GISHydro Nutrient Loading Interpolator for the Chesapeake Bay Program Model - Phase II

FINAL REPORT

Submitted to:

Maryland Department of the Environment

By:

Dr. Glenn E. Moglen
Principal Investigator
Department of Civil and Environmental Engineering
Virginia Tech
Falls Church, Virginia 22043

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Overview

This document presents the GISHydro program with a specific emphasis of its application to the problem of estimating nutrient loads based on the Chesapeake Bay Program Office (CBPO) modeling of nutrient loading in the Chesapeake Bay Watershed. The nutrient loads employed in the GISHydro program correspond directly to the CBP Watershed Model Scenario Output Database, Phase 4.3 (please see: http://www.chesapeakebay.net/data_modeling.aspx). Best management practices (BMP) nutrient and sediment reduction efficiencies are also drawn from the Phase 4.3 modeling effort (please see: http://archive.chesapeakebay.net/pubs/NPS_BMP_Tables_011806.pdf) and are summarized in Table 6-1 of this document.

This document assumes that the reader is fairly capable in the use of web browsers and Microsoft Excel and modestly capable in the use of GIS software – specifically ArcView 3.3. GISHydro is an ArcView GIS 3.3 project that includes all the data and algorithms to perform a wide range of hydrologic analyses. One suite of data and tools contained in this program is geared towards the use of GISHydro to produce nutrient loading estimates (nitrogen, phosphorus, and sediment) for any arbitrary polygon area (e.g. could be a property outline or watershed boundary). GISHydro contains some additional tools that allow the user to specify a range of BMP plans and examine the nutrient loading reductions associated with these plans. Alternatively, GISHydro contains an auxiliary set of nutrient loading tables that produces estimates of Maryland's 2004 Tributary Strategy loads without the need (or ability) to specify any BMPs explicitly.

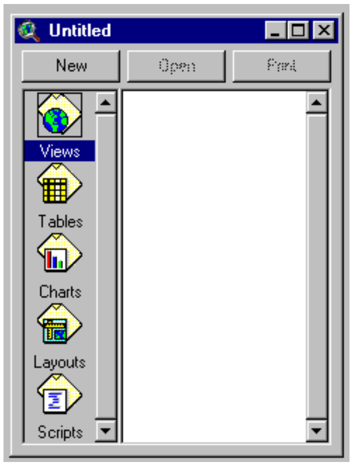
The first part of this document presents some basics for using the ArcView GIS software program. These basics emphasize navigating around the "View" window with a modest exposure to some of the other "documents" that ArcView allows you to examine and manage. The remainder of these preliminaries cover how to obtain an account on the GISHydro web server and install the software on your machine necessary to communicate with the web server (Citrix). That is, the GISHydro software resides on a computer that you will access over the web; however, to communicate and share files with that computer, you need to install a free software program on your computer called "Citrix" (versions of Citrix are available for both PCs and Macs). Information is provided on how to upload and download files to and from the GISHydro web server. Finally, a section is provided that explains some basic terminology used by both the GISHydro software and within this documentation.

The second part of this document contains a series of exercises that illustrate the use GISHydro to produce nutrient loading estimates. Step-by-step descriptions of analyses ranging from setting up a nutrient loading study to importing output into Microsoft Excel, to using alternative Maryland Department of Planning land use data to specifying BMPs are provided. The reader who works through each of these exercises and has good GIS skills should be able to broadly apply this program to any nutrient loading analysis within the State of Maryland.

ArcView Tutorial

This brief tutorial will provide an overview of the organization and basic use of ArcView. To learn more, it is strongly recommended that you obtain a book on ArcView and/or read the on-line help.

Documents



ArcView allows the user to view and use a number of different types of "documents" in order to perform GIS-based analyses. The window at the right shows an "empty" ArcView project as you first enter the software. The different icons on the vertical bar indicate a number of the broad categories of documents that ArcView recognizes: views, tables, charts, layouts, and scripts. We will discuss only those documents which need to be understood to effectively use GISHydro.

Views

The "View" window is the document you are most likely to think of when you think of a GIS. This is the window that visually displays the spatially distributed data that is being analyzed. Within GISHydro there will be two view windows that are used extensively: the "Maryland View" and the "Area of Interest". We will discuss the contents and functionality of these views later.

Themes

Strictly speaking, "themes" are not documents, but are rather "sub-documents" that appear within the "View" window. A theme is an areal coverage showing the distribution of a certain property such as county boundaries, the road network, land use, etc. Themes come in three types: feature, image, and grid. Feature data is ArcView's name for the "Vector" data format in generic GIS terms. Image data is ArcView's way of allowing the user to load in aerial photography or scanned maps to provide useful background context to a map. Although this data is a "Raster" data format in generic GIS terms (i.e. the picture is really a large matrix of pixels), there is no "intelligence" associated with the image, it is simply there to add context. Grid data is ArcView's name for the "Raster" data format in generic GIS terms. The spatial analyst extension of ArcView must be installed and active for ArcView to handle this data type; however, if you are using the web-based version of GISHydro, spatial analyst is already part of the application. Most of the important data manipulations taking place within GISHydro take advantage of the grid data type and the functionality associated with it.

Tables

The true “power” of a GIS is its ability to associate tables with visually displayed information like land use, elevation, or soils maps. Within the GISHydro there will be two kinds of tables that are of particular interest. The first is a table that associates land use and soil type with a particular curve number. We have provided a standard lookup table, identical to the one used previously in the original “GISHydro”. The second table (actually two tables) provides a breakdown of the land use distribution by soil type and shows the curve numbers used.

Layouts

For purposes of reports or simply conveying complex spatial relationships, you will often find that you would like to print a copy of the ArcView “View” window. This is best done using the Layout document type which automates much of the necessary labeling, orientation, and scale issues associated with producing a proper map.

Scripts

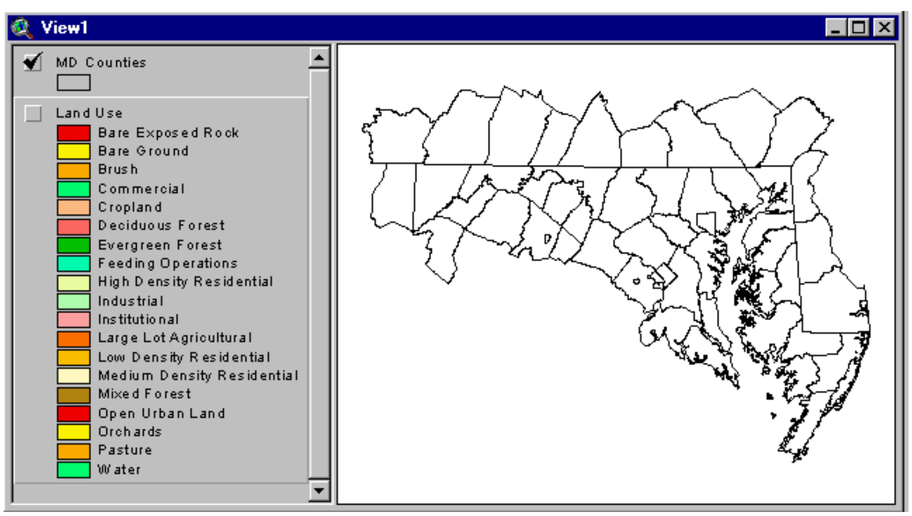
The script document type gives the user access to ArcView at a programming level. It allows the user to automate repetitive tasks or perform complicated operations simply by clicking a button. For example, GISHydro is actually a series of scripts linked together to allow a variety of specific actions by the user.

The View Window

We will now discuss just a few of the most basic concepts within the ArcView “View” environment:

Active vs. Visible Themes

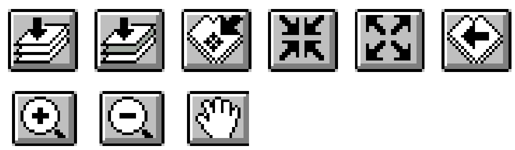
Shown at the right is an ArcView “View” window with two themes loaded into it. The two themes are “Land Use” and “MD Counties” as shown in the “legend” portion of the window. You will note that the legend entry for a theme consists of three parts: a “visibility” box, an “information content” box, and (very subtle) simply the area occupied by the theme within the legend which we will call the “activity” box.



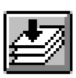
You will notice that the visibility box is checked on for "MD Counties" which indicates to ArcView that this information should be displayed within the View window. You should also notice that the activity box of "Land Use" is "popped up" relative to "MD Counties". This means that "Land Use" is the active theme (even though it is not visible). Many of the functions of ArcView are designed to work only on the active theme(s). To make a theme active, simply click anywhere within the legend box occupied by the theme. You should see that it seems to pop up relative to the other themes. If you want more than one theme active at a time, hold down the shift button and click on all the theme legends you want to have active. It is easy to mistakenly think that the displayed theme is the active one. As this example illustrates, this is not necessarily the case. Activity and visibility are two different properties of a theme.

<u>Navigating within the View Window</u>

ArcView provides a number of buttons and tools to move around within the "View" window and inspect the data. At right, the top row of icons are "buttons" which allow you to easily zoom and pan the extent of the view window that you want to see. The second row of icons are "tools" that require some additional input from you to make the view window zoom or pan as you desire. From left to right the top row of buttons work as follows:

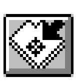


- **Zoom to the Extent of All Data:** This button zooms to the extent of all themes loaded into the view window. If you have themes of differing extent (for instance a theme covering only a single county) and another theme covering the entire state, this button will zoom to the extent of the state.

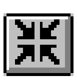


- **Zoom to the Extent of Active Data:** This button zooms to the extent of only active theme(s) in the view window. If your single county coverage is the only active theme, pressing this button will zoom to the extents of the county, regardless of the extents of other data in the view window.

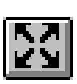
- **Zoom to Selected Data:** When only some items of a vector theme have been selected, this button will zoom the view to only to the extents of these selected items.



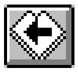
- **Zoom In Incrementally:** This allows you to zoom in centered on the current condition of the view window a small amount. This button is good if you want to slightly nudge the view window to display the contents at center slightly larger. If you want to perform a more substantial zoom you should use the "magnifying glass tool (+)" described below.



- **Zoom Out Incrementally:** This button is the opposite of the one above, panning the view

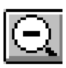
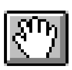


out by a small amount. If you want to perform a more substantial pan you should use the "magnifying glass tool (-)" described below.

- **Zoom to Previous View:** ArcView remembers previous conditions of the view window. You  can click this button to scroll backwards through view extents you have already had.

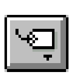
You might also note that all of these functions can also be performed from the "View" menu choice as well. It is often the case that menu choices have corresponding buttons to speed the operation. In the case of navigating the view, you will probably find it easier to use the buttons than the menu choices.

We now move to the three "tools" that allow you to speed the window navigation process. From left to right the bottom row of tools work as follows:

- **Magnifying Glass Tool(+):** This tool allows you to draw a rectangle around the area you wish  to zoom to. The rectangle can be as big or little as you wish and you can use this tool repeatedly to zoom in as tight to a location as you wish.
- **Magnifying Glass Tool(-):** This tool works like the one above except that the amount of  "panning" performed is inversely proportional to the size of the window you draw. If you draw a big rectangle within the View window, it works much like the "Zoom out incrementally" button. If you draw a very small window, the view will pan out to a very great degree.
- **Hand Tool:** This tool works by grabbing a point in the view window and dragging it up,  down, to the left or right as desired to move the center of the view from one location to another.

<u>The "Identify" Tool</u>

With any theme active, you can use the identify tool to inspect the contents of any pixel or item. Click on the theme(s) you want to be active, click on the identify tool, then click on the pixel or item you want to know more about. A dialogue box will appear providing information on the selected pixel or item. Note that image data, like areal photos, have no underlying information to be shared via the identify tool.



<u>The "Label" Tool</u>

When trying to orient yourself within GISHydro, you may find it helpful to use the provided road network theme. By first selecting the Label tool and then clicking on any road in the vicinity of the desired watershed outlet, ArcView will label that road with a recognizable name such as I-495, MD 193, etc. This should help you feel very confident of your whereabouts when trying to find a specific location.

The Table Window

As stated earlier, tables are an integral part of GIS operations. To look at the table associated with any theme in the View window you should make that theme active (popped up), then select "Theme: Table..." from the menu list. You should be able to look at the tables associated with any feature theme, and many grid themes. Grid themes of continuous data may not have viewable tables because they would simply have too many entries.

The Layout Window

We will not discuss layouts at length here. We strongly suggest you consult additional tutorials or other documentation to learn more about the layout facility. You will want to use this facility for the creation of finalized maps associated with your GIS work.

To quickly generate a print-ready map, orient the view just as you would like for it to be displayed. From the "View" menu choice, choose "Layout...". You will be asked to choose a basic orientation and style template and then a "Layout" window will appear. Everything in this window is potentially editable by double-clicking on the desired item to change its contents, size, orientation, etc.

Getting and using a GISHydroweb account

There are several things you need to know to currently use GISHydro2000 from the web. These instructions will allow you to test the web-based version, however, the details of logging in may change over the next few weeks to months.

Step 1: Obtain Login Information

Access to the GISHydro2000 web version is free, however to control access to the web site is password protected. This is done for two reasons:

1. To provide added security to the server that is supporting the web version.
2. To help us document usage of the server.

To obtain a username and login, please contact Glenn Moglen (moglen@vt.edu) and request a login to the server. You should provide the following information with your username request:

- Your full name
- Your email address
- Your company or employer
- Your phone number

Step 2: Download Plug-in

The web-based version runs by using software from Citrix. In order to use this software, it is necessary to download and install a plug-in from this company. The plug-in you download depends on the operating system your machine is running.

- Windows XP or earlier, use: http://129-2-71-200.umd.edu/Citrix/MetaFrame/ICAWEB/en/ica32/ica32t.exe

- Windows Vista, use: http://129-2-71-200.umd.edu/Citrix/MetaFrame/ICAWEB/en/ica32/XenAppHosted.msi

There's also a link to these plug-in programs at: http://www.gishydro.umd.edu/web.htm

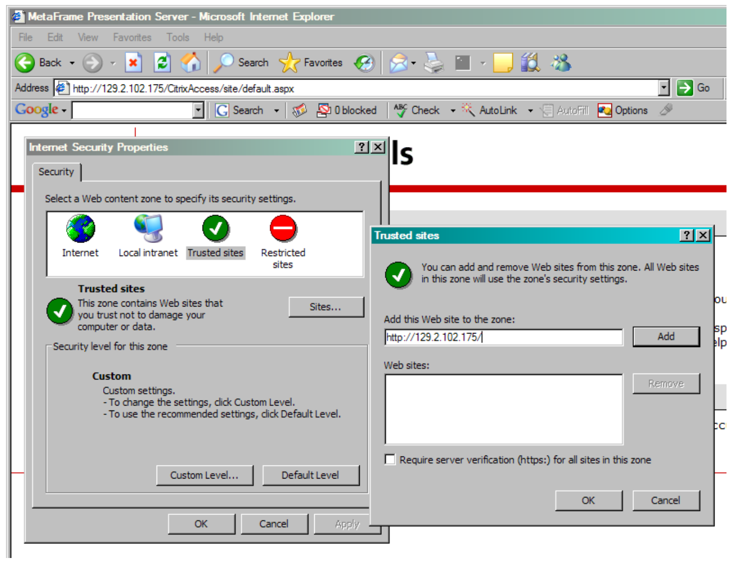
Step 3: Install Plug-in

Once you have downloaded the plug-in, double click on its filename or icon and install. You should receive the following prompt window at the initiation of the installation:

Click on the "Yes" window and accept all the subsequent installation wizard boxes to complete the installation.

Step 4: Set Security in Internet Explorer

It is recommended to indicate to your computer that the server that is supporting the GISHydro2000 program is a "trusted site". To do this, in internet explorer select: Tools: Internet Options. Click on the "Security" tab and then click on the "Trusted Sites" Icon. Then click on the "Sites" button. In the window to the left of the "Add" button, type the URL, http://129-2-71-200.umd.edu. Then click the "Add" button and you should see the URL for this site jump to the lower window labeled "Web Sites:". Click the "OK" buttons to accept this site and close out the change of this internet option. (NOTE: If you are communicating with the server via a Mac computer, you can simply disregard this step.)



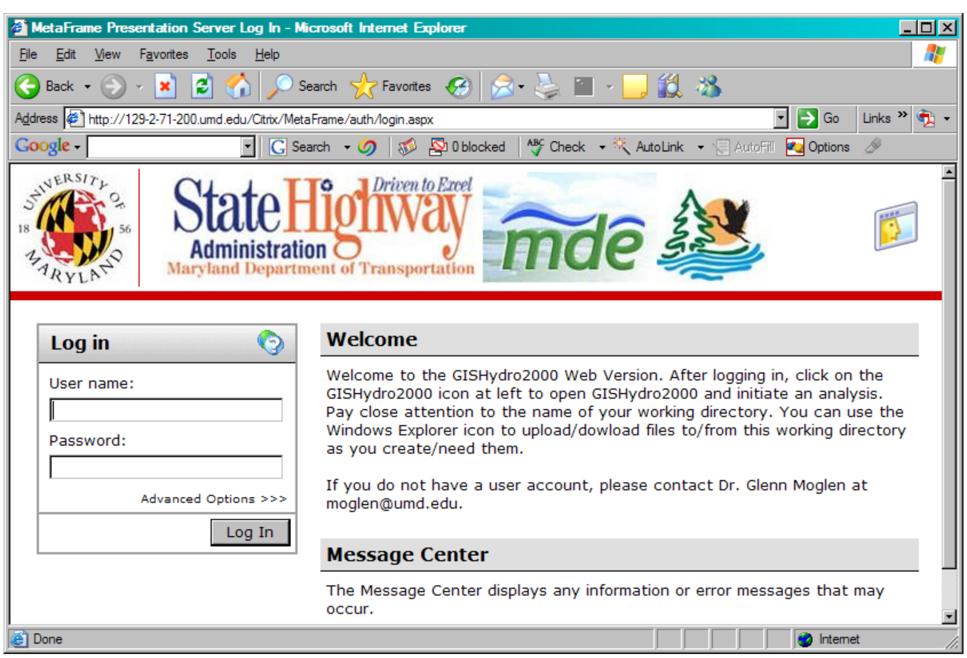
Step 5: Logging into Server

At the Internet Explorer address window, type:

http://129-2-71-200.umd.edu

(alternatively, you can simply follow the link from the main GISHydro web page and follow the link from there.)

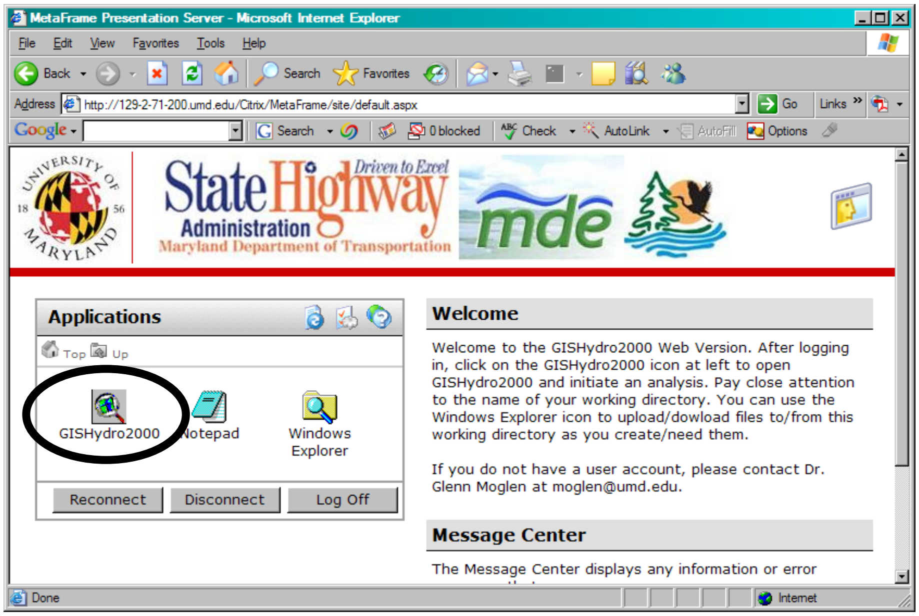
You will then see the browser appear as shown at right. Enter your user name and password obtained earlier in **Step 1**.



