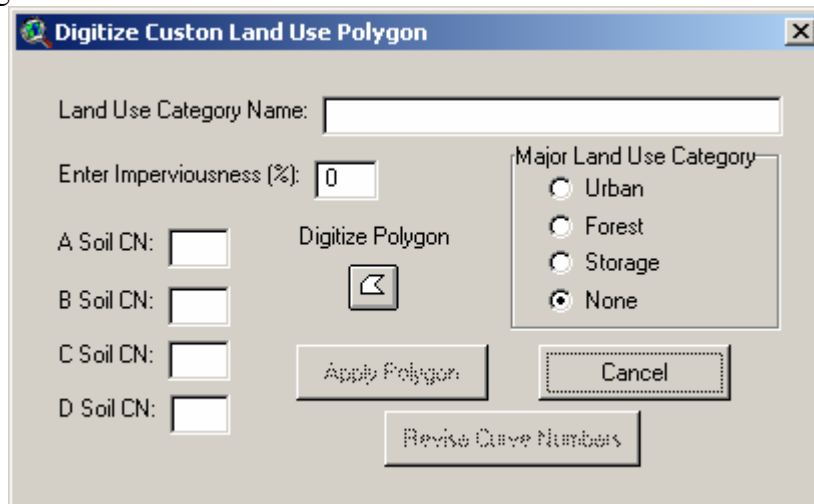
There are several reasons why one might wish to use this tool:

1. When working with ultimate zoning data, the base information contained within the GISHydro2000 database may not be current in the location of a particular watershed analysis. This tool can be used to update the base information to reflect recent zoning changes.
2. The most likely land use data to be used in GISHydro2000 to reflect “current” conditions are the data supplied by the Maryland Department of Planning (MDP). These data indicate generalize land cover across approximately 25 land cover categories. The hydrologic characteristics of some of these categories (e.g. “Institutional”) are not particularly well-defined and may vary considerably from one location to another. This tool can be used to create a new land use category that reflects land cover/land use conditions that are well-understood by the engineer making the change through paper maps or field reconnaissance.
3. A second weakness of the MDP data is its broad “low density residential” land use category which includes housing densities from half-acre lots up to 2-acre lots. The imperviousness and/or curve numbers associated with this range of housing densities can vary considerably depending on whether the actual density is close to the upper or lower bound of this range. This tool can be used to create a new land use category that more precisely captures the actual housing density through the specification of curve numbers or degree of imperviousness specified directly by the engineer for this new land use category.

Using the Tool

Step 1 – Select the Quadrangles/Delineate the Study Watershed (as usual): The analysis performed by the engineer proceeds as before with the engineer using the “Q” button to define the quadrangles that are indicated for a particular analysis. GISHydro2000 will create the “Area of Interest” view with focused on the data for the selected quadrangles. The land use modification tool can now be used, although I suggest the user go one step further and also delineate the watershed before proceeding to use this tool since only the land use within the watershed need be updated.

Step 2 – Invoke the Land Use Modification Dialog: Press the “LU” () button, located to the right of the “Q” button used earlier to initiate the analysis. This will bring up the dialog box shown below:



* Note: Steps 3 through 6 below can be performed in any order provided the directions in these steps are followed appropriately.


Step 3: Entering the Land Use Category Name: Enter in this box the text describing the land use category. You may want to include a special parenthetical comment indicating that this is a special, user defined category. For example, “Residential, 1-acre houses (user defined).” This field is for informational purposes only and is not a required input.

Step 4: Indicating the Major Land Use Category: There exist three special classes of land use that need to be indicated for correct calculation of the “Basin Statistics” and/or the USGS regression equations. These categories are, “urban”, “forest”, and “storage”. User simply needs to click on the category that applies to the new land use category being specified. If none of these categories apply, leave the selection set as the category, “none”. Please note that the “forest” and “storage” categories assume and impose an imperviousness of 0%.

Step 5: Indicating the Curve Numbers and/or Imperviousness: The default imperviousness is 0% as the dialog box opens. There are no default curve number values. So long as the major land use category is “urban” or “none” the imperviousness box is editable. Any numerical entry in imperviousness box will result in the calculation of the associated A, B, C, and D curve numbers according to the formulas:

$$\begin{aligned}
 x \cdot 98 + (1 - x) \cdot 39 &= CN_A && \text{(A Soil)} \\
 x \cdot 98 + (1 - x) \cdot 61 &= CN_B && \text{(B Soil)} \\
 x \cdot 98 + (1 - x) \cdot 75 &= CN_C && \text{(C Soil)} \\
 x \cdot 98 + (1 - x) \cdot 80 &= CN_D && \text{(D Soil)}
 \end{aligned}$$

where x is the imperviousness expressed as a fraction of 1. All curve numbers are rounded to the nearest integer value. Please note that any manual entry in the imperviousness box after the curve number boxes have been filled out will undo entries manually entered in the curve number boxes. If you wish to manually *both* specify curve numbers and imperviousness, you should first specify the imperviousness and then the curve numbers.

Step 6: Digitizing the Land Use Polygon: Press the “Digitize Polygon” button () and digitize on the computer screen the outline of the polygon of land use you are specifying. Two things to note: 1) To end the digitizing of the polygon, double-click rapidly at the last location of the polygon you are updating; 2) You cannot digitize multiple polygons for a given category simultaneously. If you have multiple polygons you wish to digitize that you wish to have the same land use, you must repeatedly perform identical data entry steps indicated here for each area as if each polygon were a different land use, but assigning the same land use category name, major land use, and curve numbers/imperviousness. If you digitize more than one polygon without hitting the “Apply Polygon” button in between, only the last digitize polygon will be recorded into your updated land use/curve number coverages.

Step 7: Applying the Polygon: Only after both a polygon has been digitized and curve number/imperviousness information has been entered will the “Apply Polygon” button become active (black). At the time this button is pressed, the text information indicated in the dialog box along with the last digitized polygon (see Step 6 above) are written to disk. If the “Apply Polygon” button is not pressed and the dialog box is exited (through the use of the “Cancel” button or the “X” box at the upper-right corner of the dialog) then any information contained in the dialog box at the time of exiting is lost. The Land Use Modification Dialog may be opened once and multiple polygons of land use entered and applied, or the dialog may be opened multiple times each time specifying one or more polygons of land use.

Step 8: Revising the Curve Numbers: After one or more polygons of modified land use are entered and applied, the “Revise Curve Numbers” button becomes active “black”. Until this button has been pressed, the land use and curve number themes have not been revised to reflect any of the changes entered in this dialog. This button needs to be pressed only once, at the conclusion of the entry of all modified land use polygons, but may actually be pressed anytime after the first land use change polygon has been completely entered. Note that once this button has been pressed, the legend colors for the display of the “Land Use” and “Curve Number” themes are changed. Since it is impossible to anticipate what kinds of land use will be entered by the engineer, no effort has been made to control the color legends for these themes. For the land use theme, the engineer must manually modify the legends for these themes with the appropriate colors associated with all previously existing and new categories of land use. This is chronologically the last button you will press when using this dialog. Once you are finished with this dialog you can proceed with your hydrologic analysis as done previously.

Step 9: Using the “Cancel” Button: Pressing this button (or the “X” button at the upper-right corner of the dialog) cause the dialog box to close with any information contained in the dialog at the time of exiting being permanently lost. For instance, you may wish to use this button if you are unhappy with the polygon you have digitized. You could then re-open the dialog box by pressing the “LU” with no memory of any information entered previously (the defined polygon or other text information) being retained since the last time the “Apply Polygon” button was pressed.

Documenting Modified Land Use: The “Digitize Custom Land Use Polygon” dialog stores information in two places during and after use of this dialog is completed. Non-GIS information is stored in the landuse lookup table. The digitized polygons are stored in a shapefile (3 physical files make up 1 shapefile). Both of these entities are written to the c:\temp directory.

The Landuse Lookup Table: This table is visible within the GIS as one of the table called, “Landuse Lookup Table.” The file that contains the information in displayed in this table is located on the machines hard-drive at, “c:\temp\templutab.dbf”. The default version of this table corresponding to the selection of Maryland Department of Planning land use data is shown below:

Lucode	Classifica	Hyd_a	Hyd_b	Hyd_c	Hyd_d	Imp	Lucat
10	Urban	89	92	94	95	0.30	u
11	Low Density Residential	54	70	80	85	0.25	u
12	Medium Density Residential	61	75	83	87	0.30	u
13	High Density Residential	77	85	90	92	0.65	u
14	Commercial	89	92	94	95	0.82	u
15	Industrial	81	88	91	93	0.70	u
16	Institutional	81	88	91	93	0.50	n
17	Extractive	77	86	91	94	0.11	n
18	Open Urban Land	39	61	74	80	0.11	n
20	Agriculture	67	78	85	89	0.00	n
21	Cropland	67	78	85	89	0.00	n
22	Pasture	39	61	74	80	0.00	n
23	Orchards	32	58	72	79	0.00	n
24	Feeding Operations	89	92	94	95	0.00	n
25	Row Crops	67	78	85	89	0.00	n
40	Forest	30	55	70	77	0.00	f
41	Deciduous Forest	30	55	70	77	0.00	f
42	Evergreen Forest	30	55	70	77	0.00	f
43	Mixed Forest	30	55	70	77	0.00	f
44	Brush	30	48	65	73	0.00	f
50	Water	100	100	100	100	0.00	s
60	Wetlands	100	100	100	100	0.00	s
70	Barren Land	77	86	91	94	0.50	n
71	Beaches	77	86	91	94	0.00	n
72	Bare Exposed Rock	77	86	91	94	1.00	n
73	Bare Ground	77	86	91	94	0.50	n
80	Transportation	100	100	100	100	1.00	n
191	Large Lot Agricultural	67	78	85	89	0.15	n
192	Large Lot Forest	30	55	70	77	0.15	f
241	Feeding Operations	67	78	85	89	0.10	n
242	Agricultural Buildings	67	78	85	89	0.10	n

The “Hyd_x” fields (columns) indicate the curve numbers that apply to this land use category for soil type “x.” The “Imp” field shows the default imperviousness associated with each land use category as a decimal fraction. The “Lucat” field indicates the major land use class (see Step 4) that applies to each land use category (“u”=urban, “f”=forest, “s”=storage, and “n”=none. The values and category descriptions appearing in the leftmost two fields will vary depending on the land use coverage selected by the engineer at the time the analysis is initiated. Additional records (rows) starting

with values of Lucode = 501 will be added to this table if the land use modification dialog is used to indicate new land use polygons. This table should be included as a standard part of all hydrologic analysis reports.

The “lumod” shapefile: This file is not loaded into the GIS. It exists only on disk as “c:\temp\lumod.xxx” (where xxx are the 3 file extensions: “shp”, “shx”, and “dbf” that make up a shapefile.) If land use is changed as part of a given analysis, this shapefile should be included electronically as a standard part of the reporting of that analysis.

Some Comments on Representative Imperviousness Values

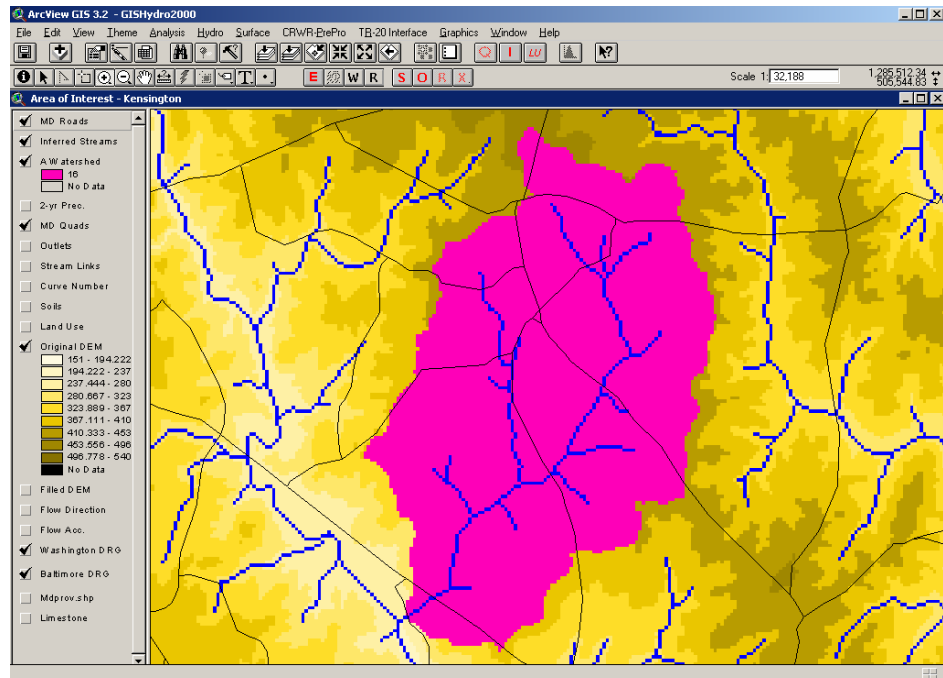
The NRCS has published some representative imperviousness values for several different categories of urban land. These are repeated below in Table 1.

Table 1. Representative percent imperviousness values from NRCS.