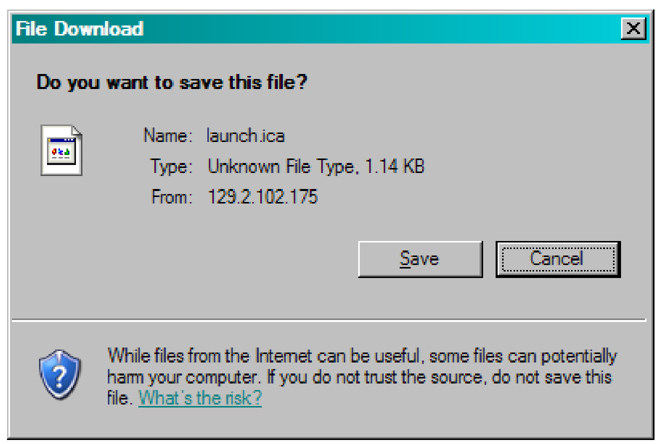
Now click the "Log In" button.

Step 6: Launching GISHydro2000

To launch GISHydro2000, simply click on the "GISHydro2000" icon (shown circled at right) and GISHydro2000 should start up. You are now logged in!

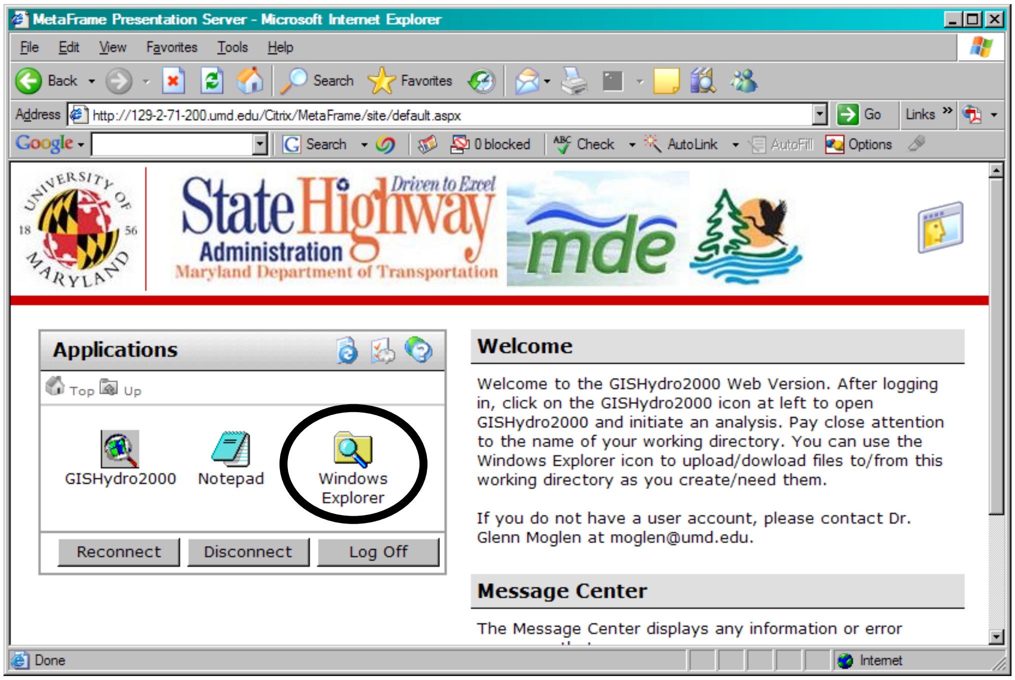


If you have not properly installed the plug in, when you click on the "GISHydro2000" icon, you will instead see the dialog box shown at right. If you get this dialog box, go back and review Steps 2 and 3 and make sure that they were done correctly and completely.

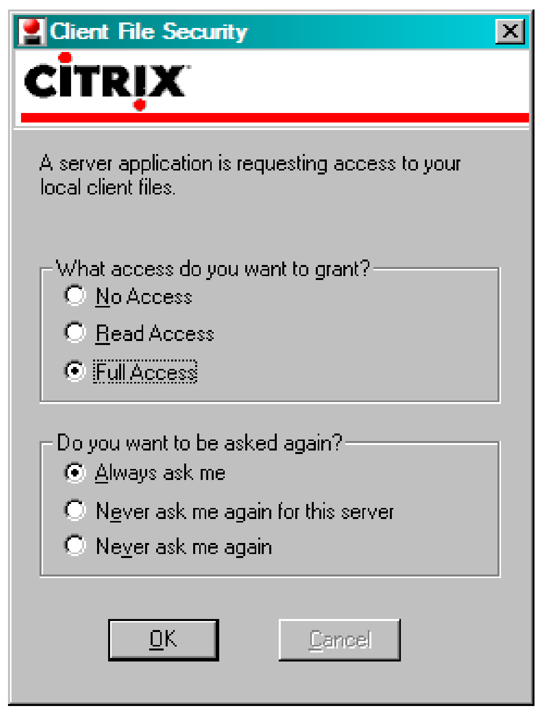


File Management basics for GISHydroweb

Step 1: Providing Remote File Access



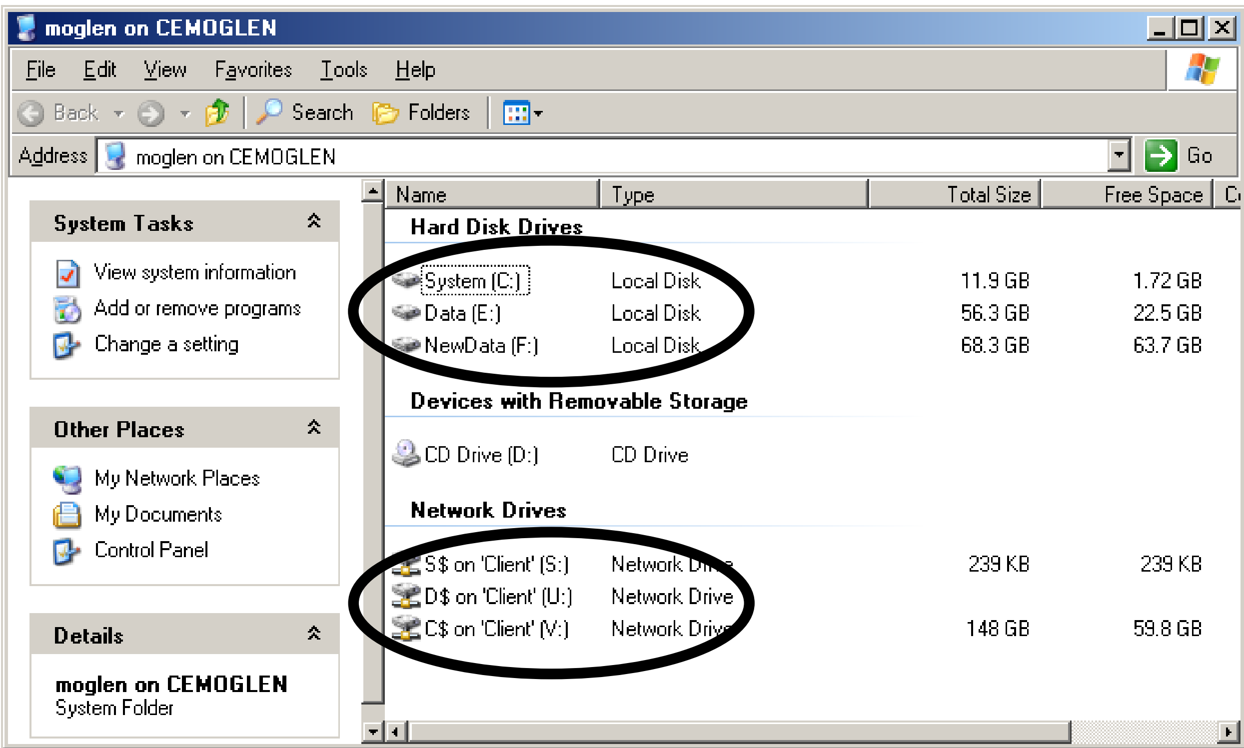
Similar to Step 6 in "**Getting and using a GISHydroweb account**", Click on the Windows Explorer icon (shown circled at right) to launch the windows explorer application. This will result in the shown dialog from the Citrix software. You want to choose "Full Access" to the first question. This will have the effect of mapping the drives on your local machine to the directory structure seen by the server. The effect will be as if the local drives on your machine become available drives to the server. GISHydro2000 will write all files during a given session to the "e:\temp\xxxxx" directory of the server. A number "xxxxx" is randomly assigned as the file name, but you can modify it as you wish. Thus, using Windows Explorer will allow you to copy and move files to/from the e:\temp\xxxxx directory on the server to your local machine as desired. More explanation on this temporary directory is provided in Step 2 below.



Step 2: Copying files between the GISHydro server and your local machine

When working with the webserver, you may naturally wish to upload files from your local machine to the webserver or to download files created by GISHydro on the server down to your local machine. These two activities are described in this step.

a. Preparing for upload or download – understanding what you see: In Step 1 above, you were able to launch a version of Windows Explorer. Let's first look at the application window



that appears. Circled in the application window below are two groups of drives that should appear in the explorer window.

- The top group, labeled "Hard Disk Drives" shows the drives located on the GISHydro web server. Please note that drive "Data (E:)" (also referred to in this document as simply "e:" is where GISHydro and the "e:\temp" directory is located which should contain any user files that you generate during a session on GISHydro.

- The bottom group, labeled "Network Drives" shows the drives on your local machine that you have used to connect to the web server. Shown in the screen capture are three drives which are given logical drive names (from the server's perspective) of "S:", "U:", and "V:". These correspond to the "S:", "D:" and "C:" drives, respectively on my local machine. What you see may vary from this, but the character appearing before the "$" (e.g. "C$" above) indicates the name of the drive on your local machine (e.g "C:" in this example).

- ***All file movement between the server and your local machine needs to be performed through the Windows Explorer application run from the server.*** Windows explorer on your local machine will not work for moving files up/down to/from the server.

b. Preparing to "Drag and Drop": Probably the easiest way to copy files between the server and your local machine is to use the "drag and drop" method. To do this, you should have two copies of Windows Explorer open (i.e. perform Step 1 twice). (Be sure that you are launching Windows Explorer only from the server.) We will refer to these two Windows Explorer windows as "WinExp1" and "WinExp2".

c. Uploading a file:

- In "WinExp1", go to one of the ***"Network Drives"*** (e.g. "C$" which is seen as "V:" by the server) and navigate in WinExp1 until you've located the file you wish to copy to the server.

- In "WinExp2" navigate to "e:\temp" under ***"Hard Disk Drives"***. If you are already working in a specific subdirectory off of "e:\temp", go to that sub-directory (e.g. "c:\temp\liberty"). If you have not yet begun an analysis in GISHydro, you may need to use WinExp2 to create a new folder off of "e:\temp" called, for example "liberty" to which you will be copying files.

- With both WinExp1 and WinExp2 open to the correct folders, simply click on the file in WinExp1, drag it over to WinExp2, and drop the file there. This should initiate a file copy command and upload the file from your local machine to the server.

d. Downloading a file:

- This process is essentially the inverse of uploading a file as described above.

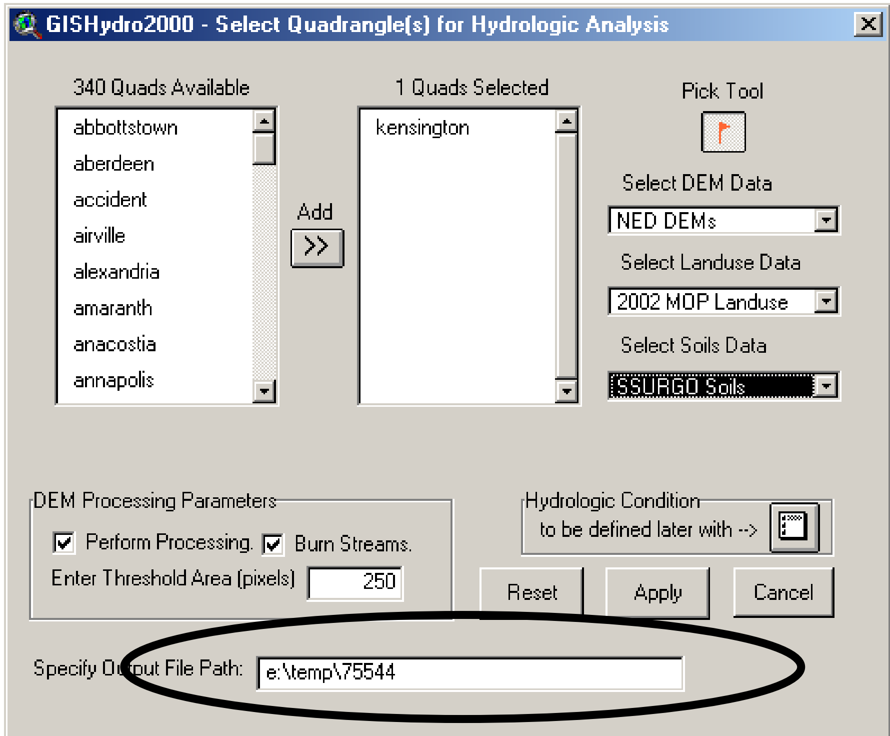
- In "WinExp1", navigate to the folder under ***"Hard Disk Drives"*** that contains the file you wish to download to your local machine.

- In "WinExp2", navigate to the folder under ***"Network Drives"*** where you wish to receive the downloaded file from the server.

- With both WinExp1 and WinExp2 open to the correct folders, simply click on the file in WinExp1, drag it over to WinExp2, and drop the file there. This should initiate a file copy command and download the file from the server to your local machine.

Step 3: File Paths and Valid File Names in GISHydro2000 Software

For security reasons, and to keep files from different users and different projects separate, it is important to understand the file management strategy of GISHydro. As shown at below, the bottom part of the "Select Quads" dialog indicates the default path that GISHydro2000 has assigned for your analysis session. You may accept (and record) this number, or you can specify a more meaningful name of your own. Just be sure to retain the "e:\temp" part and to only use letters or numbers – do not use spaces or unusual characters such as "?", "#", "%" etc. All files you generate in this GISHydro2000 web session will be sent to this path or to directories located deeper along this path.



Step 4: Longevity of Files in the "e:\temp" Directory

Files written to the "e:\temp" directory should be considered temporary. You must make use of the windows explorer tool to move all work to your local machine from the server. At the time of this writing, files will be deleted from the "e:\temp" directory periodically and without warning (generally files less than one week old will not be deleted unless space requirements require otherwise). It is up to you as a user to copy your work promptly and maintain your own permanent version of all created files on your own local machine.

Final Comment:

The number of persons the server can simultaneously support is 10. So, (1) please log out promptly once you've completed your analysis, and (2) if you are unable to log in because all 10 of the licenses are already being used, please let me know. I'd like to know how often this license limit kicks in.

Terminology:

As with any software, there are terms used in this document to indicate various concepts. It is important to read this section closely so that you can understand the meaning of and assumptions behind any a analysis you might perform with GISHydro.

What is a "Development File"?

The starting point of any analysis is the analyst provision of a "Development File". This file is simply a polygon shapefile that indicates unique polygon areas for which nutrient load analyses will be determined. These polygons can be large or small, regular square areas, watershed boundaries, or political boundaries. For more about creating such a file, please see **Appendix A**

"Current" and "Future" refer to land use

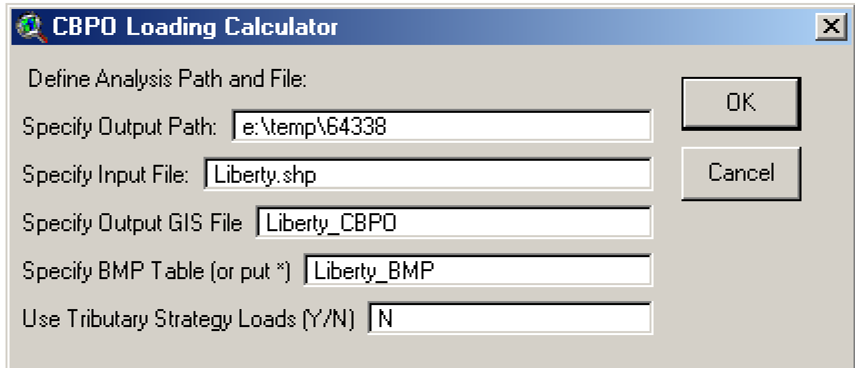
There are many permutations of nutrient loading analyses that GISHydro can perform. The most basic issues concerning the calculation of loadings revolve around the land use associated with a loading calculation and whether BMPs are implemented in that calculation.

In GISHydro and within this document, the use of the word "current" is meant to refer to the ***land use only*** and have no implications regarding the presence or absence of BMPs or what nutrient loading rates are used.

"Current" *land use* is derived from the Chesapeake Bay Program *land cover* which underlies the polygon studied by the analyst. This land cover data was derived from satellite imagery based on conditions that existed around year 2000. That land cover is converted to land use using the conversion rules outlined illustrated in a worked example in **Appendix B.**

"Future" land use is a concept imposed entirely by the analyst when performing a study. The intention of the program is to use "current" land use conditions as they exist today (more precisely, year 2000) and how they might be changed in the future according to land development plans that, for instance, propose to change current forest or agricultural land into pervious and impervious urban land.

Implementing Specific BMPs vs. Tributary Strategies



At the outset of a study, the analyst defines the loading rates that are to be used in that study. This is done based on the final entry in the dialog box shown at right (the "CBPO Loading: Set Development File" initiates this dialog box). If the analyst leaves the "N" in places for this last choice (i.e. Tributary Strategy Loads are ***not*** used) then loadings are calculated based on a set of default/best fit loading rates sensitive to geographic location and the land use in question. These rates, on average, are somewhat larger than Tributary Strategy loading rates, which assume that all nonpoint source best management practices for the 2004 Tributary Strategies are implemented, except septic system upgrades and BMPs reflected as changes in land cover (e.g. forest buffers).

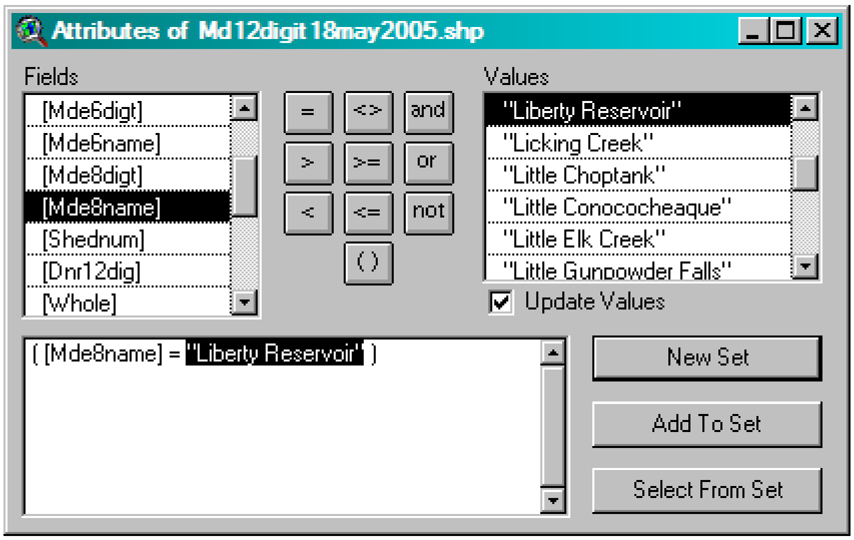
Loadings from all land use with designation, "Water", are subject to atmospheric deposition. Atmospheric deposition is accounted for in the form of reduced loading rates in the 2004 Tributary Strategies loadings. That is, atmospheric deposition loading rates are, on average, about 16.6 percent smaller under Tributary Strategy loadings compared to default loadings rates.

If you choose "N" for this last entry, you will be allowed to custom specify which BMPs, if any, you wish to implement in a given study polygon. If you choose "Y" for this last entry, it is assumed that all possible BMPs are implemented and so you will not be able to specify any additional BMPs.