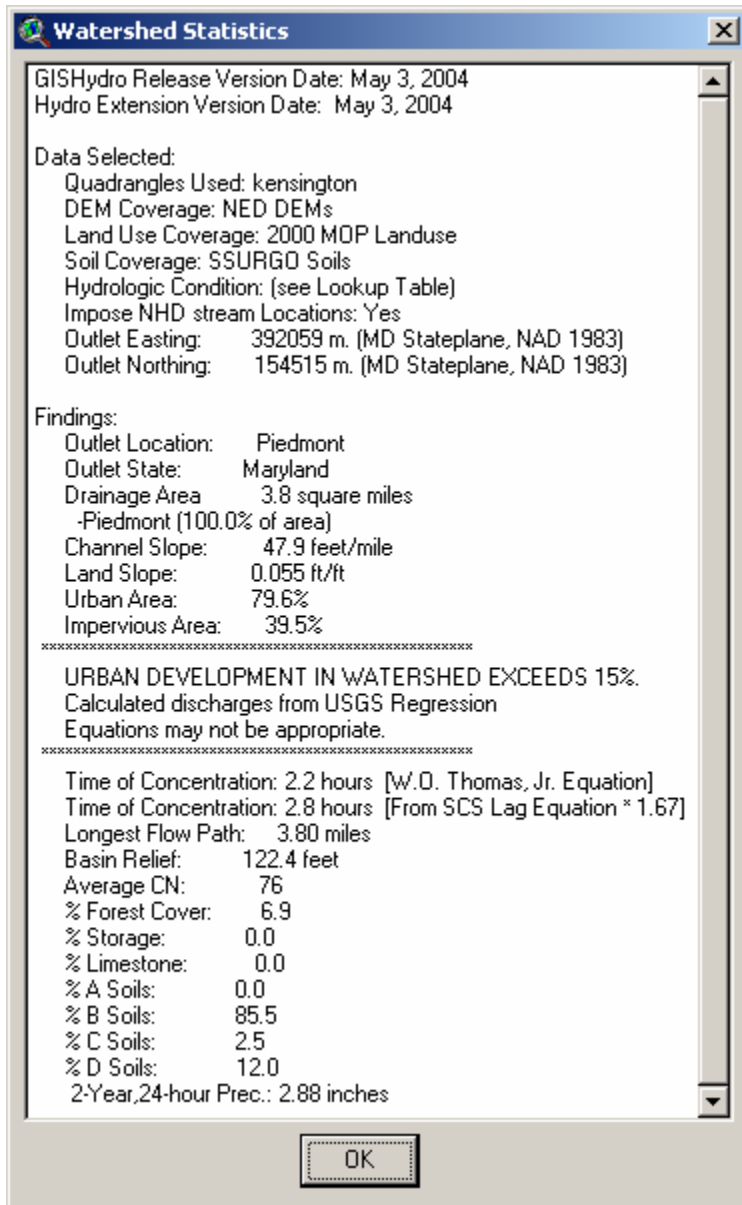
Land Use Category	Imperviousness (%)	Imperviousness values used by default in GISHydro2000 are very consistent with Table 1 and may be viewed or changed by modifying the contents of the “Landuse Lookup Table” contained in GISHydro2000 and discussed above under “Documenting Modified Land Use”.
Commercial and business	85	
Industrial	72	
Residential (1/8 acre or less)	65	
Residential (1/4 acre)	38	
Residential (1/3 acre)	30	
Residential (1/2 acre)	25	
Residential (1 acre)	20	
Residential (2 acres)	12	

Illustration

The screen capture to the right shows a small delineated watershed in the Kensington quadrangle. To illustrate the use of the land use modification tool, the default basin statistics are shown in the “Watershed Statistics” dialog box shown below. (It is not necessary to perform this step, but it is done here to

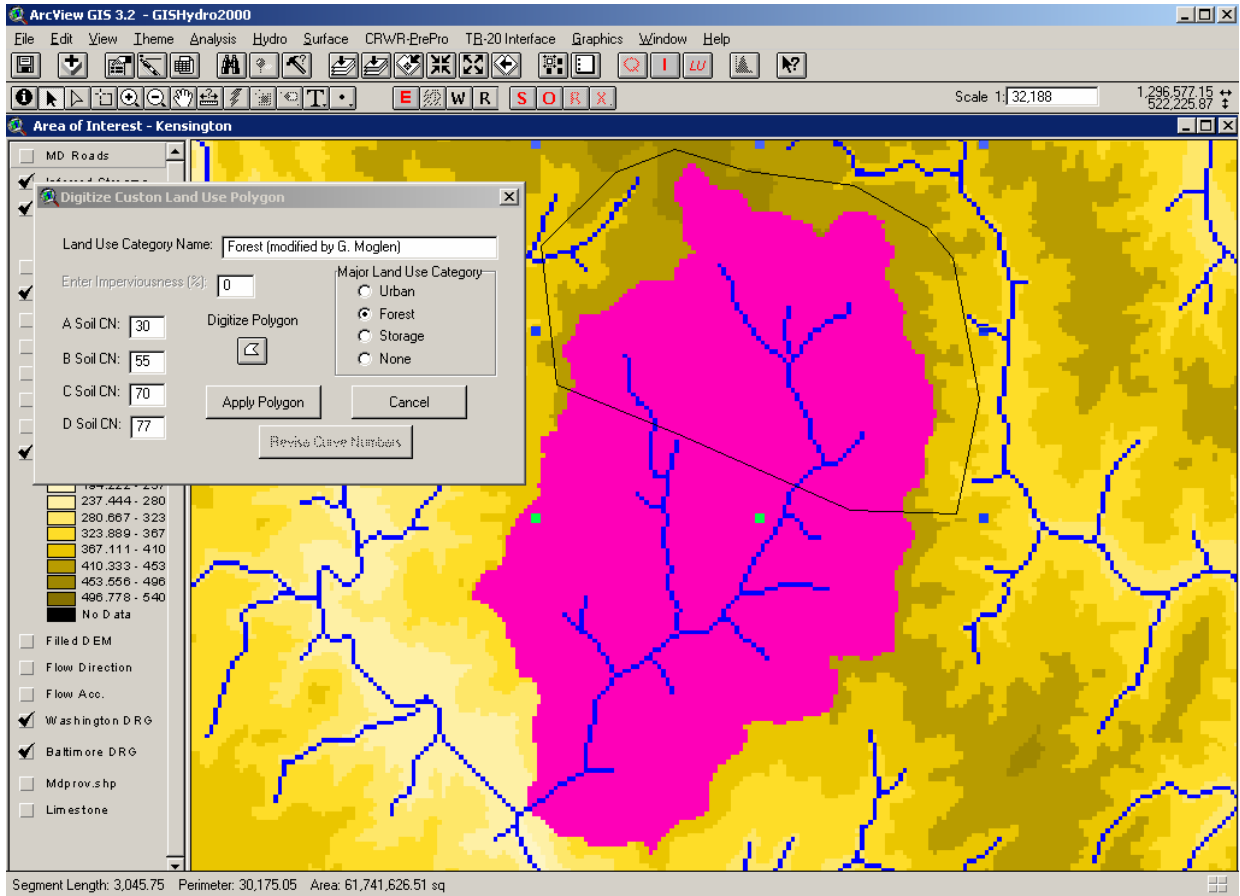


illustrate the effects of the land use modification tool.




We now begin the process of updating the land use within the delineated watershed. For illustration purposes two new land use polygons will be indicated.

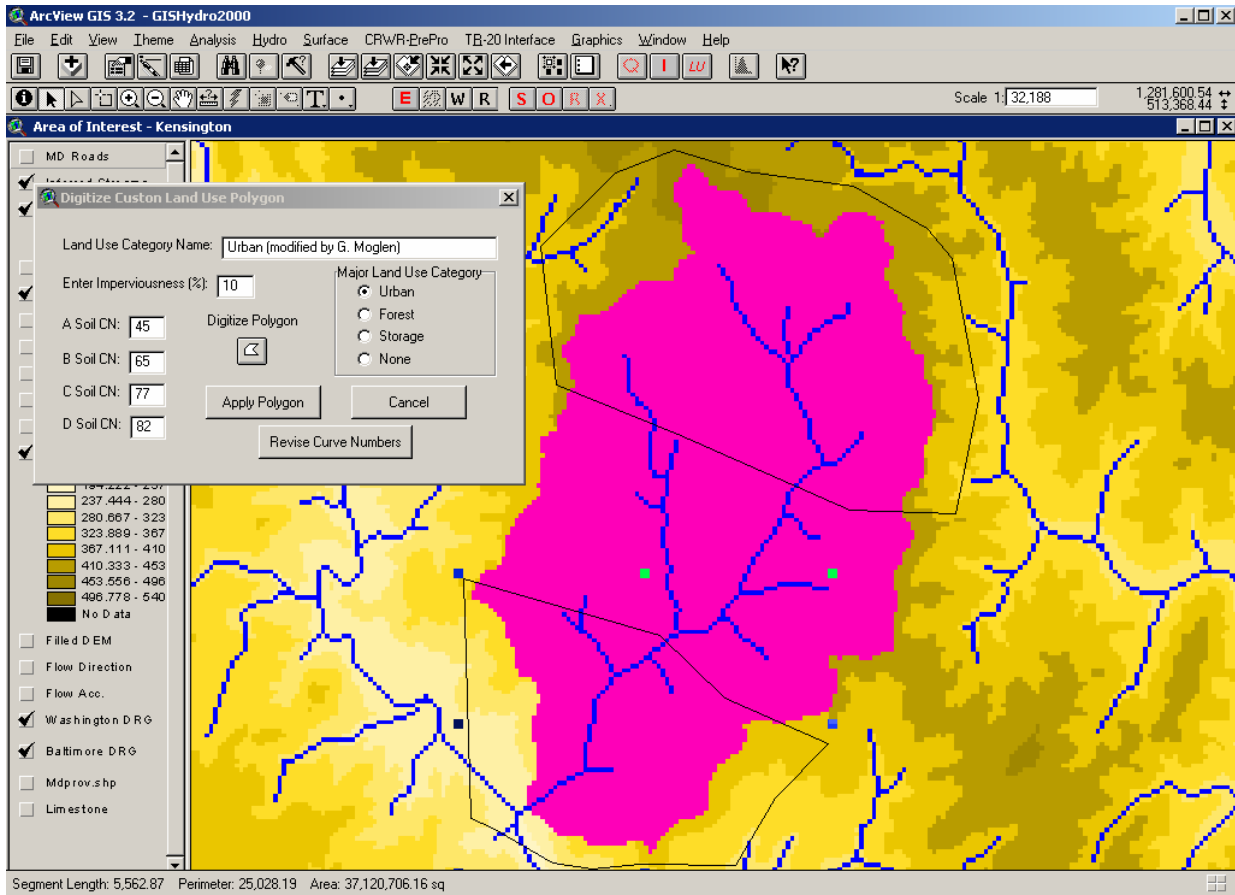
- **Polygon #1:** The first polygon will occupy the northern third of the watershed and will be of forested land use.
- **Polygon #2:** The second polygon will occupy the southern third of the watershed and will be of urban land use, with 10% imperviousness.




Polygon #1: Steps shown on this page:

1. Invoke the land use modification tool by pressing the “LU” button.
2. Indicate a name for the land use category. (Here we enter, “Forest (modified by G. Moglen)” to indicate both the land use type and the fact that this is a departure from the default 2000 land use defined by the MDP.)
3. Since this is a forested polygon, click on the “Forest” indicator under the “Major Land Use Category.” Notice that this has the effect of “graying out” the imperviousness text box with the value fixed at 0%.
4. Set the curve numbers for the A-D soils by typing the values in the appropriate text box. The values shown are 30, 55, 70, and 77 for A, B, C, and D soils, respectively. These values need to be manually entered.
5. Press the “Digitize Polygon” button () and digitize on the computer screen the outline of the forested polygon. To end the digitizing process, double-click rapidly on the final point of the polygon. Notice that the digitizing process need only apply over the domain of the watershed. Land use modifications outside the boundaries of the watershed will have no effect on the basin statistics or subsequent calculations.

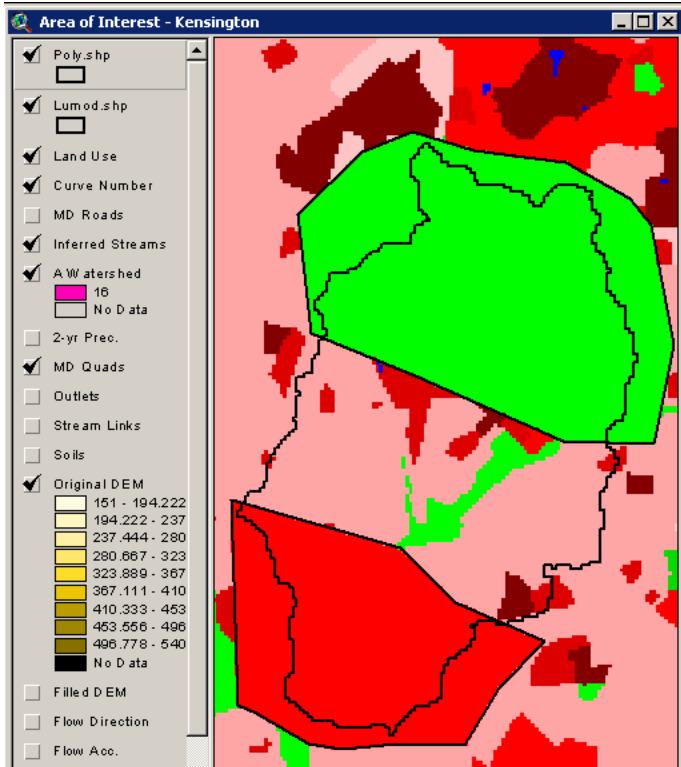
Press the “Apply Polygon” button to accept the text and polygon information shown above. Notice that the “Apply Polygon” button only becomes active after steps 2 through 5 have been completed. Also, steps 2 through 5 can be performed in any order.