Exercise 1a: Initiating a Nutrient Loading Analysis in GISHydro - Starting from an Existing Polygon Shapefile

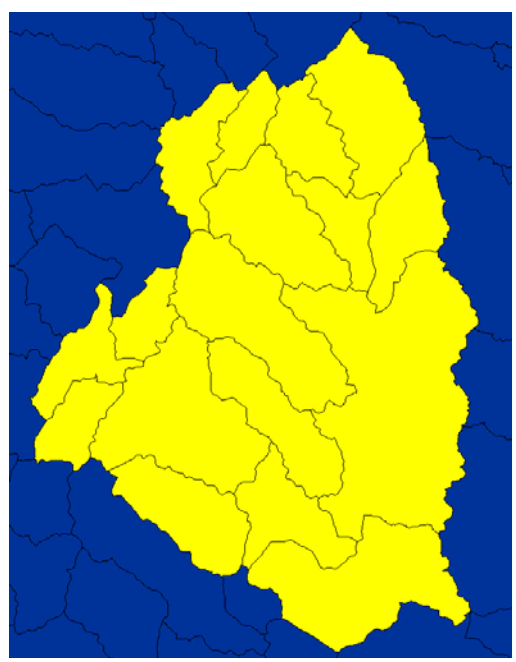
Starting Point: You have GISHydro installed (or access via the GISHydro web server) and you have the Maryland 12 digit watershed polygon theme loaded into the view.

1. Load in appropriate polygon theme (e.g "Md12digit18may2005.shp"). This theme contains the 12 digit watershed polygon boundaries covering the entire State of Maryland.
2. Since we don't want to do an analysis of the entire state, let's select just a few 12 digit watersheds to focus on, for instance those polygons that comprise the "Liberty Reservoir" watershed (8-digit code: 02130907). Click on the Query Builder icon (looks like a hammer), and then create the following query:

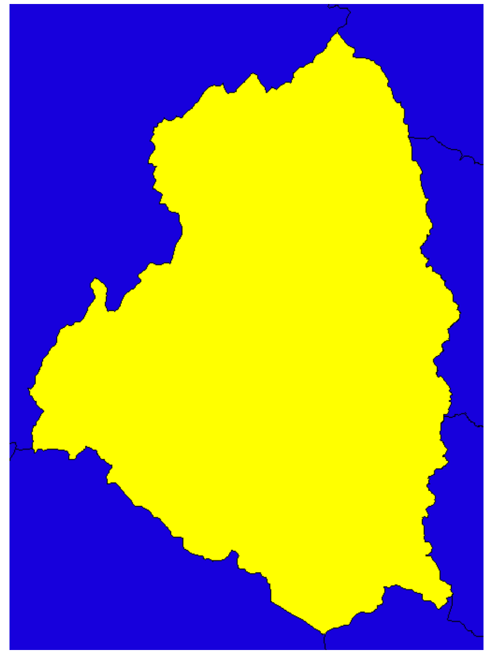


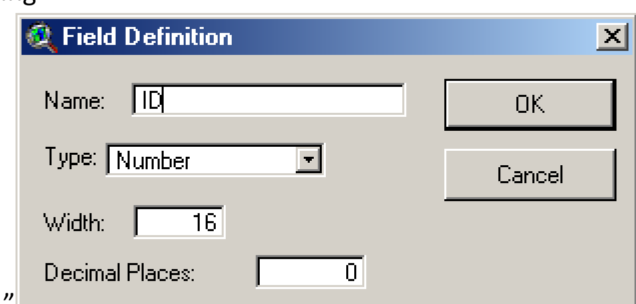
Click on the "New Set" button and you will select all polygons that satisfy: ([Mde8name] = "Liberty Reservoir")

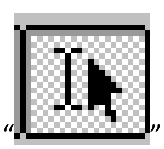
3. You should find that 17 polygons satisfy the query described above and are shown mapped in yellow in the figure at right:



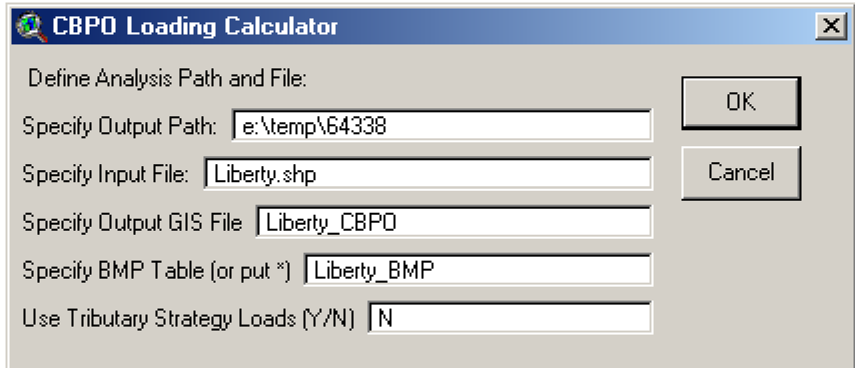
(Note that this exercise is based on the 12 digit watershed boundaries used in Maryland. The analysis can also be performed for the entire Liberty Reservoir area as a single polygon which corresponds to an 8 digit basin as shown at right. The degree of resolution or typical scale of the polygons you choose in an analysis should be governed by the scale at which specific information is needed. Obviously, it is quicker and easier to work with one large polygon than 17 smaller polygons covering the same area. As the analyst, the choice of analysis scale should be governed by the scale at which information is needed and the time/effort you are willing to invest in your analysis.)



4. We want to make a separate theme of just these selected polygons. To do this, choose: "Theme: Convert to Shapefile…" and specify an appropriate theme name (e.g. "liberty.shp") and note the directory where you have saved this theme.
5. The GISHydro/CBPO tool requires all input shapefiles for nutrient analysis to include a field in the theme's attributed table called, "ID". The original shapefile from which we've extracted the Liberty polygons did not include this field so we need to add it manually.
   a. Choose: "Theme: Table…" to open the theme's attribute table.
   b. Choose: "Table: Start Editing"
   c. Choose: "Edit: Add Field…" 

and indicate "ID" as your desired field name. You can leave all other entries at their default values.
   d. Click the "" icon and then you should be able to enter values in the "ID" field (column) of the theme's attribute table. Simply number each row consecutively from 1-17.
   e. Choose: "Table: Stop Editing" and then click "Yes" to save the edits.

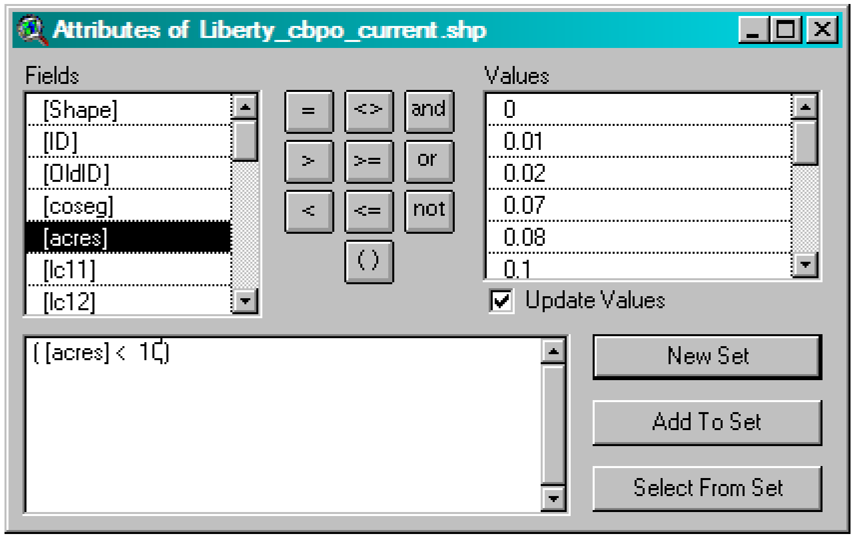
6. We are now ready to initiate a CBPO nutrient loading analysis. With the Liberty.shp shapefile as the top-most theme in the view, choose: "CBPO Loading: Set Development File". You should see a dialog similar to the one at right. It's best to change the output path to something informative to you (e.g. "e:\temp\liberty" – you must retain the "e:\temp\"[1] portion for any analysis). Also, if you intend to impose specific BMPs in your analysis you should be sure that the last entry, "Use Tributary Stategy Loads (Y/N)" is set to "N". In this case "N" means that, initially, no BMPs are assumed in the nutrient loading calculations. Tributary Strategy loads, if chosen, assume full implementation of Maryland's tributary strategies. Once you click the "OK" button GISHydro will process the input shapefile, this may take a few seconds to minutes, depending on the number of polygons in the shapefile.



7. When control of GISHydro returns to the user you should find that a new theme has appeared at the top of the view called something like, "Liberty_cbpo_current.shp". This theme visually should look a lot like your original input theme, but if you look closely you'll see that some of the polygons have been split along the Carroll/Baltimore county border. Opening the theme's attribute table, Use: "Theme: Open Table" should reveal that, in fact, the 17 input polygons have been split into 40 polygons. A few of these splits are due to the county border issue, but most are essentially meaningless differences in the understood watershed boundaries between the original ""Md12digit18may2005.shp" shapefile and the watershed ("cosegments") used by the CBPO. Our, next step will be to delete many of these very small split polygons.

[1] Please note that if you are using the webserver GISHydro is installed on the "e:" drive. If you are working on a stand-alone version of GISHydro, it will probably be installed on the "c:" drive. Examples presented here will assume the user is working on the web version of GISHydro.

8. To remove the meaningless split polygons:



   a. Choose, “Table: Start Editing” from the top of the ArcView interface.
   b. Use the Query Builder and build the query illustrated in the dialog box above.
   c. Click: “New Set” in the dialog box. This will select the polygons with area less than 10 acres. We want to delete these polygons from the analysis.
   d. Choose: “Edit: Delete Records” from the menu choices at the top of the ArcView interface.
   e. Choose: “Table: Stop Editing”, from the menu choices at the top of the ArcView interface, then click “Yes” to save the changes. You should find you now have 20 polygons remaining in your table/theme. Return to the view window. You probably will not be able to notice any visible change in the areal extent of the mapped polygons even though you’ve deleted half of them, the deleted area was a very small percentage of the total area.

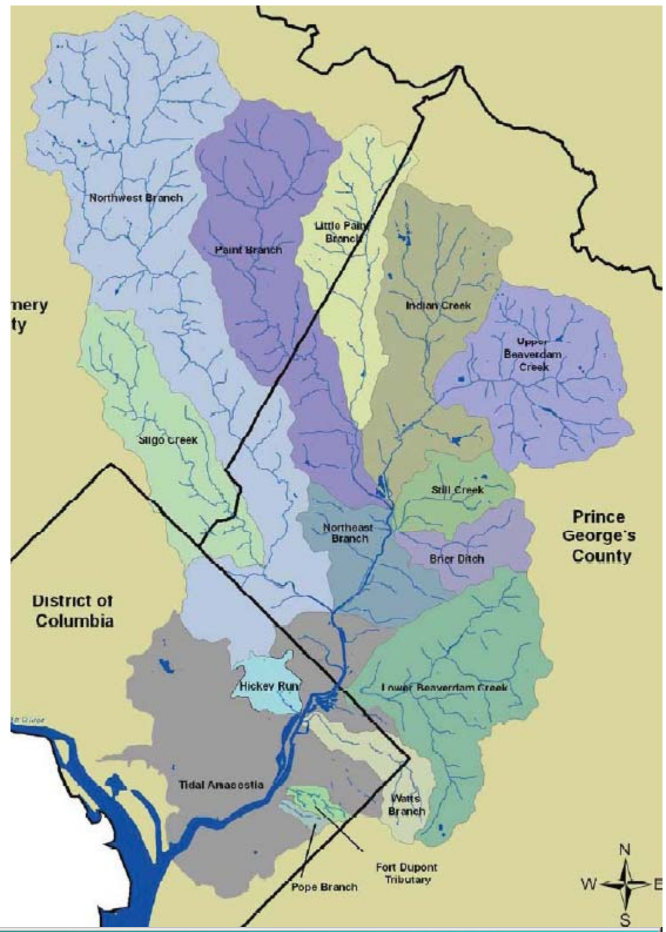
Potential next exercises: Exercises 2, 4, or 5.

Exercise 1b: Initiating a Nutrient Loading Analysis in GISHydro - Generating your own Watershed Polygon Shapefile

Starting Point: You have GISHydro installed (or access via the GISHydro web server) and you have a watershed in mind that you plan to analyze for nutrient loading. Note: in addition to the steps described here, you may find the documentation at:

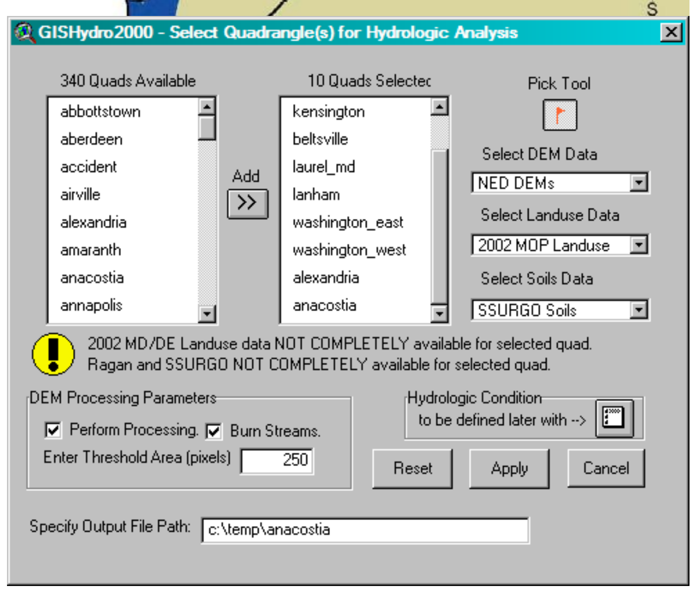
http://www.gishydro.umd.edu/workshop/Manual2007.pdf

In this document you should particularly focus on Exercise I-A, Exercise I-B (Part One only), and Exercise II-A.

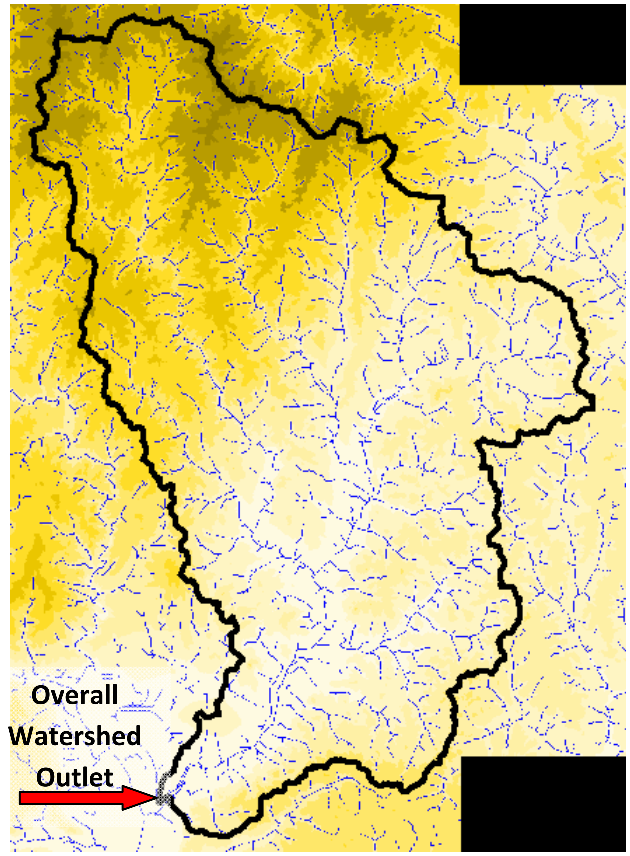


In this exercise our starting point is a known watershed, the Anacostia, and a figure (shown at right) from the Anacostia Watershed Society which shows the overall watershed subdivided into major tributary sub-watersheds. Our goal is to produce a polygon shapefile that approximates the watershed and sub-divisions shown in the figure. This polygon shapefile can then be used as our starting point for nutrient loading analysis.

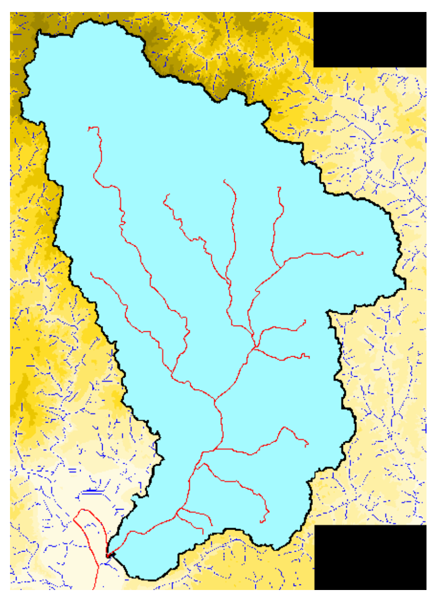
1. Click the "Select Quads" button (looks like a "Q") and then indicate the USGS 7.5 minute quadrangles that cover your desired watershed. This is done by either using the "Pick" tool in the select quadrangle(s) dialog box, or by choosing the desired quads by name. In this case, the quads that are needed are: Sandy_Spring, Clarksville, Kensington, Beltsville, Laurel_md, Lanham, Washington_east, Washington_west, Alexandria, and Anacostia (Sandy_Spring and Clarksville) are now shown in the screen capture at right because they have scrolled off the top of the selected quads list. Once you have selected all the quads needed you can simply click the "Apply" button.



Some processing of the selected data will ensue that may take about 60 to 90 seconds to complete. You will then see a new view window called the "Area of Interest" view that shows your selected data and is ready for you to indicate the location of your overall watershed outlet.



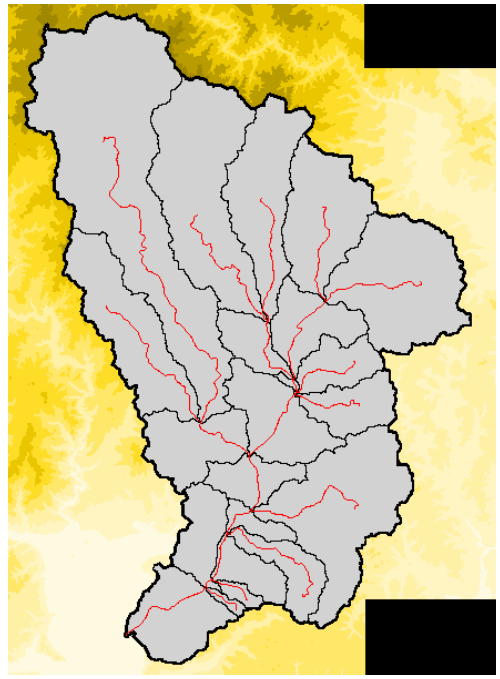
2. You will need to zoom to location of the overall watershed outlet, click the "W" tool button and then click on the blue pixel on the shown stream network that best captures your estimation of the overall watershed outlet. Please note, in this picture the black outline of the Anacostia watershed is added for perspective, however, this outline will not be present in your analysis. You will need to visualize the watershed (and watershed outlet) you wish to delineate by examining the drainage network, road network, or other themes and using them for guidance. Also note that before clicking the "W" tool and then clicking in the view to delineate your watershed you will need to use the "Magnifying Glass Tool(+)" (described in earlier in the ArcView tutorial section of this document on approximately page 8) to zoom in to a small area near the watershed outlet so you can indicate the overall watershed outlet with good precision.



3. After the overall watershed is successfully delineated, the next step is to indicate to GISHydro how you would like to sub-divide the watershed. Placing your cursor within the overall watershed boundaries, click the "S" tool to indicate stream origination points and then click carefully on one point within each desired separate sub-watershed. The figure shown at right shows the resulting simplified drainage network that should produce a fair approximation of the sub-divisions indicated in the earlier Anacostia Watershed Society figure.

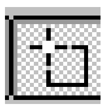
4. When you feel you have indicated all necessary streams in Step 3, choose the "CRWR-PrePro: Add Streams" menu choice. You will be presented with a "Yes/No" dialog box.

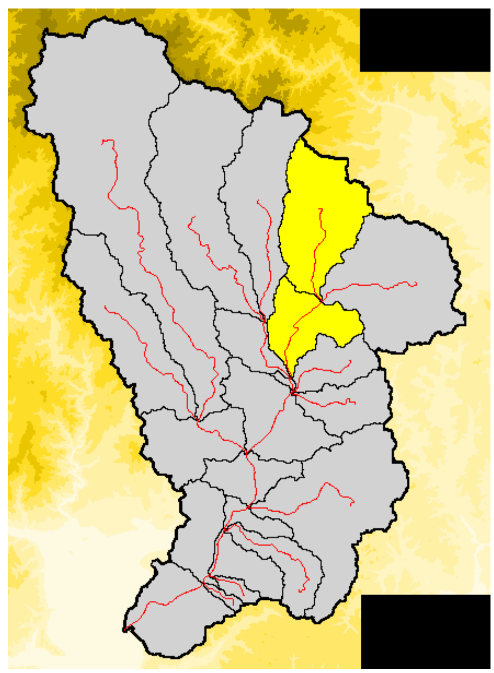
Choose “No” so that GISHydro uses only the streams you’ve indicated in the Step 3 when sub-dividing.



5. Choose, “CRWR-PrePro: Delineate Subwatersheds”. The view should change and you should see a gray colored theme appear which shows the boundaries of your sub-divided watershed as shown in the figure at right.

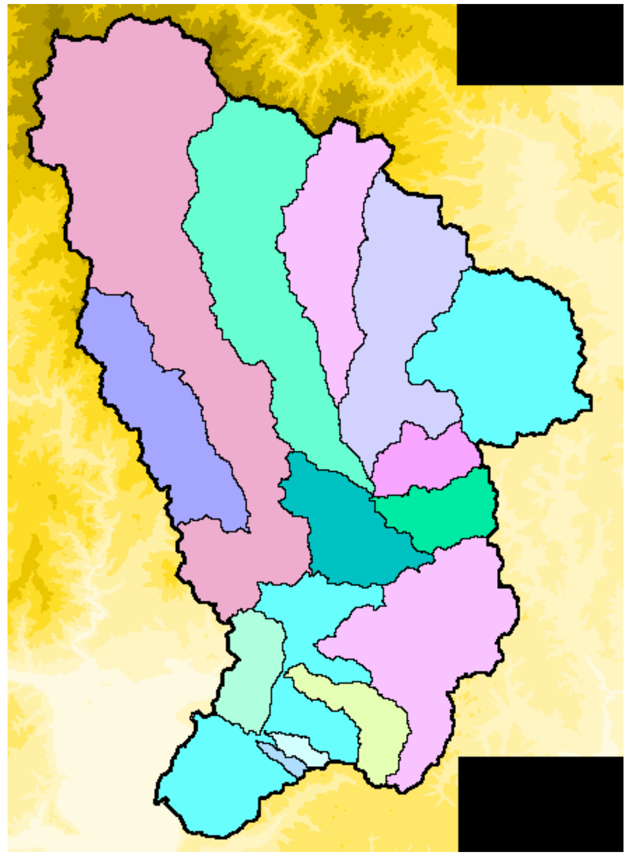
6. A quick glance at this figure should reveal that there are more sub-divided regions than you may have intended based on the figure from the Anacostia Watershed Society. This is because GISHydro, by default, performs a subdivision at each confluence of all streams that you have indicated in Step 3. The solution to this problem is to “Merge Selected Subwatersheds”. First click on the “subsheds.shp” shapefile in the legend so it is the active theme.

   Next, use the select tool:  to select two polygons that you want to merge together. Polygons can only be merged two at a time, so select two polygons, such as shown at right. Once two polygons are selected that are desired to be merged into one, choose: “CRWR-PrePro: Merge Selected Subwatersheds” and the subwatersheds will be combined into a single polygon.



7. Repeat Step 6 as necessary until all polygons have been merged to approximate the figure from the Anacostia Watershed Society or as desired. Note: you may need to use the “Magnifying Glass Tool(+)” to zoom into very small areas and combine relatively small subwatersheds into larger polygon entities.

When you are complete, you should have a system that looks like the figure at right. Note that there are some discrepancies between this figure and the one supplied originally from the Anacostia Watershed Society. These difference are primarily in the far downstream area in the "Tidal Anacostia" segment and, to a lesser degree, in the "Hickey Run" subwatershed. These differences are not addressable using GISHydro, but could be modified using the basic GIS polygon editing tools. We refer the reader to the online help in ArcView for directions on how to do this.

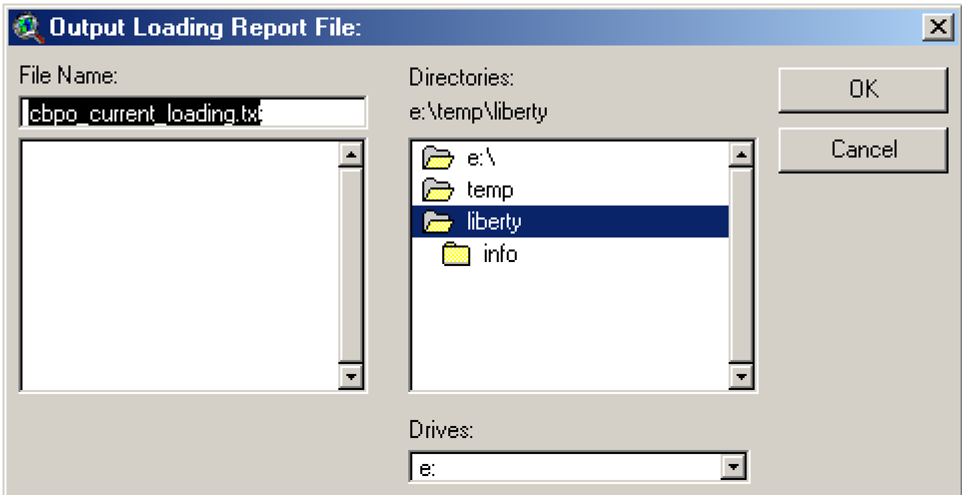


8. The GISHydro tool automatically creates and "ID" field in the attribute table for the polygon shapefile shown at right. You can simply use this file as input to the GISHydro nutrient loading tools. To do this, you must first place this shapefile in the "Maryland View". Click on the "subsheds.shp" shapefilein the legend area to make it the active theme. Choose "Edit: Copy Themes". In the project window, shift to the "Maryland View" and then choose, "Edit: Paste" (or simply Ctrl-v) to add the theme to the Maryland View.
9. Using the "subsheds.shp" file as your input development file to the CBPO nutrient loading estimator tool, go to Step 6 of Exercise 1a. Continue from Step 6 to the end of Exercise 1a.

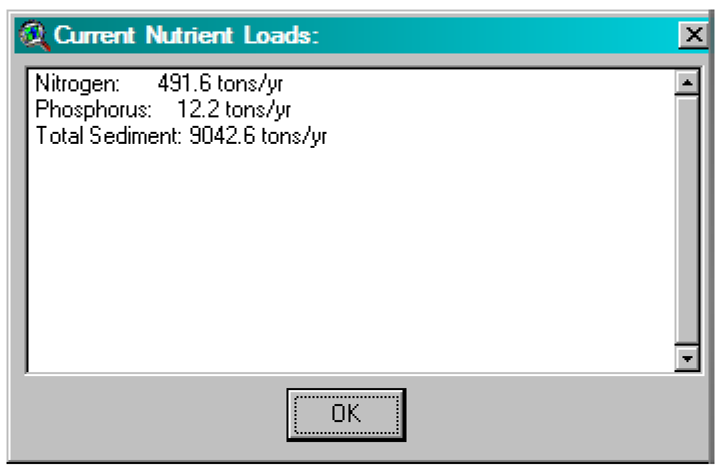
Exercise 2: Performing a Conventional/Default Nutrient CBPO Nutrient Loading Analysis

Starting Point: Exercise 1 complete. (If using MDP land use, Exercise 5 should be complete, too.)

1. Using the endpoint from Exercise 1, choose: “CBPO Loading: Calculate Current Load”. You will see a dialog box similar to the following:



Accept the contents of this dialog or change the file name as you wish. The text file GISHydro will use will be examined in a subsequent exercise. Click on the “OK” button. You will then see a dialog such as the one shown below (although the numbers will vary depending on the particular analysis you’ve selected):



The dialog shows the aggregate loadings of nitrogen, phosphorus, and sediment across the entire set of polygons examined. Click the “OK” button to proceed. After you click the “OK” button, GISHydro will write the text file you indicated above. This file will give specific information about nutrient/sediment loads, broken down by polygon and CBPO land use type. We will examine this text file in the next exercise.

Potential next exercises: Exercises 3 and 6.

Exercise 3: Tabular Analysis of the CBPO/GISHydro Nutrient Loading Output File:

Starting Point: Exercises 1 and 2 complete.

This exercise demonstrates how you can use Microsoft Excel to import the output file from Exercise 2. Once you've imported the file, you can use all the tools in Excel to compare numbers, or prepare graphs and tables.

Helpful Hint: The GISHydro webserver login page will automatically log the user out after a short amount of idle time. There are two ways of dealing with issue:

1. ***Simply log back into the webserver, and launch windows explorer application (2 copies) on the webserver, so you can download the output file from Exercise 2 to your local machine.***
2. ***At the time of originally logging into the server, in addition to launching GISHydro also launch windows explorer application (2 copies) on the webserver, so you can download the output file from Exercise 2 to your local machine.***

(Please see the tutorial, "File Management Basics for GISHydroweb" if you need help downloading the output file from Exercise 2.)

1. Open Excel on your local machine.
2. In Excel, choose: "File: Open" and navigate to the text file you output in Exercise 2. (Note that you will need to make Excel list files of type "*.txt" in order for the file: "cbpo_current_loading.txt" to appear in the browser. Once it does, select this file and click on the "Open" button.
3. The file import wizard will appear. Simply click on the "Finish" button.
4. You should now see be able to view the text file you created in Exercise 2 loaded into Excel.
5. The text file breaks into 6 blocks (with 5 sub-blocks each for Nitrogen, Phosphorus, and Sediment):
    - Block 1: Distribution of Underlying Land Cover (areas in acres): This block presents the detected land cover data from the CBPO land cover GIS data. Each row corresponds to an individual polygon in the development file. A small key appears just below this block to define the land cover codes.
    - Block 2: Distribution of Underlying Land Use (areas in acres): This block presents the inferred land use using CBPO rules to convert land cover to land use. Each row corresponds to an individual polygon in the development file.

- Block 3: Specified BMPs for current conditions: This block presents all specified BMPs, their BMP type, land use to which they apply , BMP area, whether the BMP acts additively or multiplicatively, and the nutrient reduction efficiencies for nitrogen, phosphorus, and sediment.   Each row corresponds to an individual BMP acting on an individual polygon in the development file. This block is empty if Tributary Strategy loads are used or if no BMPs are specified.

- Block 4: Nitrogen:

    - Block 4a: CALIBRATION VALUES LOADINGS: Nitrogen Loading Rate Table in lbs/(acre-year): This block presents the nitrogen loading rates by land use for each intersected CBPO co-segment by the development file. Each row corresponds to an individual co-segment.

    - Block 4b: Nitrogen Loading Table in tons/year: Each row in this block presents the (unmitigated by BMPs) loadings of nitrogen for each polygon in the development file.   This block is essentially the product of the land use presented in Block 2 and the loading rates presented in Block 4a.

    - Block 4c: Nitrogen aggregate alpha BMP values: This block presents the additive BMP scaling factors based on the BMPs specified in Block 3. A scaling factor of 1 means there are no BMP reductions for this entry. Each row corresponds to an individual polygon in the development file.

    - Block 4d: Nitrogen aggregate beta BMP values: This block presents the multiplicative BMP scaling factors based on the BMPs specified in Block 3. A scaling factor of 1 means there are no BMP reductions for this entry. Each row corresponds to an individual polygon in the development file.

    - Block 4e: Nitrogen Loading Table (with BMPs active) in tons/year: This block is the counterpart to Block 4b except that now BMP effects are taken into account. Each row in this block presents the loadings of nitrogen for each polygon in the development file.   This block is essentially the product of the land use presented in Block 2, the loading rates presented in Block 4a, and the alpha and beta values presented in Blocks 4c and 4d.

- Block 5: Phosphorus:

    - Block 5a: CALIBRATION VALUES LOADINGS: Phosphorus Loading Rate Table in lbs/(acre-year): This block presents the phosphorus loading rates by land use for each intersected CBPO co-segment by the development file. Each row corresponds to an individual co-segment.

- Block 5b: Phosphorus Loading Table in tons/year: Each row in this block presents the (unmitigated by BMPs) loadings of phosphorus for each polygon in the development file. This block is essentially the product of the land use presented in Block 2 and the loading rates presented in Block 5a.

- Block 5c: Phosphorus aggregate alpha BMP values: This block presents the additive BMP scaling factors based on the BMPs specified in Block 3. A scaling factor of 1 means there are no BMP reductions for this entry. Each row corresponds to an individual polygon in the development file.

- Block 5d: Phosphorus aggregate beta BMP values: This block presents the multiplicative BMP scaling factors based on the BMPs specified in Block 3. A scaling factor of 1 means there are no BMP reductions for this entry. Each row corresponds to an individual polygon in the development file.

- Block 5e: Phosphorus Loading Table (with BMPs active) in tons/year: This block is the counterpart to Block 5b except that now BMP effects are taken into account. Each row in this block presents the loadings of phosphorus for each polygon in the development file. This block is essentially the product of the land use presented in Block 2, the loading rates presented in Block 5a, and the alpha and beta values presented in Blocks 5c and 5d.

- Block 6: Sediment:

    - Block 6a: CALIBRATION VALUES LOADINGS: Sediment Loading Rate Table in tons/(acre-year): This block presents the sediment loading rates by land use for each intersected CBPO co-segment by the development file. Each row corresponds to an individual co-segment.

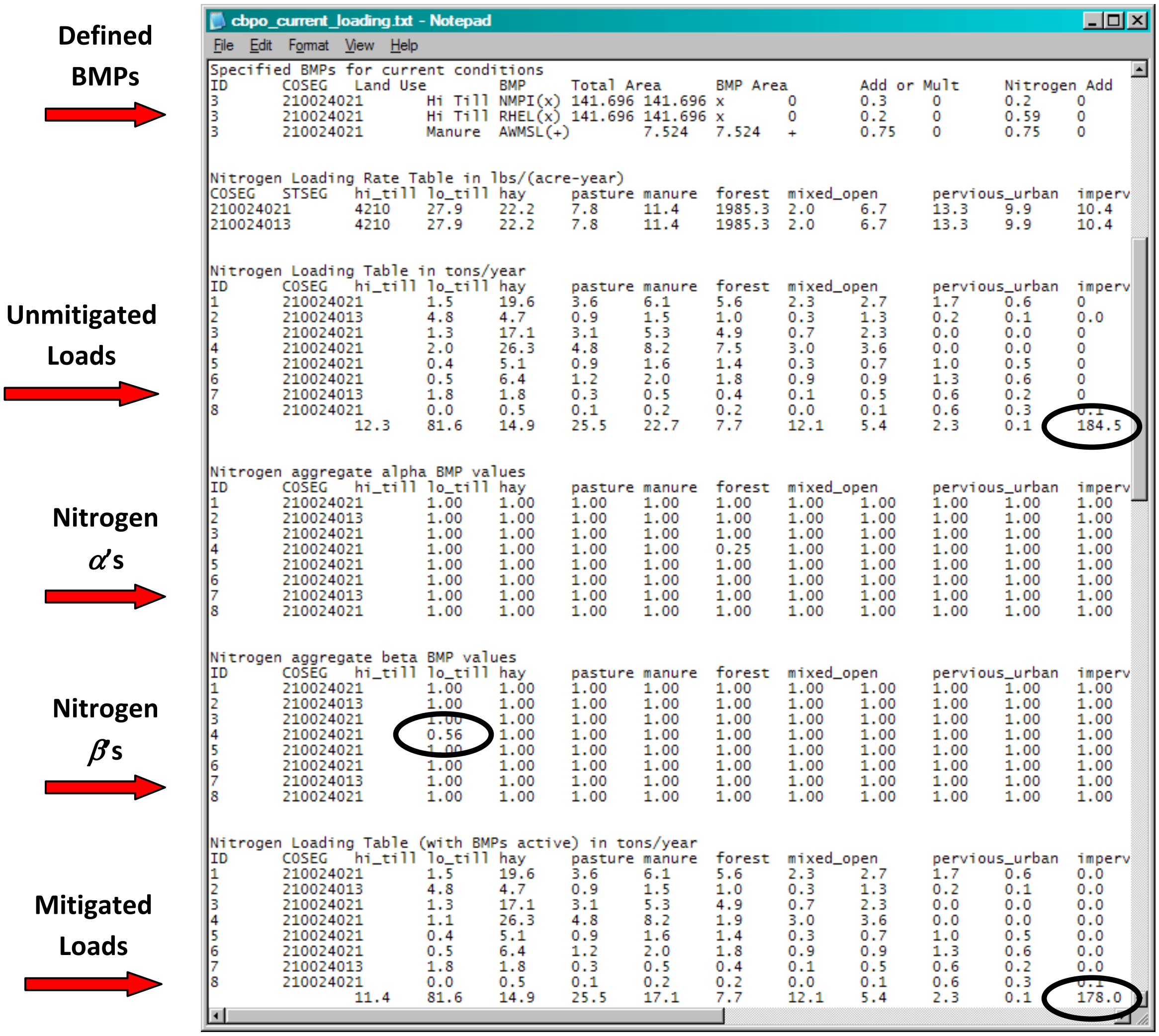
    - Block 6b: Sediment Loading Table in tons/year: Each row in this block presents the (unmitigated by BMPs) loadings of sediment for each polygon in the development file. This block is essentially the product of the land use presented in Block 2 and the loading rates presented in Block 6a.

    - Block 6c: Sediment aggregate alpha BMP values: This block presents the additive BMP scaling factors based on the BMPs specified in Block 3. A scaling factor of 1 means there are no BMP reductions for this entry. Each row corresponds to an individual polygon in the development file.

    - Block 6d: Sediment aggregate beta BMP values: This block presents the multiplicative BMP scaling factors based on the BMPs specified in Block 3. A scaling factor of 1 means there are no BMP reductions for this entry. Each row corresponds to an individual polygon in the development file.

- Block 6e: Sediment Loading Table (with BMPs active) in tons/year: This block is the counterpart to Block 6b except that now BMP effects are taken into account. Each row in this block presents the loadings of sediment for each polygon in the development file. This block is essentially the product of the land use presented in Block 2, the loading rates presented in Block 6a, and the alpha and beta values presented in Blocks 6c and 6d.

6. A screen capture of Blocks 3 – 4e is shown in the figure below. The circled items highlight aggregate reported loadings and the role of a single BMP in reducing nitrogen loading slightly from 184.5 tons/year to 178.0 tons/year in the development file due to two specified high till BMPs.