Polygon #2: Steps shown on this page:

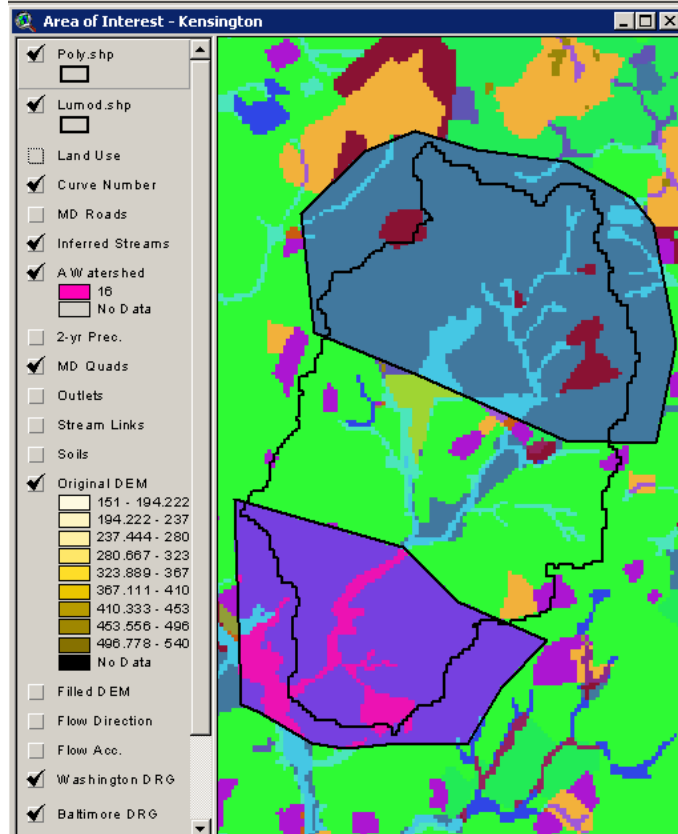
1. Indicate a name for the land use category. Here we enter, “Urban (modified by G. Moglen).”
2. Since this is an urban polygon, click on the “Urban” indicator under the “Major Land Use Category.”
3. In the “Enter Imperviousness” text box, type “10” to indicate 10% imperviousness. This will automatically populate the A-D curve number boxes following the equations presented earlier on page 2. If different curve number values are desired they should be entered *after* the imperviousness is indicated.
4. Press the “Digitize Polygon” button () and digitize on the computer screen the outline of the forested polygon.
5. Press the “Apply Polygon” button to accept the text and polygon information shown above.

Having “applied” both polygons, we can now do the final step, which is to press the “Revise Curve Numbers” button. This has the effect of updating both the “Land Use” and “Curve Number” themes shown in the area of interest view per the modifications applied with the land use modification dialog. The resulting view is shown at the top of the next page:



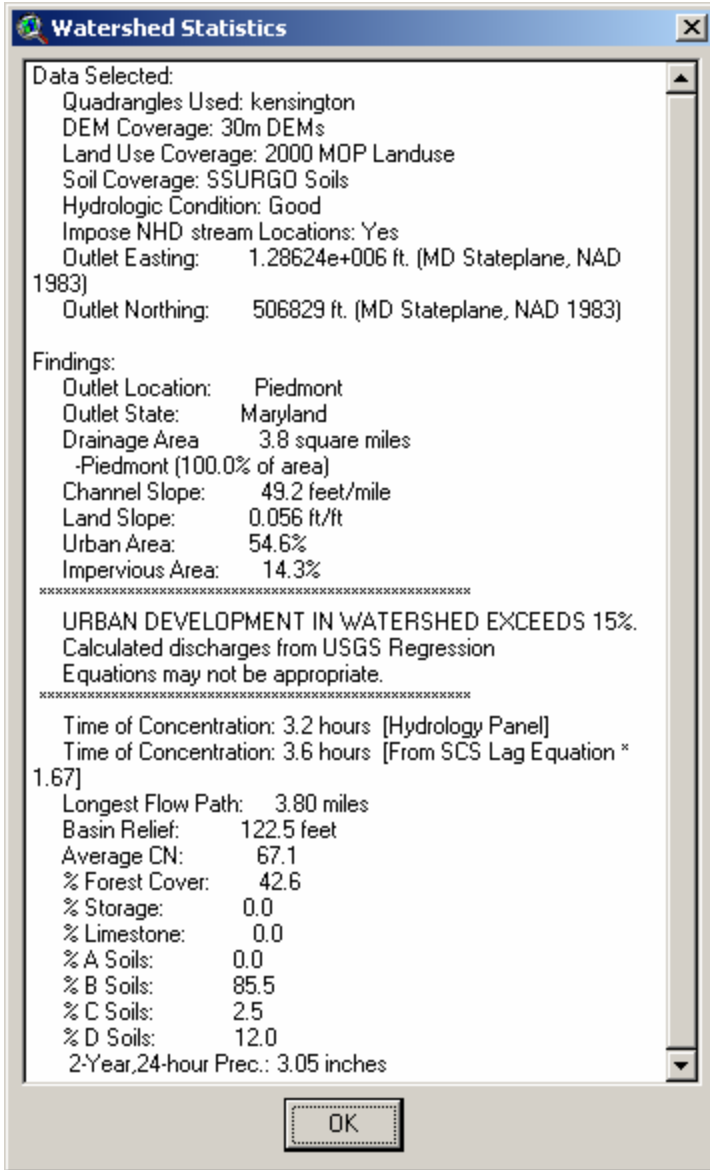
The view shows the land use as it now exists with the modifications described earlier. (It should be noted that this illustration at right has been enhanced a little bit to make the modifications to the land use theme more clear. The watershed outline is shown explicitly – this would not normally be the case, and the shapefile, “lumod.shp” has also been loaded into the view to make the land use changes clear. This is also not normally the case. Finally, the color scheme: green for the forested polygon and red for the urban polygon was chosen to make the land use changes more clear. The effect on the curve number theme is not as clear, but is shown in the

illustration below to demonstrate that the modifications have propagated to the curve number themes as well. The areas within the two digitized polygons clearly exhibit different values than the neighboring areas outside these polygons. This is consistent with what one would expect for land use modifications such as the ones illustrated in this example.



The Landuse Lookup Table as it appears in the GISHydro2000 project is shown at right. Notice the two new records with Lucode equal to 501 and 502 at the bottom of this table. These are the two records that were added to this table through the use of the land use modification tool.

Lucode	Classifica	Hyd_a	Hyd_b	Hyd_c	Hyd_d	Imp	Lucat
10	Urban	89	92	94	95	0.30	u
11	Low Density Residential	54	70	80	85	0.25	u
12	Medium Density Residential	61	75	83	87	0.30	u
13	High Density Residential	77	85	90	92	0.65	u
14	Commercial	89	92	94	95	0.82	u
15	Industrial	81	88	91	93	0.70	u
16	Institutional	81	88	91	93	0.50	n
17	Extractive	77	86	91	94	0.11	n
18	Open Urban Land	39	61	74	80	0.11	n
20	Agriculture	67	78	85	89	0.00	n
21	Cropland	67	78	85	89	0.00	n
22	Pasture	39	61	74	80	0.00	n
23	Orchards	32	58	72	79	0.00	n
24	Feeding Operations	89	92	94	95	0.00	n
25	Row Crops	67	78	85	89	0.00	n
40	Forest	30	55	70	77	0.00	f
41	Deciduous Forest	30	55	70	77	0.00	f
42	Evergreen Forest	30	55	70	77	0.00	f
43	Mixed Forest	30	55	70	77	0.00	f
44	Brush	30	48	65	73	0.00	f
50	Water	100	100	100	100	0.00	s
60	Wetlands	100	100	100	100	0.00	s
70	Barren Land	77	86	91	94	0.50	n
71	Beaches	77	86	91	94	0.00	n
72	Bare Exposed Rock	77	86	91	94	1.00	n
73	Bare Ground	77	86	91	94	0.50	n
80	Transportation	100	100	100	100	1.00	n
191	Large Lot Agricultural	67	78	85	89	0.15	n
192	Large Lot Forest	30	55	70	77	0.15	f
241	Feeding Operations	67	78	85	89	0.10	n
242	Agricultural Buildings	67	78	85	89	0.10	n
501	Forest (modified by G. Mogl	30	55	70	77	0.00	f
502	Urban (modified by G. Mogl	45	65	77	82	0.10	u



Finally, the basin statistics can be recalculated for the example watershed that should now reflect the changes on the curve number. The resulting “Watershed Statistics” dialog is shown at left. Several values related to the land use and curve number modifications have clearly changed and are noted in Table 2 below.