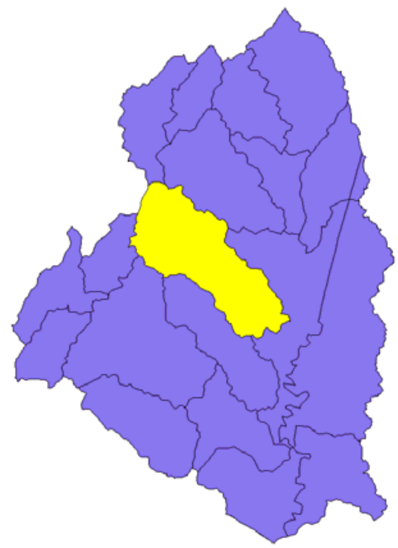

```
Specified BMPs for current conditions
ID      COSEG    Land Use        BMP      Total Area      BMP Area        Add or Mult     Nitrogen Add
3       210024021        Hi Till NMPI(x) 141.696 141.696 x        0       0.3     0       0.2     0
3       210024021        Hi Till RHEL(x) 141.696 141.696 x        0       0.2     0       0.59    0
3       210024021        Manure  AWMSL(+)        7.524   7.524   +       0.75    0       0.75    0


Nitrogen Loading Rate Table in lbs/(acre-year)
COSEG    STSEG    hi_till lo_till hay     pasture manure  forest  mixed_open      pervious_urban  imperv
210024021        4210     27.9    22.2    7.8     11.4    1985.3  2.0     6.7     13.3    9.9     10.4
210024013        4210     27.9    22.2    7.8     11.4    1985.3  2.0     6.7     13.3    9.9     10.4


Nitrogen Loading Table in tons/year
ID      COSEG    hi_till lo_till hay     pasture manure  forest  mixed_open      pervious_urban  imperv
1       210024021        1.5     19.6    3.6     6.1     5.6     2.3     2.7     1.7     0.6     0
2       210024013        4.8     4.7     0.9     1.5     1.0     0.3     1.3     0.2     0.1     0.0
3       210024021        1.3     17.1    3.1     5.3     4.9     0.7     2.3     0.0     0.0     0
4       210024021        2.0     26.3    4.8     8.2     7.5     3.0     3.6     0.0     0.0     0
5       210024021        0.4     5.1     0.9     1.6     1.4     0.3     0.7     1.0     0.5     0
6       210024021        0.5     6.4     1.2     2.0     1.8     0.9     0.9     1.3     0.6     0
7       210024013        1.8     1.8     0.3     0.5     0.4     0.1     0.5     0.6     0.2     0
8       210024021        0.0     0.5     0.1     0.2     0.2     0.0     0.1     0.6     0.3     0.1
                 12.3    81.6    14.9    25.5    22.7    7.7     12.1    5.4     2.3     0.1     184.5


Nitrogen aggregate alpha BMP values
ID      COSEG    hi_till lo_till hay     pasture manure  forest  mixed_open      pervious_urban  imperv
1       210024021        1.00    1.00    1.00    1.00    1.00    1.00    1.00    1.00    1.00    1.00
2       210024013        1.00    1.00    1.00    1.00    1.00    1.00    1.00    1.00    1.00    1.00
3       210024021        1.00    1.00    1.00    1.00    1.00    1.00    1.00    1.00    1.00    1.00
4       210024021        1.00    1.00    1.00    1.00    0.25    1.00    1.00    1.00    1.00    1.00
5       210024021        1.00    1.00    1.00    1.00    1.00    1.00    1.00    1.00    1.00    1.00
6       210024021        1.00    1.00    1.00    1.00    1.00    1.00    1.00    1.00    1.00    1.00
7       210024013        1.00    1.00    1.00    1.00    1.00    1.00    1.00    1.00    1.00    1.00
8       210024021        1.00    1.00    1.00    1.00    1.00    1.00    1.00    1.00    1.00    1.00


Nitrogen aggregate beta BMP values
ID      COSEG    hi_till lo_till hay     pasture manure  forest  mixed_open      pervious_urban  imperv
1       210024021        1.00    1.00    1.00    1.00    1.00    1.00    1.00    1.00    1.00    1.00
2       210024013        1.00    1.00    1.00    1.00    1.00    1.00    1.00    1.00    1.00    1.00
3       210024021        1.00    1.00    1.00    1.00    1.00    1.00    1.00    1.00    1.00    1.00
4       210024021        0.56    1.00    1.00    1.00    1.00    1.00    1.00    1.00    1.00    1.00
5       210024021        1.00    1.00    1.00    1.00    1.00    1.00    1.00    1.00    1.00    1.00
6       210024021        1.00    1.00    1.00    1.00    1.00    1.00    1.00    1.00    1.00    1.00
7       210024013        1.00    1.00    1.00    1.00    1.00    1.00    1.00    1.00    1.00    1.00
8       210024021        1.00    1.00    1.00    1.00    1.00    1.00    1.00    1.00    1.00    1.00


Nitrogen Loading Table (with BMPs active) in tons/year
ID      COSEG    hi_till lo_till hay     pasture manure  forest  mixed_open      pervious_urban  imperv
1       210024021        1.5     19.6    3.6     6.1     5.6     2.3     2.7     1.7     0.6     0.0
2       210024013        4.8     4.7     0.9     1.5     1.0     0.3     1.3     0.2     0.1     0.0
3       210024021        1.3     17.1    3.1     5.3     4.9     0.7     2.3     0.0     0.0     0.0
4       210024021        1.1     26.3    4.8     8.2     1.9     3.0     3.6     0.0     0.0     0.0
5       210024021        0.4     5.1     0.9     1.6     1.4     0.3     0.7     1.0     0.5     0.0
6       210024021        0.5     6.4     1.2     2.0     1.8     0.9     0.9     1.3     0.6     0.0
7       210024013        1.8     1.8     0.3     0.5     0.4     0.1     0.5     0.6     0.2     0.0
8       210024021        0.0     0.5     0.1     0.2     0.2     0.0     0.1     0.6     0.3     0.1
                 11.4    81.6    14.9    25.5    17.1    7.7     12.1    5.4     2.3     0.1     178.0
```

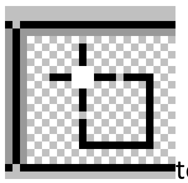
Potential next exercises: Exercise 6.

Exercise 4: Controlling the Default Agricultural Land Use Distribution

Starting Point: Exercise 1 complete.

The GISHydro/CBPO tool works by first detecting the underlying land cover within the polygons you've indicated for analysis in your development file. That land cover is converted to land use, using rules consistent with the CBPO. As part of these rules, agricultural land cover is converted to a set of agricultural land uses according the agricultural census data underlying the polygon in question. Since that census data only has county-wide resolution, a more refined understanding of the actual agricultural land uses present is not possible. In this exercise, a tool will be presented to give you the ability to over-ride the default county census data to agree with external information you may have.



1. Click on the  tool. In the view, click on a polygon for which you plan to provide an updated set of agricultural land use distribution information. For instance see the map at right which shows the 12-digit watershed "021309071057" selected. *Note: before you can select a polygon, please be sure that the output file, "Liberty_cbpo_current.shp" is the active (i.e. "popped up") theme in the view.*

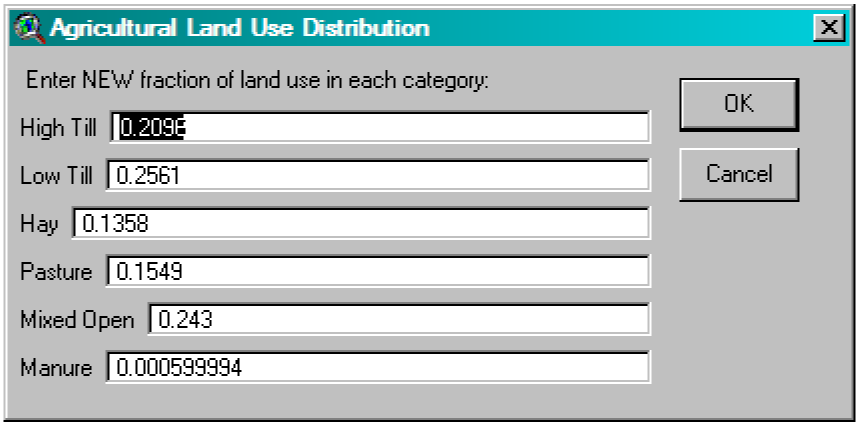
2. Before making any changes, let's examine the default land use attributes for the selected watershed. Choose, "Theme: Table…"

Attributes of Liberty_cbpo_current.shp

Shape	ID	OldID	coseg	acres	lc11	lc12	lc13	lc14	lc20	lc30	lc40	lc60	lc70	hi_till	lo_till	hay	pasture	manure	forest	mix_open
Polygon	3	1	650024013	6810.49	82	899	862	189	19786	8782	0	30	0	922.3038	1126.9179	597.5613	681.6071	2.6402	1953.0715	1069.2740
Polygon	5	2	650024013	2277.77	6	459	160	44	6430	3043	0	109	0	299.7278	366.2227	194.1938	221.5068	0.8580	676.7475	347.4897
Polygon	7	3	650024013	3696.07	0	20	22	0	10478	6061	0	33	0	488.4211	596.7778	316.4484	360.9562	1.3982	1347.9351	566.2515
Polygon	9	4	650024013	3902.86	1402	2707	823	142	10757	1709	0	16	0	501.4264	612.6684	324.8745	370.5675	1.4354	380.0728	581.3292
Polygon	12	5	650024005	370.63	0	136	51	0	1276	198	0	0	0	27.2425	72.5899	25.1425	52.3850	0.0851	44.0342	106.3024
Polygon	13	5	650024013	4156.86	216	364	160	57	12757	5063	19	61	0	594.6543	726.5790	385.2770	439.4654	1.7023	1125.9851	689.4131
Polygon	14	6	650024013	7010.67	177	368	462	143	15534	14850	0	0	0	724.1012	884.7439	469.1457	535.1302	2.0728	3302.5634	839.4876
Polygon	15	7	650024013	2923.97	0	0	33	47	7936	5129	0	0	0	369.9284	451.9974	239.6769	273.3870	1.0590	1140.6631	428.8769
Polygon	17	8	650024013	9191.39	259	2340	1330	290	23155	13946	0	0	2	1079.3462	1318.8004	699.3092	797.6657	3.0897	3101.9633	1251.3413
Polygon	20	9	650024005	12272.80	81	1888	842	749	20391	29336	0	1830	61	435.3459	1160.0155	401.7880	837.1339	1.3605	6537.7412	1698.7560

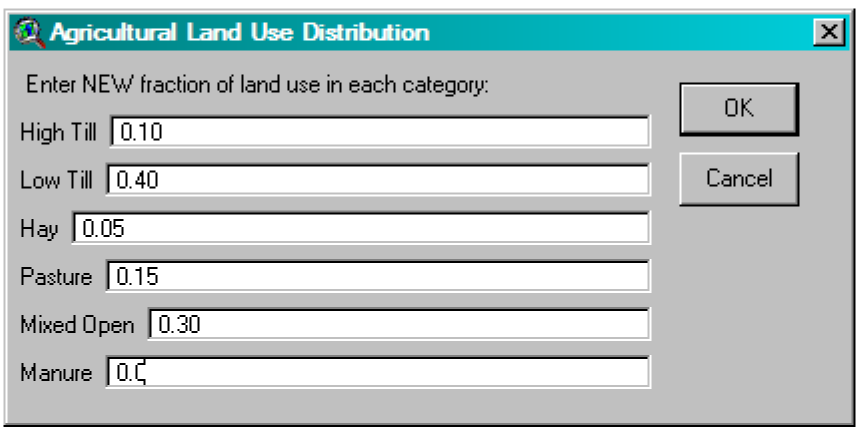
The highlighted record shows that there is approximately 1079.3 acres of high till land, 1318.8 acres of low till land, 699.3 acres of hay land, 797.7 acres of pasture land, 1251.3 acres of mixed open land, and 3.1 acres of manure land. This totals approximately 5149.5 acres of agricultural land.

3. Choose: “CBPO: Revise Ag Land Use”. A dialog like the one shown below should appear: The



numbers appearing in this dialog reflect the default agricultural census land use distribution for Carroll County, MD since watershed 021309071057 is located in Carroll County. Note that the sum of these numbers should be essentially 1.

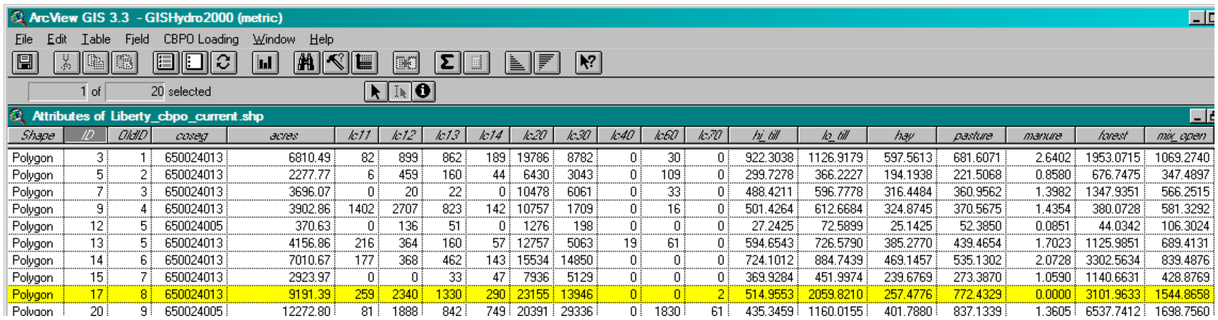
4. Let’s assume that we know the actual agricultural land use distribution in this watershed is as follows: High Till (10%), Low Till (40%), Hay (5%), Pasture(15%), Mixed Open (30%), Manure (0%). Update the values in the dialog accordingly as shown below, then click the “OK” button.



Note there are several caveats the users should be aware of with regards to this dialog:

- *Do NOT enter non-numeric data, this will cause an error.*
- *If the sum of the values entered is not equal to 1, the values will be re-scaled (up or down) proportionately so they do sum to 1. This is important because otherwise this tool would not conserve the total amount of agricultural land in the analysis polygon.*

5. The change indicated in Step 4 has taken place, though this may not be evident to the user. Let's repeat Step 2 and examine this polygon's attribute data again:



Shape	ID	OldID	coseg	acres	lc11	lc12	lc13	lc14	lc20	lc30	lc40	lc60	lc70	hi_till	lo_till	hay	pasture	manure	forest	mix_open
Polygon	3	1	650024013	6810.49	82	899	862	189	19786	8782	0	30	0	922.3038	1126.9179	597.5613	681.6071	2.6402	1953.0715	1069.2740
Polygon	5	2	650024013	2277.77	6	459	160	44	6430	3043	0	109	0	299.7278	366.2227	194.1938	221.5068	0.8580	676.7475	347.4897
Polygon	7	3	650024013	3696.07	0	20	22	0	10478	6061	0	33	0	488.4211	596.7778	316.4484	360.9562	1.3982	1347.9351	566.2515
Polygon	9	4	650024013	3902.86	1402	2707	823	142	10757	1709	0	16	0	501.4264	612.6684	324.8745	370.5675	1.4354	380.0728	581.3292
Polygon	12	5	650024005	370.63	0	136	51	0	1276	198	0	0	0	27.2425	72.5899	25.1425	52.3850	0.0851	44.0342	106.3024
Polygon	13	5	650024013	4156.86	216	364	160	57	12757	5063	19	61	0	594.6543	726.5790	385.2770	439.4654	1.7023	1125.9851	689.4131
Polygon	14	6	650024013	7010.67	177	368	462	143	15534	14850	0	0	0	724.1012	884.7439	469.1457	535.1302	2.0728	3302.5634	839.4876
Polygon	15	7	650024013	2923.97	0	0	33	47	7936	5129	0	0	0	369.9284	451.9974	239.6769	273.3870	1.0590	1140.6631	428.8769
Polygon	17	8	650024013	9191.39	259	2340	1330	290	23155	13946	0	0	2	514.9553	2059.8210	257.4776	772.4329	0.0000	3101.9633	1544.8658
Polygon	20	9	650024005	12272.80	81	1888	842	749	20391	29336	0	1830	61	435.3459	1160.0155	401.7880	837.1339	1.3605	6537.7412	1698.7560

We find that there is approximately 515.0 acres of high till land, 2059.8 acres of low till land, 257.5 acres of hay land, 772.4 acres of pasture land, 1544.9 acres of mixed open land, and 0.0 acres of manure land. This totals approximately 5149.6 acres of agricultural land. The user should verify that this new distribution is consistent with the new requested distribution (e.g. high till was to be set at 10% of the total agricultural land so 5149.5 acres * 0.10 = 515.0 acres of high till land).

Note that the right-most field in the "Liberty_cbpo_current.shp" shapefile is called "Ag_Mod". It contains either a "y" to indicate that the agricultural land use has been modified from default agricultural census data values or an "n" to indicate that the agricultural land use distribution remains at default values.

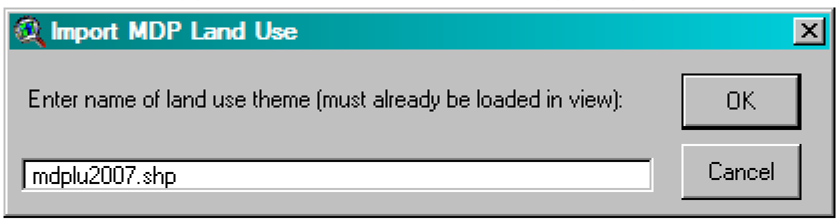
Potential next exercises: Exercises 2 or 5.

Exercise 5: Importing Maryland Department of Planning (MDP) Land Use

Starting Point: Exercise 1 complete. A shapefile of MDP land use must also be loaded into the view[2]. (Note that this exercise is not necessary to proceed to the application of BMPs in Exercise 6.)

The text file examined in Exercise 3 showed both the detected CBPO land cover and the interpreted CBPO land use. Exercise 4 showed how the user can update the default agricultural land use distribution to reflect better external information the user might have. In contrast, this exercise shows how you can use land use data from the Maryland Department of Planning (MDP) as a direct input to the GISHydro/CBPO loading tool. In this exercise, GISHydro will import a land use shapefile from the MDP that covers the user's study area and use that shapefile's information to over-ride the CBPO land cover/land use conversion that took place in Exercise 1, Step 6. In this exercise, GISHydro will convert the MDP land uses as described below into their equivalent CBPO land uses for subsequent nutrient loading analysis.

1. Choose: "CBPO Loading: Import MDP Land Use". Fill in the dialog box as shown below (where the name of the theme that you enter should match exactly the name of the shapefile of MDP land use as it appears in the view. When complete, press the "OK" button.



Note that you should have already loaded a shapefile of MDP land use (from year 2002 or 2007) into the view before initiating this step.

Potential next exercises: Exercises 2 or 4.

Step 1 is all that is necessary for the conversion to be complete, but the final result can only be understood by comparing the attribute tables of a default CBPO analysis of a watershed polygon with the MDP converted interpretation of that same polygon. That comparison appears here. Let's return our focus to the watershed 021309071057 in Carroll County for purposes of comparison.

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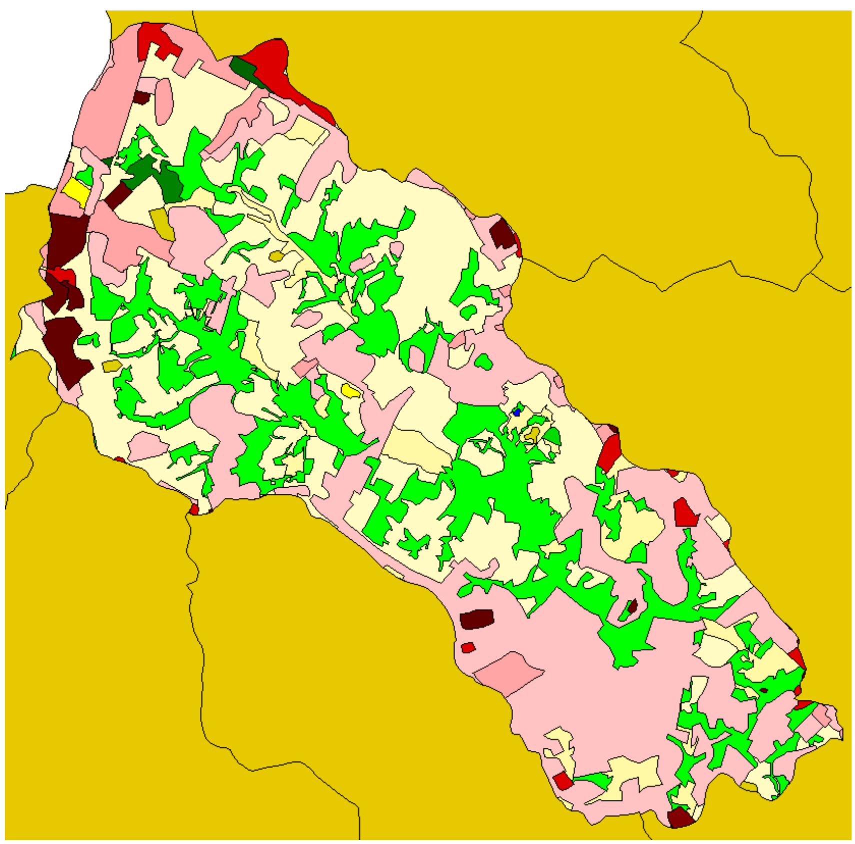
[2] The shapefile of MDP land use must be obtained from some source outside the GISHydro program. These data are not supplied by the GISHydro program in vector (shapefile) format. The 2002 MDP land use data can be obtained at: http://www.mdp.state.md.us/zip_downloads_accept.htm by individual county under the "Land Use Land Cover" data grouping. The 2007 MDP land use data are anticipated to be available in the 2009 calendar year, but are not yet available at the time of the writing of this document.

Land Use	Category	CBPO Area (acres)	MDP Area (acres)
High Till	Ag	515.0	349.6
Low Till	Ag	2059.8	1398.3
Hay	Ag	257.5	174.8
Pasture	Ag	772.4	524.4
Manure	Ag	0.0	0.0
Mixed Open	Ag	1544.9	1048.7
Forest	Forest	3102.0	1979.6
Pervious Urban	Urban	645.1	2578.4
Impervious Urban	Urban	293.1	1136.6
Water	Water	0.0	1.2

The table above shows the final land use distribution for this watershed as interpreted by both the CBPO and MDP. (Note that the CBPO agricultural land use distribution for this watershed was updated in Exercise 4 so the distribution is not the Carroll County, MD default but instead reflects 10% High Till land, 40% Low Till land, etc. Although the comparison shows that both overall distributions are similar, there are some specific observations that can be made:

- The relative proportion of land in each of the agricultural land use categories is the same in both distributions (to be explained below).
- There is more agricultural land use in the CBPO distribution than in the MDP distribution.
- There is more forest land use in the CBPO distribution than in the MDP distribution.
- There is less urban land use in the CBPO distribution than in the MDP distribution.
- There is less water land use in the CBPO distribution than in the MDP distribution.



How MDP land use quantities are detected

The first step of land use conversion is to simply detect the MDP categories and quantities present within the polygon being studied. The figure at right shows the detected MDP land uses present within the example polygon. The red shaded colors are urban land uses, the yellow/beige shaded colors are agricultural land uses, the green shaded colors are forest land uses and the blue shaded colors are water land uses. The table below provides a precise accounting of the areas of each of these land uses in the example polygon:

MDP Land Use	Description	Area (acres)
11	Low Density Residential	2826.9
12	Medium Density Residential	498.8
13	High Density Residential	1.3
14	Commercial	175.4
15	Industrial	12.0
16	Institutional	153.1
17	Extractive	11.2
18	Open Urban Land	36.3
21	Cropland	2929.2
22	Pasture	513.1
23	Orchards	20.3
25	Row Crops	0.2
41	Deciduous Forest	1912.8
42	Evergreen Forest	6.9
43	Mixed Forest	42.2
44	Brush	17.7
50	Water	1.2
241	Feeding Operations	15.7
242	Agricultural Buildings	17.2

How Agricultural land uses are converted to CBPO land uses

All agricultural land uses (MDP land use code starts with a “2”) are pooled together into a single aggregate amount of agricultural land. In this example this is 2929.2 + 513.1 + 20.3 + 0.2 + 15.7 + 17.2 = 3495.7 acres. This aggregate sum is then disaggregated according to the agricultural land proportions presented in Exercise 4. For example, the proportions for this watershed were set in Exercise 4 and are simply repeated here:

- High Till Land: 0.1 * 3495.7 = 349.6 acres
- Low Till Land: 0.4 * 3495.7 = 1398.3 acres
- Hay Land: 0.05 * 3495.7 = 174.8 acres
- Pasture Land: 0.15 * 3495.7 = 524.4 acres
- Manure Land: 0.0 * 3495.7 = 0.0 acres

- Mixed Open Land: 0.3 * 3495.7 = 1048.7 acres

Note that if the county default agricultural land use distribution had been in place in this watershed those proportions, rather than the simpler ones presented here Exercise 4 would have been used.

How Forest land uses are converted to CBPO land use

There are several MDP land use codes that correspond to different sub-categories of forest: deciduous forest (41), evergreen forest (42), mixed forest (43), brush (44), and large lot forest (192). The total area in each of these detected land use is simply pooled to convert to the CBPO land use category, “Forest”. For the case of the study polygon this results in:

- Forest Land: 1912.8 + 6.9 + 42.2 + 17.7 + 0.0 = 1979.6 acres

How Urban land uses are converted to CBPO land uses

Land Use Code	Classification	Imperviousness Fraction
11	Low Density Residential	0.25
12	Medium Density Residential	0.38
13	High Density Residential	0.65
14	Commercial	0.85
15	Industrial	0.72
16	Institutional	0.50
17	Extractive	0.11
18	Open Urban Land	0.11
70	Barren Land	0.50
71	Beaches	0.00
72	Bare Exposed Rock	1.00
73	Bare Ground	0.50
80	Transportation	0.75

CBPO recognizes three types of urban land (“Pervious Urban”, “Impervious Urban”, and “Mixed Open Land”). Mixed open land is actually created out of the pool of agricultural land described previously. This section describes how several MDP categories of urban land are converted to pervious and/or impervious urban land. The relevant MDP categories are shown tabulated at left. Detected areas in each category are split according to the indicated imperviousness fraction shown in the table. The formulas for these conversions therefore are:

- Pervious Urban Land: (1-0.25) * LU11 + (1-0.38) * LU12 + (1-0.65) * LU13 + (1-0.85) * LU14 + (1-0.72) * LU15 + (1-0.5) * LU16 + (1-0.11) * LU17 + (1-0.11) * LU18 + (1-0.50) * LU70 + (1-0.00) * LU71 + (1-1.00) * LU72 + (1-0.50) * LU73 + (1-0.75) * LU80.

- Impervious Urban Land: 0.25 * LU11 + 0.38 * LU12 + 0.65 * LU13 + 0.85 * LU14 + 0.72 * LU15 + 0.5 * LU16 + 0.11 * LU17 + 0.11 * LU18 + 0.50 * LU70 + 0.00 * LU71 + 1.00 * LU72 + 0.50 * LU73 + 0.75 * LU80.

For the study polygon this results in:

- Pervious Urban Land: (1-0.25) * 2826.9 + (1-0.38) * 498.8 + (1-0.65) * 1.3 + (1-0.85) * 175.4 + (1-0.72) * 12.0 + (1-0.5) * 153.1 + (1-0.11) * 11.2 + (1-0.11) * 36.3 + (1-0.50) * 0.0 + (1-0.00) *0.0 + (1-1.00) * 0.0 + (1-0.50) * 0.0 + (1-0.75) *0.0 = 2578.4 acres

- Impervious Urban Land: 0.25 * 2826.9 + 0.38 * 498.8 + 0.65 * 1.3 + 0.85 * 175.4 + 0.72 * 12.0 + 0.5 * 153.1 + 0.11 * 11.2 + 0.11 * 36.3 + 0.50 * 0.0 + 0.00 * 0.0 + 1.00 * 0.0 + 0.50 * 0.0 + 0.75 * 0.0 = 1136.6 acres

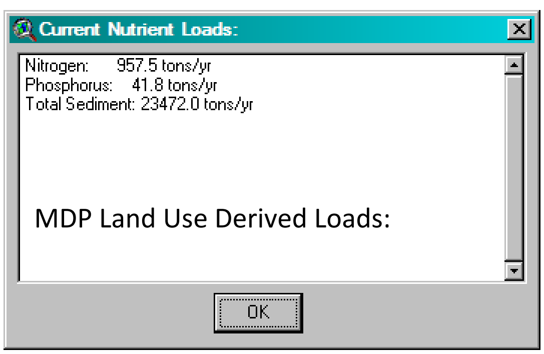
How Water land uses are converted to CBPO land uses

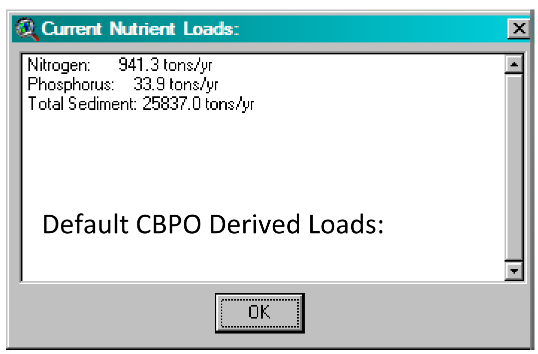
There are two MDP land use codes that correspond to different sub-categories of water: water (50) and wetlands (60). The total area in each of these detected land use is simply pooled to convert to the CBPO land use category, "Water". For the case of the study polygon this results in:

- Water Land: 1.2 + 0.0 = 1.2 acres

Comparison of Aggregate Nutrient Loading

Because of the use of MDP land use as an input to the GISHydro/CBPO tool, the understood land use distribution has shifted somewhat. As a result, the nutrient loading would be expected to shift somewhat as well. Repeating Exercise 2 for the MDP derived CBPO land uses we get:





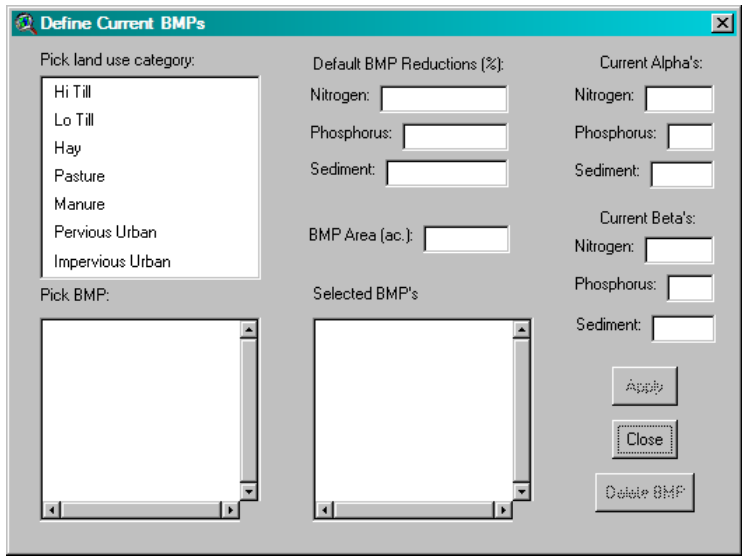
This result (at left) is comparable (but not identical to the resulting output from Exercise 2 (at right). To understand better how these relative loads have shifted, we would have to examine the detailed text output as shown previously in Exercise 3.

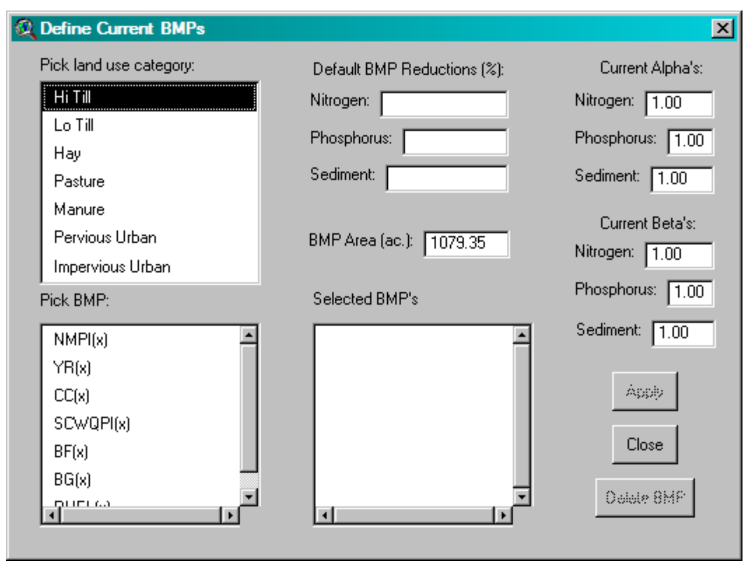
Exercise 6: Applying BMPs to a Development File

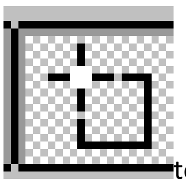
Starting Point: Exercises 1 and 2 complete.

This exercise shows how you can use the GISHydro/CBPO tool to indicate BMPs applied to a polygon area. The starting point also assumes that you have specified “N” or “n” with regards to the entry: “Use Tributary Stategy Loads (Y/N)” to “N” otherwise you will not be able to apply BMPs at all.

1. Make the GIS Output theme from Exercise 1 (e.g. “xxxx_cbpo_current.shp”) ***both*** active and visible (see pages 5-6 to refresh your memory on these theme properties if this is unclear). ***Helpful Hint: You may also find it useful to zoom the view so this file fills the view extents as much as possible – for details on controlling the view extents see the “ArcView Tutorial: Navigating within the View Window” section at approximately page 6.***





2. As in Exercise 4, Step 1, click on the tool. In the view, click on a polygon for which you plan to provide BMP information.

3. Choose: “CBPO Loading: Define BMPs”.

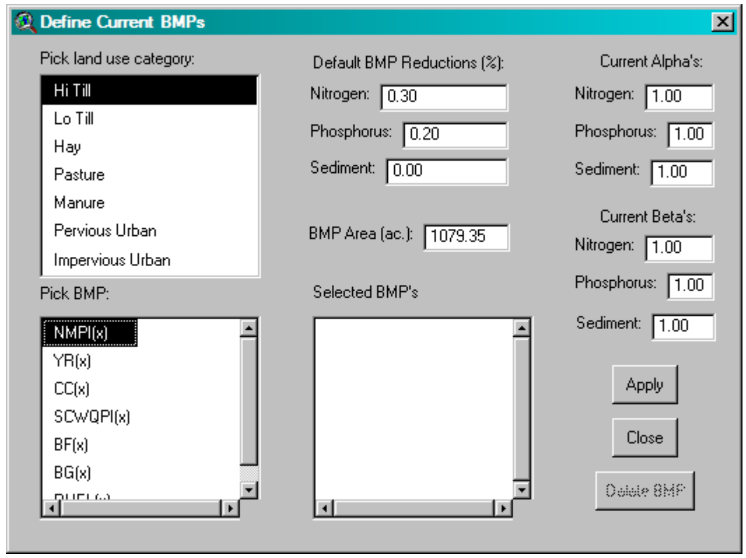
4. You will be presented with the following dialog box shown at right. Click on any of the land uses indicated in the upper-left hand box. For instance, “Hi Till” land.

5. The dialog box should update to list all of the BMPs that are applicable to the selected CBPO land use (as shown figure at bottom-right). In this case (because “Hi Till” land has been chosen) the available BMPs are NMP, YR, CC, SCWQPI, BF, BG, and RHEL. Please see Table 6-1 on next page which provides additional information about these BMPs and all BMPs included in GISHydro. Click on any of the available BMPs in the lower-left hand box. For instance, “NMP(x)”.

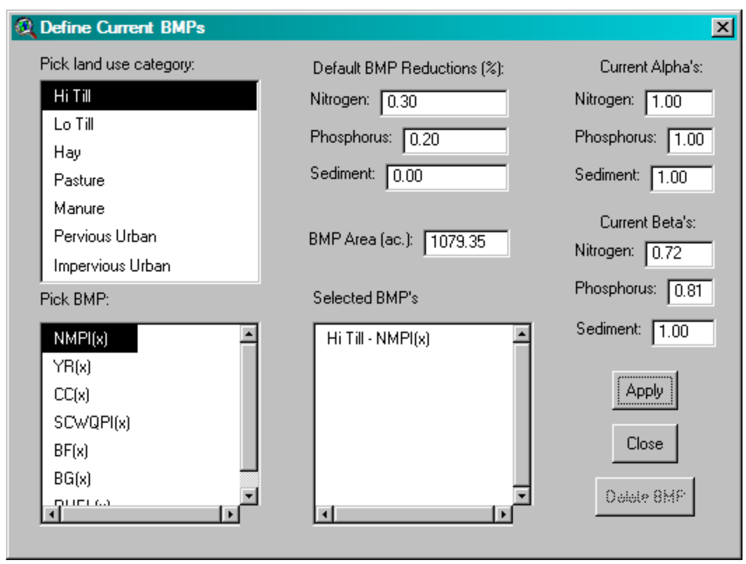
Table 6-1. List of default BMPs built into the GISHydro/CBPO Tool.

Land Use	Name	Symbol	Add. or Mult.	BMP Efficiency		
				Nitrogen	Phosphorus	Sediment
Impervious Urban	Stormwater Management - New	SWM-New	+	40	60	85
Impervious Urban	Stormwater Management - Recent	SWM - Recent	+	33	46	80
Impervious Urban	Stormwater Management - Retrofits	SWM Retrofits	+	33	46	80
Impervious Urban	Erosion and Sedimentation Control	E&S Control	+	33	50	50
Pervious Urban	Stormwater Management - New	SWM-New	+	40	60	85
Pervious Urban	Stormwater Management - Recent	SWM - Recent	+	33	46	80
Pervious Urban	Stormwater Management - Retrofits	SWM Retrofits	+	33	46	80
Pervious Urban	Erosion and Sedimentation Control	E&S Control	+	33	50	50
Manure	Animal Waste Management Systems (livestock)	AWMSL	+	75	75	0
Manure	Animal Waste Management Systems (poultry)	AWMSP	+	30	30	0
Pasture	Stream Protection with fencing	SPWF	+	75	75	75
Pasture	Stream Protection without fencing	SPWOF	+	38	38	38
Pasture	Soil Conservation and Water Quality Plan Implementation	SCWQPI	x	12	17	14
Hi Till	Nutrient Management Plan Implementation	NMPI	x	30	20	0
Hi Till	Yield Reserve / Precision Agriculture	YR	x	26	17	0
Hi Till	Cover Crop	CC	x	58	0	0
Hi Till	Soil Conservation and Water Quality Plan Implementation	SCWQPI	x	12	17	8
Hi Till	Buffer Forested	BF	x	57	70	50
Hi Till	Buffer Grassed	BG	x	43	53	50
Hi Till	Retirement of Highly Erodible Land	RHEL	x	20	59	0
Lo Till	Nutrient Management Plan Implementation	NMPI	x	30	20	0
Lo Till	Yield Reserve / Precision Agriculture	YR	x	26	17	0
Lo Till	Cover Crop	CC	x	58	0	0
Lo Till	Soil Conservation and Water Quality Plan Implementation	SCWQPI	x	12	17	8
Lo Till	Buffer Forested	BF	x	57	70	50
Lo Till	Buffer Grassed	BG	x	43	53	50
Lo Till	Retirement of Highly Erodible Land	RHEL	x	20	59	0
Hay	Nutrient Management Plan Implementation	NMPI	x	30	20	0
Hay	Yield Reserve / Precision Agriculture	YR	x	26	17	0
Hay	Soil Conservation and Water Quality Plan Implementation	SCWQPI	x	12	17	8
Water	Controlled Atmospheric Deposition	CAT	x	16	0	0

5. The dialog box should update to list the "Hi Till" land area available in the selected polygon and the default reduction coefficient for Nitrogen, Phosphorus, and Sediment. The dialog box should update as shown in the figure at the top right of this page. In this case (because "Hi Till" land has been chosen) the listed area is the understood total available area in high till land in the selected polygon, 1079.35 acres. The user can over-ride this value with any non-negative value up to this value. The "(x)" in the BMP name indicates that this BMP works in a multiplicative sense (i.e. that the reductions realized by this BMP can be superimposed on the reductions realized by other BMPs for the same land use at the same location). If a BMP is designated as additive "(+)" then it is understood that only one BMP can apply to a given unit of land. For more details on how BMPs work and are calculated please see **Appendix C**.



6. Edit the BMP Area to be just 1000 acres and then click the "Apply" button. The dialog box should now appear as shown at right. (Note that "Hi Till – NMP(x)" is now added to the list of selected BMPs.



7. You can continue to apply other BMPs to this land use (e.g. select "YR(x)" or other listed BMPs), or you can click on other land use categories (e.g. "Lo Till" or Pervious Urban"). Regardless of your choices, you must click the "Apply" button for each BMP you choose to define for the polygon selected in Step 1.

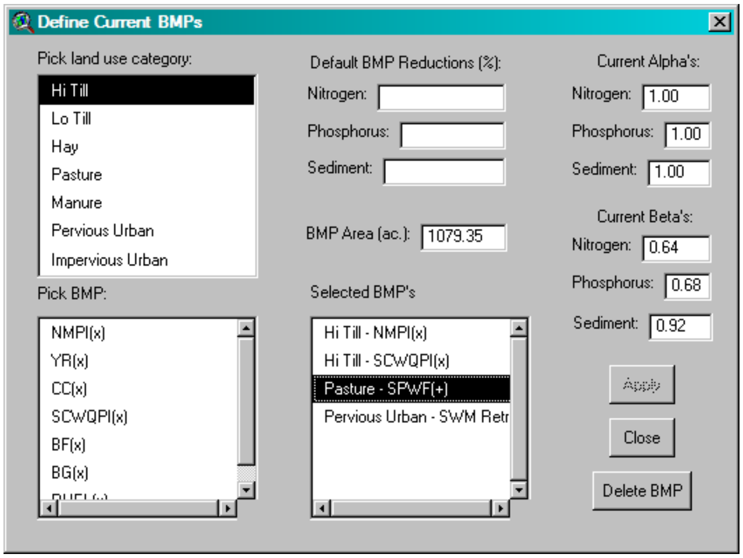
8. When you are finished defining BMPs for a given polygon, click the "Close" button. (Note that you can return to the definition of BMPs for this polygon by repeating Steps 1 and 2. You should find that GISHydro has remembered the BMPs you've defined previously for this polygon.

9. Repeat Steps 2-8 as desired for each individual polygon in your development file to define the full set of all BMPs present in a given analysis.

10. At any time, if you define a BMP mistakenly or wish to remove a particular BMP:

    a. Repeat Steps 2 and 3 with the polygon area selected associated with the BMP that you wish to remove.

    b. In the Selected BMPs list, click on the BMP that you wish to remove so that it appears in reverse video (black background, white text). Please see figure at right showing the selection of the "Pasture – SPWF(+)" BMP in the Selected BMPs list



    c. Click on the "Delete BMP" button and that BMP will be removed and all appropriate alpha and beta values will be updated.