Table 2. Comparison of Watershed Statistics for Original and Modified Land Use Data

Parameter (units)	Original Land Use	Modified Land Use
Urban Area (%)	79.7	54.6
Impervious Area (%)	34.7	14.3
T_c – Hyd. Panel (hours)	2.3	3.2
T_c – SCS Lag (hours)	2.7	3.6
Average Curve Number	76.7	67.1
Forest Cover (%)	6.9	42.6

Appendix B

Time of Concentration Dialogue Box and Reporting

In late December 2003/early January 2004 the time of concentration dialogue box was modified significantly as it applies to the “Velocity Method” time of concentration calculation.

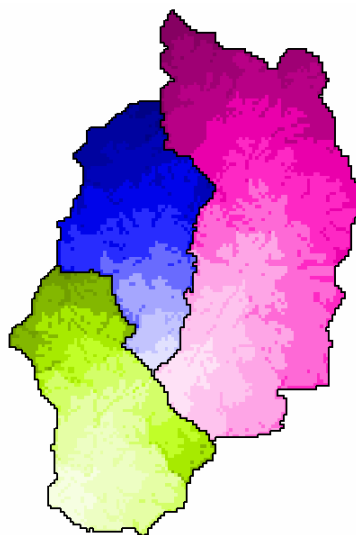
First, some background is appropriate. The velocity method divides the total travel time into increments of overland (sheet) flow, shallow concentrated flow, and channel flow.

- Overland flow is typically assumed to take place for a comparatively short distance at the upstream extreme of the flow path. From conversations with Don Woodward (NRCS-retired) and Bill Merkel (NRCS) the appropriate upper-bound for this length is generally accepted to be 100 feet (this is the GISHydro2000 default value). A sheet flow Manning’s roughness and the 2-year rainfall depth are the other remaining parameters. The default values for these are 0.1 and 3.2 inches, respectively.
- Channel flow occurs over those distances where a well-defined channel exists. In lieu of a heavy digitizing task, GISHydro2000 provides two alternatives for defining channels.
 - The first alternative defines channels to be those areas strictly digitized as blue lines in the 1:100,000 National Hydrography Dataset (NHD) developed by the USGS. 1:24,000 scale mapping would be more appropriate, but is not universally available over the spatial extent covered in the GISHydro2000 database.
 - The second alternative allows the user to specify a minimum “source area” which is interpreted as the minimum area required to form a channel. The smaller the value indicated, the greater the drainage density and vice-versa. A default value of 0.0896 mi² is suggested based on the author’s anecdotal experience that this value seems to approximately correspond to the upstream extent of digitized 1:100,000 scale blue lines in Maryland. Since GISHydro2000 keeps track of drainage area for every pixel in the Area of Interest view, it is a simple matter to determine which pixels exceed this source area and are, thus, considered channels.

Channel velocities are determined by a user specified Manning’s *n* (this is the “*nc*” value – default is as shown as $nc = 0.05$) and channel geometry equations from the U.S. Fish and Wildlife Service regional curves (McCandless and Everett, 2002; McCandless, 2003a, McCandless, 2003b). Default values are suggested for channel geometry (channel width, channel depth, channel area) based on the U.S. FWS equations and physiographic location of the watershed. It is ***not recommended*** that these values be modified unless specific additional information for the study site is available.

- Swale flow occurs as the residual of that which is neither overland nor channel flow. There is only one choice of parameters for swale flow. A roughness parameter corresponding to either “paved” or “unpaved” conditions must be selected. “Unpaved” is the default setting.

If the “Velocity Method Tc Calculation” method is chosen, the user is presented with the dialogue box shown on the next page. Once the user has specified the method

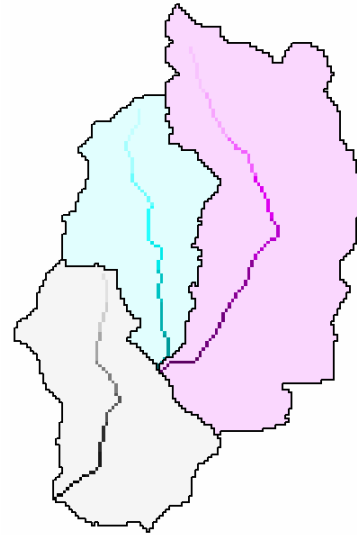


and parameter settings, the “Set” and “Close” buttons are used. When the “CRWR-PrePro: Calculate Attributes” menu choice is selected, the time of concentration is determined as one of several watershed parameters that are calculated and written to various internal tables in preparation for writing the ultimate TR-20 input file. Upon completion of the attribute calculation the engineer will notice a series of new grids in the “Area of Interest” view appearing in pairs with the names “Longest Path Sub x” and Time to Outlet Sub x” where x is a number from 0, 1, ... n -1 for n sub-areas.

The “Time to Outlet” grids provide a shaded map of travel time. The figure at the left shows a sample watershed with three sub-areas, each shaded according to travel time to the individual sub-areas. These grids are useful for visualization purposes, and the maximum value for each grid indicates the largest travel time (and hence, the time of concentration) for each sub-area.

Shown at the top of the next page, the “Longest Path” grids isolate the unique flow path in each sub-area that corresponds to the maximum travel time for that sub-area.

The greater value of this second set of grids is not so much the visual representation of the longest flow path, but the associated table for this grid. A portion of such a table is shown below. This table gives a pixel-by-pixel accounting of the time of concentration calculation from the upstream extent of the longest flow path (pixel value 1) to the downstream outlet of the sub-area (pixel value 83, in this case). From left to right the table entries are: **Value** (an identification number increasing from 1), **Count** (always 1), **Type** (overland, swale, or channel), mixed (“No” if flow is entirely overland, swale, or channel, “Yes” if flow is partially overland and swale), **Da** (the drainage area in number of 30m pixels), **Slope** (the local slope for that pixel, dimensionless), **Width** (bankfull width in feet, -1 if not a channel), **Depth** (bankfull depth in feet, -1 if not a channel), **Xarea** (bankfull cross-sectional area in ft², -1 if not a channel), **I_length** (single pixel {incremental} flow length in feet), **Tot_length** (total length from upstream end of



Attributes Of Longest Path Sub 2													
Value	Count	Type	Mixed	Da	Slope	Width	Depth	Xarea	I_length	Tot_length	Vel	I_time	Tot_time
0	2828												
1	1	overland	No	1	0.0072	-1.00	-1.00	-1.00	98.4	98	0.16	0.176	0.176
2	1	overland	Yes	2	0.0152	-1.00	-1.00	-1.00	139.2	238	1.60	0.024	0.200
3	1	swale	No	5	0.0518	-1.00	-1.00	-1.00	98.4	336	3.64	0.008	0.207
4	1	swale	No	7	0.0610	-1.00	-1.00	-1.00	98.4	434	3.95	0.007	0.214
5	1	swale	No	9	0.0518	-1.00	-1.00	-1.00	98.4	533	3.64	0.008	0.222
6	1	swale	No	10	0.0610	-1.00	-1.00	-1.00	98.4	631	3.95	0.007	0.229
7	1	swale	No	11	0.0610	-1.00	-1.00	-1.00	98.4	730	3.95	0.007	0.235
8	1	swale	No	12	0.0610	-1.00	-1.00	-1.00	98.4	828	3.95	0.007	0.242
9	1	swale	No	13	0.0427	-1.00	-1.00	-1.00	139.2	967	3.31	0.012	0.254
10	1	swale	No	14	0.0305	-1.00	-1.00	-1.00	98.4	1066	2.79	0.010	0.264
11	1	swale	No	16	0.0274	-1.00	-1.00	-1.00	139.2	1205	2.65	0.015	0.278
12	1	swale	No	28	0.0305	-1.00	-1.00	-1.00	98.4	1303	2.79	0.010	0.288
13	1	swale	No	40	0.0396	-1.00	-1.00	-1.00	98.4	1402	3.18	0.009	0.297
14	1	swale	No	61	0.0396	-1.00	-1.00	-1.00	98.4	1500	3.18	0.009	0.305
15	1	swale	No	68	0.0305	-1.00	-1.00	-1.00	98.4	1599	2.79	0.010	0.315
16	1	swale	No	75	0.0305	-1.00	-1.00	-1.00	98.4	1697	2.79	0.010	0.325
17	1	swale	No	84	0.0213	-1.00	-1.00	-1.00	98.4	1796	2.34	0.012	0.337
18	1	swale	No	86	0.0396	-1.00	-1.00	-1.00	98.4	1894	3.18	0.009	0.345

flow path in feet), **Vel.** (velocity in ft/s), **I_time** (single pixel {incremental} travel time in hours), **Tot_time** (total travel time from upstream end of flow path in hours).

Based on the results obtained and documented in these “Longest Path” grids and tables, the user may choose to iterate somewhat by varying the method of indicating where channel flow

Part of Table omitted here...

71	1	channel	No	10606	0.0072	24.58	1.84	45.14	98.4	7844	3.45	0.008	0.967
72	1	channel	No	10611	0.0072	24.59	1.84	45.16	139.2	7984	3.45	0.011	0.978
73	1	channel	No	10626	0.0072	24.60	1.84	45.21	98.4	8082	3.45	0.008	0.986
74	1	channel	No	10642	0.0072	24.61	1.84	45.25	139.2	8221	3.45	0.011	0.997
75	1	channel	No	10658	0.0274	24.63	1.84	45.30	139.2	8360	6.75	0.006	1.003
76	1	channel	No	10761	0.0305	24.72	1.85	45.62	98.4	8459	7.13	0.004	1.007
77	1	channel	No	10768	0.0213	24.73	1.85	45.65	139.2	8598	5.97	0.006	1.013
78	1	channel	No	10786	0.0072	24.74	1.85	45.70	139.2	8737	3.47	0.011	1.025
79	1	channel	No	10797	0.0061	24.75	1.85	45.73	139.2	8876	3.19	0.012	1.037
80	1	channel	No	10807	0.0072	24.76	1.85	45.77	139.2	9016	3.47	0.011	1.048
81	1	channel	No	10841	0.0091	24.79	1.85	45.87	98.4	9114	3.91	0.007	1.055
82	1	channel	No	10847	0.0072	24.80	1.85	45.89	139.2	9253	3.47	0.011	1.066
83	1	channel	No	10875	0.0072	24.82	1.85	45.98	139.2	9392	3.47	0.011	1.077

begins, the source area to form a channel, whether the swale flow is paved or unpaved, etc, although it should be noted that if the user selects different parameters for the time of concentration calculation, the longest flow path may “jump” to a different location in the watershed, so it is important that the user always examine the longest flow path theme

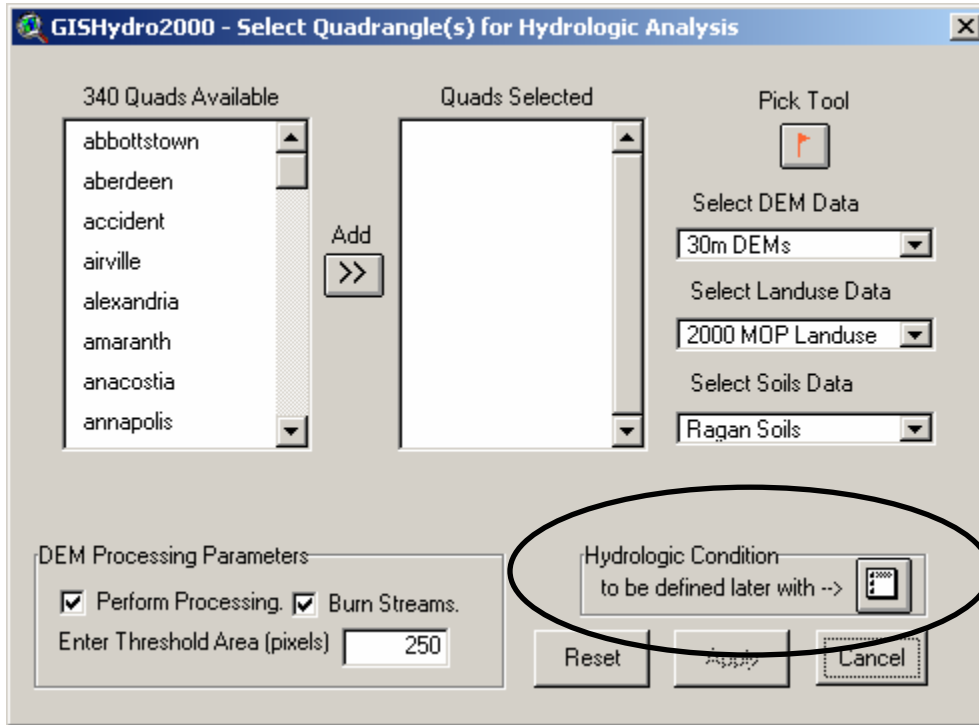
and confirm that they are consistent with his/her understanding of the upstream extent of the channel and channel roughness characteristics. Once this consistency has been verified, the user can use the GIS interface to export these longest flow path tables to individual text (or other format) files for reporting purposes.