11. With all BMPs defined,repeat Exercise 2, Step 1 to calculate your new loads, which should now be mitigated by the BMPs you've defined in this exercise. Return to Exercise 3 to see how your BMPs have reduced the calculated nutrient loads.

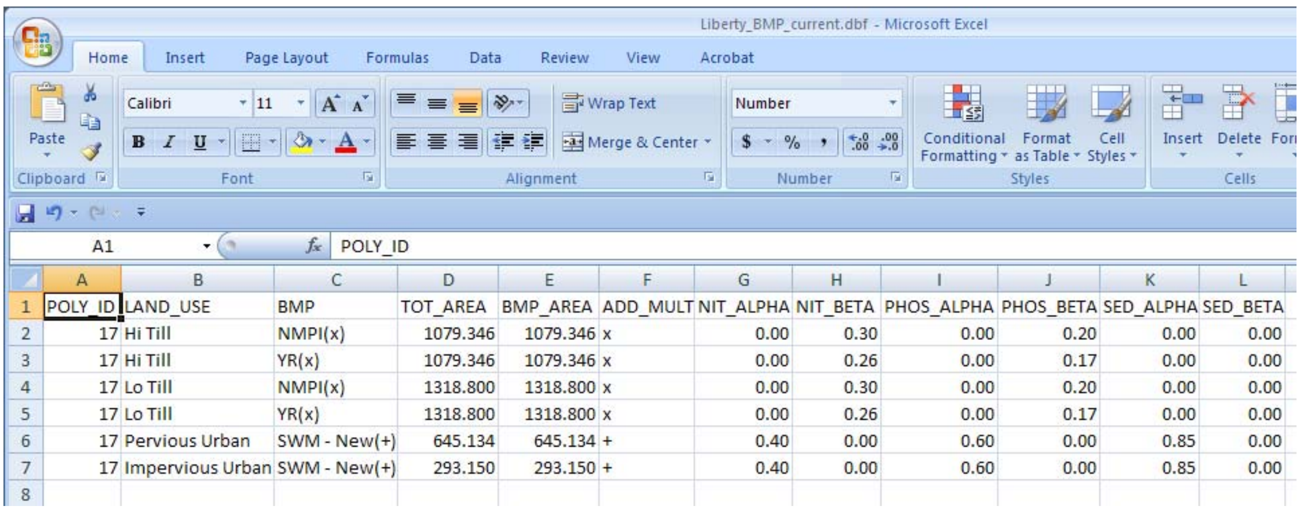
    Potential next exercise: Exercise 7.

Exercise 7: Applying BMPs from a Previous Analysis

Starting Point: Exercises 1, 2, and 6 complete.

We recognize that it could be very tedious to define tens of BMPs across all land uses and for all polygons in a development file. This exercise shows how you can edit (in Microsoft Excel) the BMP definitions file created in Exercise 6 and rapidly define many BMPs. The Excel-modified BMP definitions file can then be used as an alternative to Step 9 in Exercise 6.

GISHydro writes any defined BMPs from Steps 2-8 of Exercise 6 to a "*.dbf" file called, "xxxxx_BMP_current.dbf"[3] where "xxx" refers to the name of the development file (for instance, "Liberty" as shown in Exercise 1, Step 6). This file should be located in the output path indicated in Exercise 1a, Step 6 (e.g. begins with either "e:\temp" if working on the webserver, or "c:\temp" if working on your local machine).



POLY_ID	LAND_USE	BMP	TOT_AREA	BMP_AREA	ADD_MULT	NIT_ALPHA	NIT_BETA	PHOS_ALPHA	PHOS_BETA	SED_ALPHA	SED_BETA
17	Hi Till	NMPI(x)	1079.346	1079.346	x	0.00	0.30	0.00	0.20	0.00	0.00
17	Hi Till	YR(x)	1079.346	1079.346	x	0.00	0.26	0.00	0.17	0.00	0.00
17	Lo Till	NMPI(x)	1318.800	1318.800	x	0.00	0.30	0.00	0.20	0.00	0.00
17	Lo Till	YR(x)	1318.800	1318.800	x	0.00	0.26	0.00	0.17	0.00	0.00
17	Pervious Urban	SWM - New(+)	645.134	645.134	+	0.40	0.00	0.60	0.00	0.85	0.00
17	Impervious Urban	SWM - New(+)	293.150	293.150	+	0.40	0.00	0.60	0.00	0.85	0.00

1. Import the .dbf file described above into Microsoft Excel or Access. The file resulting from the BMP plan described in Exercise 6 (plus some additional BMPs not illustrated there) is shown imported in the screen capture above. Let's briefly interpret the information shown in this file:

   - Poly_ID: This field contains a unique numerical identifier that matches the "ID" field in the attribute table of the Output GIS file produced in Exercise 1a, Step 6.
   - Land_Use: This field contains text indicating the land use category to which the BMP is applied.

[3] Note: This file initially resides on the GISHydro web server in the e:\temp\xxxxx directory where "xxxxx" is the directory indicated in the output path from Exercise 1, Step 6. You can download this file to your local machine following the tutorial in the "Preliminaries" section on "File Management Basics for GISHydroweb". If you intend to import this file ***back*** into GISHydro for subsequent analysis, you must subsequently upload this file back to the GISHydro web server (again, this task is described in the "File Management…" tutorial in the "Preliminaries" section.

- BMP: This field contains text indicating the BMP that is being applied (see"Symbol" column of Table 6-1 for BMPs that can be indicated). Note that the trailing text on all BMPs is either "(x)" or "(+)" depending on whether the BMP acts multiplicatively or additively, respectively.

- Tot_Area: This field contains numerical information indicating the total amount of area (in acres) that exists within the polygon for the land use indicated.

- BMP_Area: This field contains numerical information indicating the amount of area (in acres) to which the BMP is applied. This number cannot exceed the value indicated in the "Tot_Area" field if BMPs are multiplicative. The sum of all BMPs areas applied to a particular land use cannot exceed the value indicated in the "Tot_Area" field if the BMPs are additive.

- Add_Mult: This field contains a single character: "+" for additive BMPs, "x" for multiplicative BMPs.

- Nit_Alpha: This field contains the α value for nitrogen for the BMP indicated. This value can be obtained from Table 6-1 under BMP efficiencies. Not that the efficiencies indicated in Table 6-1 are indicated in percent so you must divide by 100 (e.g. an efficiency of 30 becomes α = 0.30) to obtain the appropriate α value. α values apply to BMPs that are additive, so if the BMP is multiplicative, a value of "0.00" should be indicated.

- Nit_Beta: This field contains the β value for nitrogen for the BMP indicated. This value can be obtained from Table 6-1 under BMP efficiencies. Not that the efficiencies indicated in Table 6-1 are indicated in percent so you must divide by 100 (e.g. an efficiency of 30 becomes β = 0.30)to obtain the appropriate β value. β values apply to BMPs that are additive, so if the BMP is multiplicative, a value of "0.00" should be indicated.

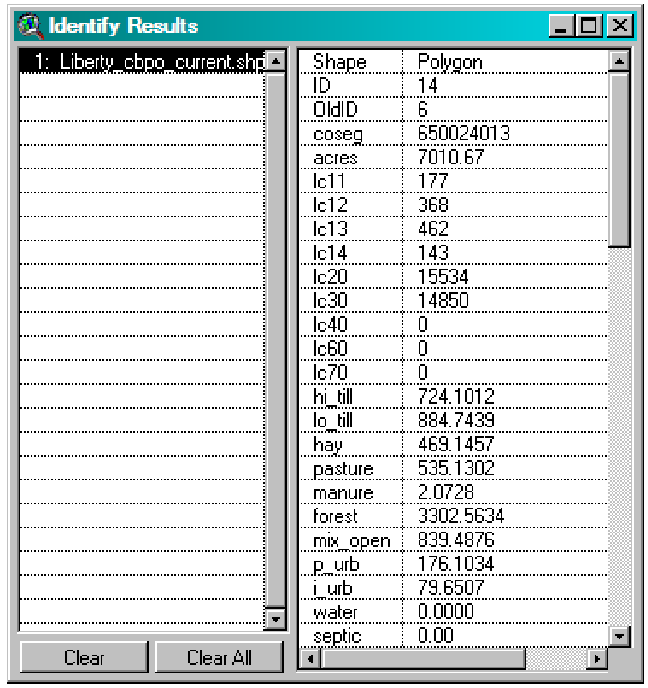
- Phos_Alpha: (same as for Nit_Alpha, except this field applies to phosphorus).

- Phos_Beta: (same as for Nit_Beta, except this field applies to phosphorus).

- Sed_Alpha: (same as for Nit_Alpha, except this field applies to sediment).

- Sed_Beta: (same as for Nit_Beta, except this field applies to sediment).

2. With the Output GIS file from Exercise 1a, Step 6 active, use the "identify" tool  (see page 7 of the ArcView tutorial for more information about this tool) and click on the polygon you are planning to apply BMPs to. A report box similar to the one shown at right will appear. The information appearing in this box will be useful for specifying the details of new BMPs.



3. Use the data entry and/or copy/paste features of Excel to repeat BMPs for one polygon to many other polygons. (You may want to consult Table 6-1 for BMP names and standard nutrient reduction values). Items to focus on for specific editing are:

   i. The "Poly_ID" (which must match one of the polygon IDs from the "ID" field of the Output GIS file created in Exercise 1a, Step 6. (For instance, use ID=14 based on above dialog box).

   ii. The Tot_Area must be appropriate for the land use and polygon ID from Step 3.i above. (For instance, if you arespecifying a "Hi Till" BMP the appropriate Tot_Area would be 724.10 acres for ID=14.)

   iii. Restrictions on the BMP_Area depend on whether you are applying an additive or multiplicative BMP:

      - If the BMPs are additive, the sum of all BMP_Areas for a given polygon and land use combination cannot exceed the Tot_Area (from Step 3.ii above).

      - If the BMPs are multiplicative, then each of the BMP_Areas for a given polygon and land use combination cannot exceed the Tot_Area (from Step 3.ii above).

4. As an example, let's repeat all BMPs from Poly_ID=17 to Poly_ID=14. In addition, let's specify a Lo Till Cover Crop BMP applying to 700 acres applying to Poly_ID=14.

   i. Repeating BMPs: In Excel, make a copy of all rows (rows 2 through 7) paste directly beneath row 7.

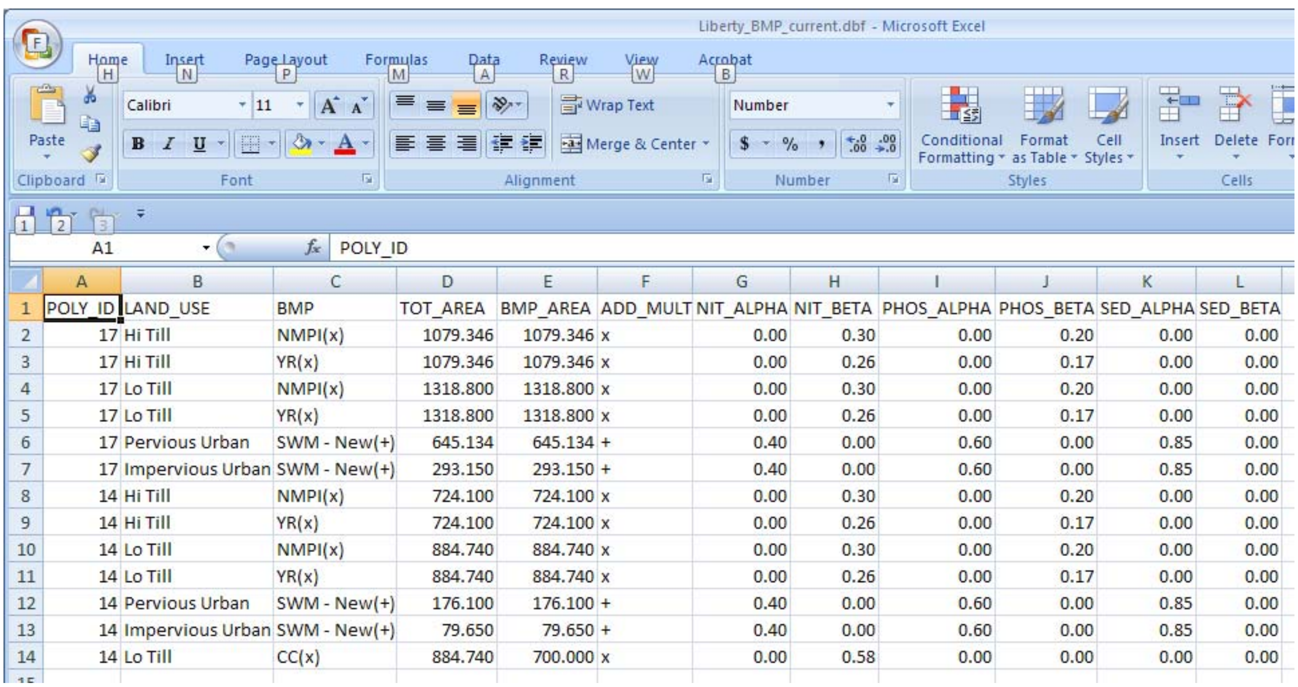
      - Change the Poly_ID for all newly copied rows (rows 8 through 13) from 17 to 14

- Based on the output from Step 2, Poly_ID 14 has:
  - o 724.10 acres of Hi Till land use
  - o 884.74 acres of Lo Till land use
  - o 176.10 acres of Pervious Urban land use
  - o 79.65 acres of Impervious Urban land use

  Use the editing tools in Excel to replace the Tot_Area and BMP_Area values in rows 8 through 13 to the appropriate values indicated here.

ii. New Lo Till BMP:

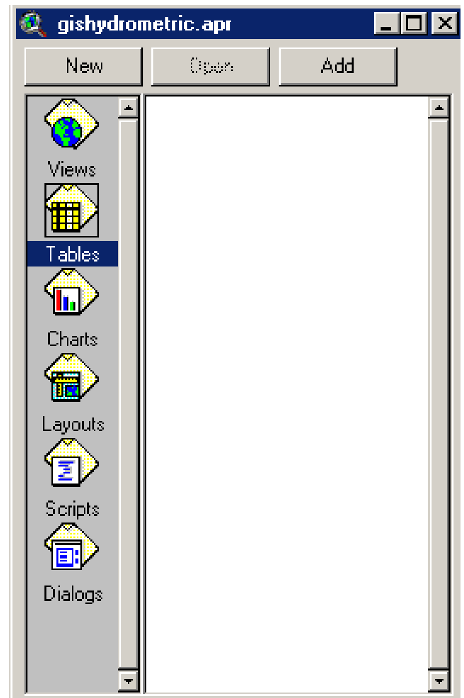
- Make a new row (row 14) in the spreadsheet. We will create new entries from left to right across the BMP definitions file:
  - o Set Poly_ID to 14
  - o Set Land Use to “Lo Till”
  - o Examine Table 6-1, then set BMP to ”CC(x)” to indicate the cover crop BMP which acts multiplicatively
  - o Set Tot_Area to 884.74 acres
  - o Set BMP_Area to 700 acres
  - o Set Add_Mult to “x” (for multiplicative)
  - o Examine Table 6-1. The, efficiencies for the cover crop BMP are 58, 0, and 0, for nitrogen, phosphorus, and sediment, respectively. In units of percent. Since the cover crop BMP is multiplicate, all α values are 0.00 and the β values for are 0.58, 0.00, and 0.00 for nitrogen, phosphorus and sediment, respectively.



	A	B	C	D	E	F	G	H	I	J	K	L
1	POLY_ID	LAND_USE	BMP	TOT_AREA	BMP_AREA	ADD_MULT	NIT_ALPHA	NIT_BETA	PHOS_ALPHA	PHOS_BETA	SED_ALPHA	SED_BETA
2	17	Hi Till	NMPI(x)	1079.346	1079.346	x	0.00	0.30	0.00	0.20	0.00	0.00
3	17	Hi Till	YR(x)	1079.346	1079.346	x	0.00	0.26	0.00	0.17	0.00	0.00
4	17	Lo Till	NMPI(x)	1318.800	1318.800	x	0.00	0.30	0.00	0.20	0.00	0.00
5	17	Lo Till	YR(x)	1318.800	1318.800	x	0.00	0.26	0.00	0.17	0.00	0.00
6	17	Pervious Urban	SWM - New(+)	645.134	645.134	+	0.40	0.00	0.60	0.00	0.85	0.00
7	17	Impervious Urban	SWM - New(+)	293.150	293.150	+	0.40	0.00	0.60	0.00	0.85	0.00
8	14	Hi Till	NMPI(x)	724.100	724.100	x	0.00	0.30	0.00	0.20	0.00	0.00
9	14	Hi Till	YR(x)	724.100	724.100	x	0.00	0.26	0.00	0.17	0.00	0.00
10	14	Lo Till	NMPI(x)	884.740	884.740	x	0.00	0.30	0.00	0.20	0.00	0.00
11	14	Lo Till	YR(x)	884.740	884.740	x	0.00	0.26	0.00	0.17	0.00	0.00
12	14	Pervious Urban	SWM - New(+)	176.100	176.100	+	0.40	0.00	0.60	0.00	0.85	0.00
13	14	Impervious Urban	SWM - New(+)	79.650	79.650	+	0.40	0.00	0.60	0.00	0.85	0.00
14	14	Lo Till	CC(x)	884.740	700.000	x	0.00	0.58	0.00	0.00	0.00	0.00

5. Once all edits are made, the resulting table should look as shown above. Save your revised dbf file under a different name in dbf format (note that if you are working in Office 2007 with

Microsoft Excel no longer can write to dbf formats – thank you Microsoft!). If this is the case, you will need to save to an *.xlsx" format and then open this file in Microsoft Access 2007. Access can then be used to export to a "*.dbf" format. If you are working on the GISHydro webserver, you will should now upload this file to the same directory of your other files for this analysis (see section called "File Management basics for GISHydroweb" from earlier in this document for a reminder of how to move copies of files between your local machine and the GISHydro web server).



6. In the project view of GISHydro, click the "Tables" icon and click on the table called, "User-Defined Current BMP Table". Click the delete button and click "Yes" to delete this old table.

7. In the project view of GISHydro (see at right), click on the "Tables" icon, and click the "Add" button. You will be presented with a browser dialog. Point the browser to the *.dbf file created in Step 3. This will load in your new, revised, bigger BMP definition table.

8. The table loaded in Step 7 will load in with its file name by default. Double click on the file name and the table should appear. Scan through the table to confirm that the table has loaded properly.

9. Click "Table: Properties". For table title, change from the filename that appears there to, "User-Defined Current BMP Table".

2. As a check, you should now be able to repeat Steps 2 and 3 from Exercise 6 for any polygon in your development file and confirm that the BMPs you set in Microsoft Excel/Access are understood within the GIS.

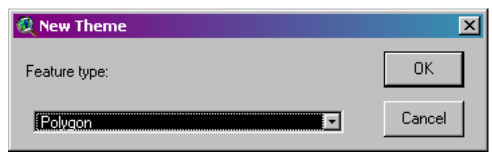
Appendix A: Preparing a Development File for Nutrient Loading Analysis

General Information/Rules

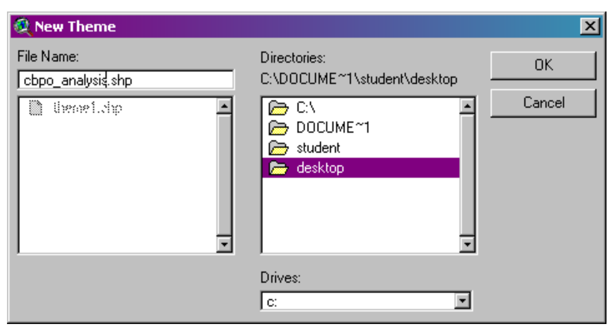
To use the Nutrient Loading Interpolator, you must create a polygon shapefile. This shapefile should have the following properties:

1. The file should be in the Maryland Stateplane projection, NAD 1983, in horizontal units of meters.
2. The file should contain one or more polygons that indicate boundaries over which current (and possibly future) nutrient load calculations are desired. If future nutrient loads are desired, each polygon should represent a single future land use.
3. In the attribute table:
    a. There should be a field called "ID" with unique values for each record in the table.
    b. (optional) If future nutrient loads are desired, there should be a field called "**LU_New**" that contains text descriptions of the land use that will appear in that polygon under post development conditions. (Spelling, capitalization, and spaces count!) A tool within GISHydro (illustrated below) will aide you in setting up this field and populating the table entries with allowable land uses.