Appendix C

Notes on the Modify Hydrologic Condition Dialog

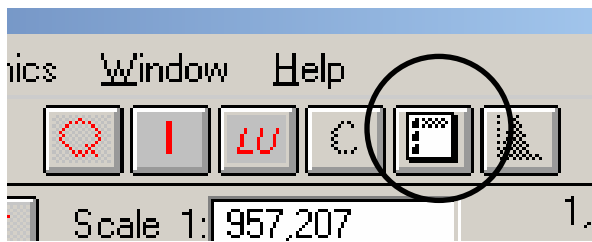
This document explains and illustrates a structural change to GISHydro2000 focused on the need to specify curve numbers within GISHydro2000 that vary according to land use category. A new “Modify Hydrologic Condition” dialog now allows the engineer to specify that, for instance, medium density residential land might be in “fair” hydrologic condition while, deciduous forest might be in “good” hydrologic condition, and commercial land might be in “poor” hydrologic condition. Use of this dialog is not necessary. If this dialog is not used, hydrologic conditions are treated as “good” across all land used categories.

The engineer proceeds as usual with the first indication of change shown below in the “Select Quadrangle(s)” dialog box. The circled area shows a change where the user

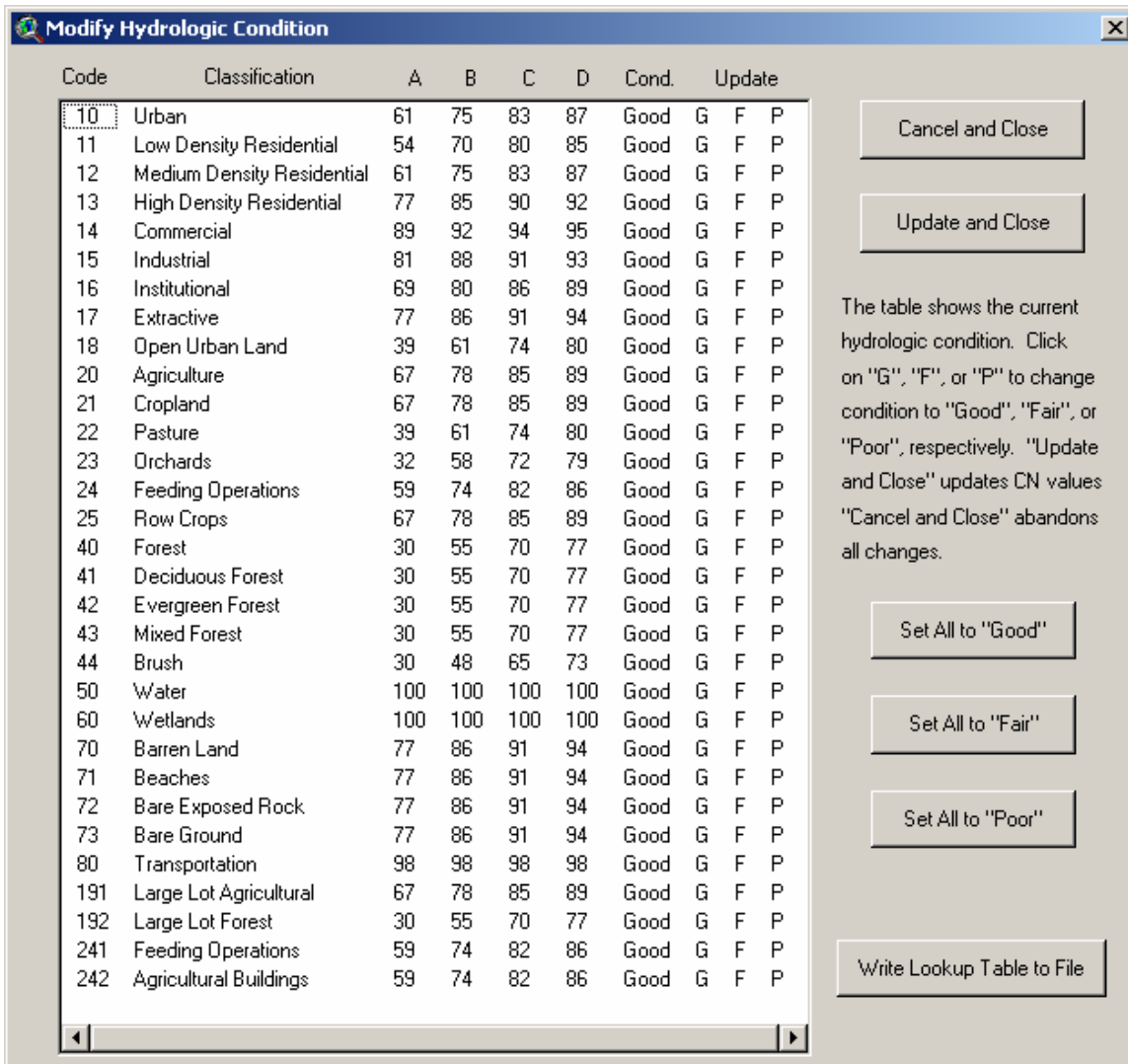


had previously checked either “Good” or “Fair” hydrologic condition to be applied uniformly across all land use categories. The user now makes no selection here, but postpones such decision(s) until slightly

later in the analysis process. At this point, the engineer needs only to specify the other normal selections: quad(s), DEM, Landuse, Soils, and parameters controlling DEM processing.



Once the engineer has selected the extent and types of data to be used, an “Area of Interest” view appears as previously. At this point the engineer should notice that the button circled in the image to the left becomes functional. Pressing this button initiates the “Modify Hydrologic Condition” dialogue as shown on the next page.



From left to right across the table, this dialog shows the land use code, land use category, the A, B, C, and D curve numbers for each category, the current understood hydrologic condition, and then the letters “G,” “F,” and “P.” The engineer can update the hydrologic condition for any one category by pressing the appropriate letter “G” (Good), “F” (Fair), or “P” (Poor) as needed. If a wholesale change is desired, the buttons “Set All to ‘Good’”, “Set All to ‘Fair’”, and “Set All to ‘Poor’” change the hydrologic condition across all hydrologic conditions simultaneously.

Once all desired changes are made, the engineer should press, “Update and Close,” this will update all the indicated changes in the table and apply these changes to the “Curve Number” theme as it appears in the “Area of Interest” view. For reporting purposes, the “Write Lookup Table to File” behaves the same as the “Update and Close” button, but also provides a file browser dialog box for the engineer to direct an output text file for the updated lookup table. The “Cancel and Close” button exits the dialog with none of the changes that may have been entered taking effect.

A few cautionary words are necessary. If changes are made to the lookup table, then any previous calculations involving the curve number (e.g. selecting the “Basin Statistics” choice from the “Hydro” menu or the “Calculate Attributes” from the

“CRWR-PrePro” menu must be repeated (after modifying the lookup table) so as to incorporate the revised curve number values. Also, if any custom land uses are added using the “Digitize Custom Land Use Polygon” (obtained by pressing the “*LU*”) button, the curve numbers associated with any added special land uses will appear in the “Modify Hydrologic Condition” dialog. However, the curve numbers associated with such specialized land use categories ***will not*** be editable because GISHydro2000 has no way of knowing what the appropriate “Good,” “Fair,” and “Poor” hydrologic conditions for such polygons would be.