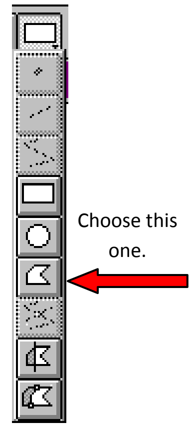
Mechanics of GIS Preparation for Analysis



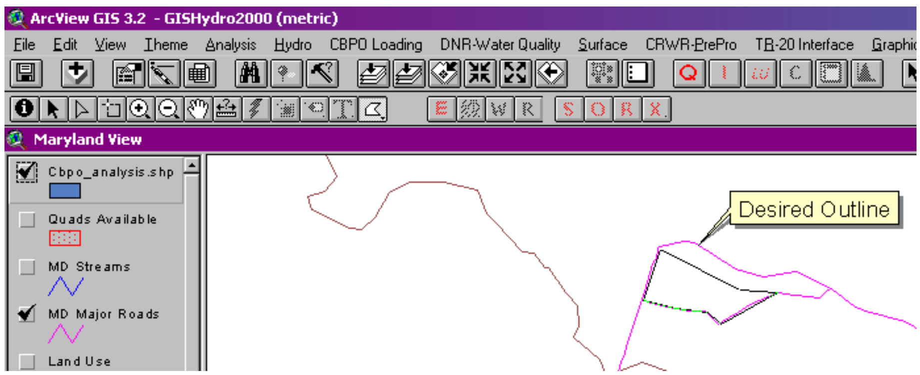
1. From the "Maryland View" of GISHydro2000, choose "View: New Theme…". You will be prompted with the dialog box shown at right. Click the down arrow and choose "Polygon" as shown. Click the OK button.
2. You will now be prompted to specify a path and name for the GIS theme you are creating. A sample dialog box is shown at right with the filename, "cbpo_analysis.shp" indicated. Click "OK" once you have specified your desired filename and path.



3. You will now see the theme you have indicated at the top of the table of contents of the "Maryland View" window. You are now ready to begin digitizing the polygons that cover your area of interest. You might find it helpful to zoom in to the scale of your study area using the navigation tools in ArcView, or you might want to load in additional GIS themes that will be helpful for placing your polygons. The default polygon to digitize is a rectangle, but more likely you will want to digitize an irregular polygon. Click ***carefully*** at the bottom right of the rectangle tool (you will see a small triangle there indicating a drop-down menu). When you click there the dropdown menu shown at right will appear. Select the irregular polygon tool from this list as indicated.

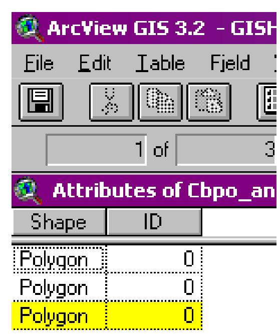


4. You are now ready to begin digitizing. A sample of the digitizing process in

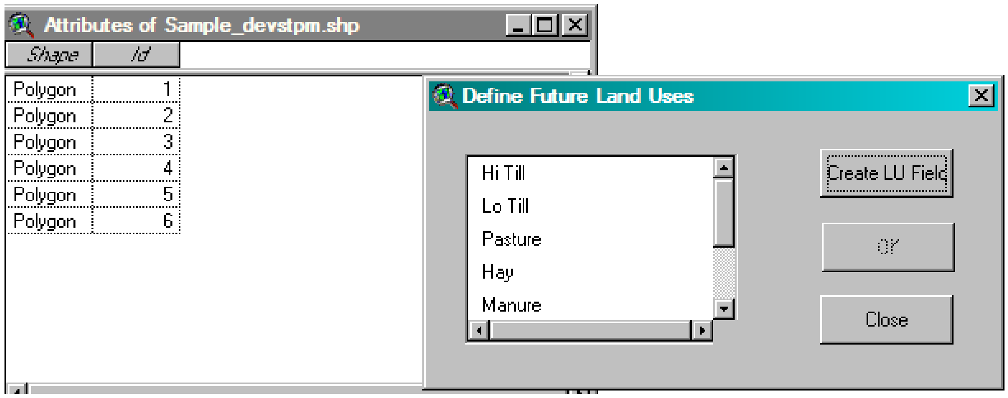


action is shown above. When the entire polygon has been digitized as desired, double-click quickly on the last point to finish that polygon. Repeat as needed for all analysis areas.

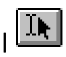
5. With the polygon theme active, choose, "Theme: Table..." to open the attribute table of the polygon theme you have digitized. The last polygon you have digitized will be shown selected (in yellow highlight) as shown in the screen capture at right (I have digitized 3 polygons, though the process for doing this was only shown once). By default, all polygons are given ID=0. You can number you polygons using the data entry tool . Be sure to press the "Enter" key after your last entry to apply it. It is advisable to give each polygon area a unique ID (I will use 1, 2, and 3).

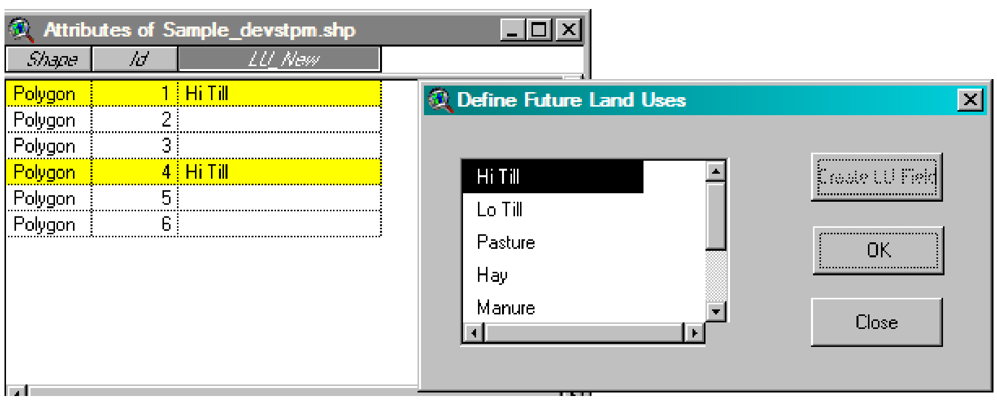


6. If you do not require calculations of future loadings, skip to Step 11.
7. (optional: to calculate future loadings) As indicated in the "General Information" section above, if you wish to specify new (future) land uses, you will need to add a field to the attribute table and specify these land uses. To do this, there is a GISHydro dialog tool to help you. With your polygon theme's table the active document, choose: "CBPO Loading: Define Land Uses" (*repeat*: the table *must* be active, not the view).



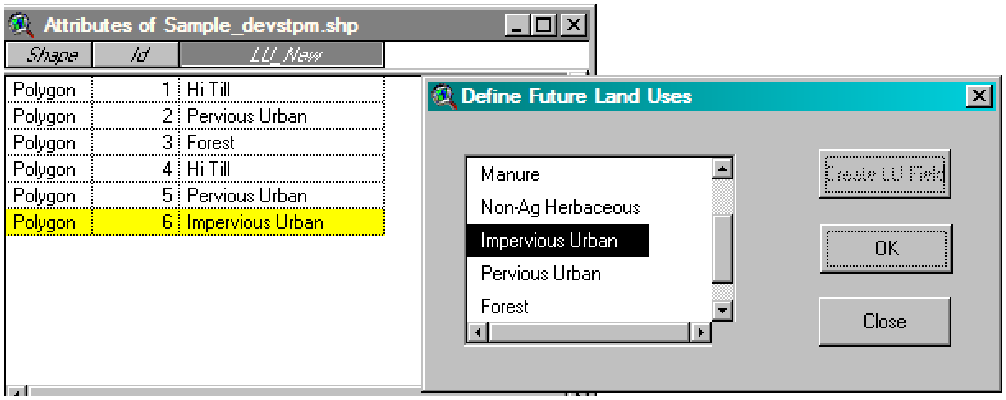
The "Create LU Field" button should be active (not grayed out) if you have not yet created an "LU_New" field. To create this field, simply click the "Create LU Field" button.

8. (optional: to calculate future loadings) With the "LU_New" field, created, you now must populate all records of the polygon attribute table with CBPO recognized land uses. To do this, select one or more records from the polygon attribute table using the select tool  . To simultaneously select more than one record, hold down the shift key and click all records that you want to select. The "selected" property toggles, so clicking a selected record unselects it if you accidentally select a record you don't want to include. Once you've selected all the records



in the table you want to assign a given land use, click the entry from the scrolling menu choices at the left of the dialog box ("Hi Till" is shown as selected in the figure above). Click the "OK" button to assign the selected land use to the selected records in the attribute table.

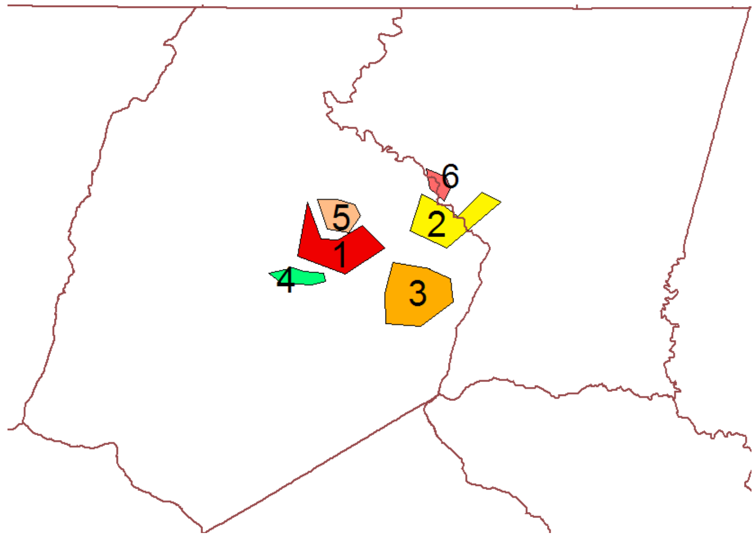
9. (optional: to calculate future loadings) Repeat step 8 until all records in the attribute table are populated such as shown in the figure at the top of the next page. If one or more records are not assigned a future land use, these records will not contribute to the calculated future loadings.



10. (optional: to calculate future loadings) When you are satisfied with all of your entries, click the "Close" button. You are now ready to begin a nutrient loading analysis with the file you have just created.
11. (continuing from Step 6) When you are satisfied with all of your entries, both to the spatial representation of all polygons and to the attribute table numbering, choose "Table: Stop Editing", then click on "Yes" to the "Save Edits?" question. You will see the field headings in your attribute table shift from regular to italics, indicating that the table is now closed to editing. *Note: You can always return to editing the table using "Table: Start Editing" if your attribute table is the active document or return to adding new polygons from the "Theme: Start Editing" if the view window is the active document.* You are now ready to begin a nutrient loading analysis with the file you have just created.

Appendix B: Example of Land Cover to Land Use to Nutrient Load Calculation

Consider the following hypothetical development shapefile located partially in Frederick and Carroll counties of Maryland. After setting the development file for this shapefile, we find that polygons 2 and 6 are split because each resides partially in Frederick and Carroll counties. The split takes place along the county lines. We will focus on polygon 2.



Total Acreage

The GIS calculates that the total acreage of polygon 2 is distributed as follows: in Carroll county (1951.3 acres), in Frederick county (4799.5 acres).

Land Cover Distribution

Using the CBPO Phase 4 land cover, the GIS determines the number of 30m pixels in each of 9 land cover classes fall within the polygon 2 area as follows:

Land Cover ID	Description	Carroll County (number of 30m pixels)	Frederick County (number of 30m pixels)
11	CBPLU High Intensity Urban	0	0
12	CBPLU Low Intensity Urban	117	24
13	CBPLU Herbaceous Urban	63	0
14	CBPLU Woody Urban	0	0
20	CBPLU Herbaceous	7444	18338
30	CBPLU Woody	1145	3220
40	CBPLU Exposed	0	0
60	CBPLU Water	5	0
70	CBPLU Herbaceous Wetlands	0	1

Land Use Distribution

Land Cover is converted to Land Use using rules set out in the document, “Chesapeake Bay Watershed Model Land Use and Model Linkages to the Airshed and Estuarine Models” (January, 2000). The rules for this conversion were applied as follows:

- **Agricultural Land:** The land cover CBPLU Herbaceous (20) was divided into six land uses: hi till, low till, pasture, hay, manure, and non-agricultural herbaceous. The CBPO used agricultural census data to determine these proportions. We did not use the census data directly, but rather we simply used the reported values from the table: "1990 Phase 4.2 Watershed Model Land Use Sorted by Major Tributary Basin". This table provides the acreage in each land use division. The acres in each of the above categories were summed and then the relative fraction of each specific land use was calculated. This fraction was then used to apportion the herbaceous land cover into the appropriate fractions of land use. Thus, we are treating all herbaceous land [CBPLU Herbaceous (20)] as being uniformly constituted of these six fractions of land use within each county segment. For example, consider the two county segments intersected by polygon 2. The table below shows the acreage and area fractions for these two county segments (cosegs).

Land Use	Coseg 210024013 (acres)	Fraction in coseg 210024013	Coseg 210024021 (acres)	Fraction in coseg 210024021
Hi Till	20038	0.2096	3823	0.0226
Lo Till	24475	0.2561	63997	0.3780
Pasture	14808	0.1549	38959	0.2301
Hay	12982	0.1358	33208	0.1961
Manure	53	0.0006	206	0.0012
Non-Ag Herbaceous	23226	0.2430	29110	0.1719
Sum	95582	1.0000	169303	1.0000

Land use in each of these agricultural categories is then determined by the product of the acreage in CBPLU Herbaceous and the fractions indicated in the above table. For instance, we have 7,444 pixels CBPLU Herbaceous (1,655.5 acres) in polygon 2 of Carroll county. Likewise we have 18,448 pixels (4,078.0 acres) in polygon 2 of Frederick county. To single out Hi Till land use in Carroll county this is (1655.5 acres) * (0.2096) = 347.0 acres. The remaining values are tabulated below:

Land Use	Coseg 210024013 (acres)	Coseg 210024021 (acres)
Hi Till	347.0	92.2
Lo Till	424.0	1541.6
Pasture	256.4	938.4
Hay	224.8	799.8
Manure	1.0	4.9
Non-Ag Herbaceous	402.3	701.1
Sum	1655.5	4078.0

- All remaining land use conversions are simpler to calculate and do not vary in proportion from one county segment to another:
  - **Impervious Urban Land:** this quantity is calculated as a weighted function of 5 different categories of CBPLU land cover as follows:

    $$U_{impervious} = 0.85 \cdot (HIU) + 0.40 \cdot (LIU) + 0.10 \cdot (HU) + 0.10 \cdot (WU) + 0.40 \cdot (E)$$

    where $U_{impervious}$ is the amount of impervious urban land, *HIU* is CBPLU High Intensity Urban (code 11), *LIU* is CBPLU Low Intensity Urban (code 12), *HU* is CBPLU Herbaceous Urban (code 13), *WU* is CBPLU Woody Urban (code 14) and *E* is CBPLU Exposed (code 40).
  - **Pervious Urban Land:** this quantity is the complement of impervious urban land and is calculated as follows:

    $$U_{pervious} = 0.15 \cdot (HIU) + 0.60 \cdot (LIU) + 0.90 \cdot (HU) + 0.90 \cdot (WU) + 0.60 \cdot (E)$$

    where $U_{pervious}$ is the amount of pervious urban land.
  - Forest: this quantity is calculated as a function of 2 CBPLU land cover categories as follows:

    $$F = 1.00 \cdot (W) + 1.00 \cdot (HW)$$

    where *F* is the amount of forested land, *W* is CBPLU Woody (code 30) and *HW* is CBPLU Herbaceous Wetlands (code 70).
  - **Water:** is simply taken as the acreage in CBPLU Water (code 60).

Applying these rules to the remaining (non-agricultural) land uses we determine the following land use distributions in polygon 2 across the two counties:

Land Use	Coseg 210024013 (acres)	Coseg 210024021 (acres)
Impervious Urban	11.8	2.1
Pervious Urban	28.2	3.2
Forest	254.6	716.3
Water	1.1	0.0

Calculating Nutrient Loads

Nutrient loads are determined as a function of land use, area, and spatial location. The primary output of the Chesapeake Bay Program model are estimates of nutrient loads. In Phase 4 modeling, these estimates are reported from two perspectives: edge of stream and as delivered to the Bay. Because the perspective of our modeling seeks to treat all lands equitably and because loadings imposed on local streams, not just the Bay, are a concern, our modeling assumes the edge of stream perspective for determining loads and changes in loads. Loads are calculated using the following general equation:

$$L_{i,j} = \sum_k c_{i,j,k} \cdot A_{j,k}$$

Where $L_{i,j}$ is the nutrient load for nutrient, *i*, from location, *j*; $c_{i,j,k}$ is the loading coefficient for nutrient, *i*, from location, *j.* for land use, *k*; and $A_{j,k}$ is the area of location, *j* in land use, *k*. The loading coefficients for nutrients: Total Nitrogen, Total Phosphorus, and Total Sediment were determined by dividing the modeled total loading for each of these nutrients for each state segment and land use by the area of that land use within the state segment. The table used to derive these loadings was provided by Gary Shenk of the Chesapeake Bay Program in the file "sseosallcall.prn" (**s**tate **s**egment **e**dge **o**f **s**tream **all** land uses **cal**ibrated). The mechanics of calculating nutrient loads then becomes a straightforward bookkeeping exercise in which the areas of land uses identified in the previous step are then multiplied with the appropriate loading coefficients and then summed across all locations of interest. Considering the case of polygon 2 we can develop the following table for the nutrient, Total Nitrogen:

Land Use	Coseg 210024013			Coseg 210024021		
	Area (acres)	Loading Coef. (lbs/acre)	Product (lbs)	Area (acres)	Loading Coef. (lbs/acre)	Product (lbs)
Hi Till	347.0	27.86	9667.7	92.2	27.86	2568.0
Lo Till	424.0	22.20	9413.4	1541.6	22.20	34227.4
Pasture	256.4	11.39	2921.5	938.4	11.39	10691.0
Hay	224.8	7.83	1759.9	799.8	7.83	6260.5
Manure	1.0	1985.31	1972.0	4.9	1985.31	9715.9
Non-Ag Herbaceous	402.3	6.66	2678.1	701.1	6.66	4667.1
Impervious Urban	11.8	9.90	116.9	2.1	9.90	21.1
Pervious Urban	28.2	13.31	375.7	3.2	13.31	42.6
Forest	254.6	2.03	517.1	716.3	2.03	1454.7
Water	1.1	10.44	11.6	0.0	10.44	0.0
Sum	**1951.3**		**29,434.1**	**4799.5**		**69,648.4**

Similar tables can be developed for Total Phosphorus and Total Sediment. The above table shows that the total loading of Nitrogen for current land use conditions in polygon 2 is 29,434.1 + 69,648.4 = 99,085.5 lbs or 49.54 tons of Nitrogen.

Assuming a fictitious future land use of "pervious urban" for Polygon 2 the future loading for this pixel is simply the product of Polygon 2's area (1951.3 acres in coseg 210024013) and (4799.5 acres in 210024021) and the pervious urban loading rate of 13.31 lbs/acre. Thus the future loading is 89,853.1 lbs or 44.92 tons of Nitrogen. The change in loading (future land use – current land use) is 44.92 – 49.54

= -4.62 tons. Thus, for this particular polygon, the fictitious future loading actually produces 4.62 tons of nitrogen *less* than current conditions. We should note that overall (across all 6 polygons shown at the beginning of the example, the modeled future land use (pervious urban everywhere) produces 8.75 tons of Nitrogen *more* than the current land use.

Appendix C: Mathematics of BMP Modeling

This appendix presents a new GIS-based tool added to the GISHydro2000 program for working with BMPs in nutrient loading calculations. This tool works with the list of BMPs developed by the Department of Natural Resources (DNR) and the Maryland Department of the Environment (MDE) in cooperation with the US EPA's Chesapeake Bay Program Office (CBPO). Further, this tool is consistent with these agencies in its modeling approach to the application of BMPs as either additive or multiplicative in their performance. The details of this approach are defined below, first in formal mathematical terms, and second in the form of simple illustrative example.

Additive vs. Multiplicative BMPs

As will be described in this appendix, some BMPs are applied additively to their associated land use while others are applied multiplicatively. Generally speaking, only a single additive BMP may be applied to a given piece of land while multiplicative BMPs can be superimposed, one upon the other to the same piece of land, regardless of the existence of any other BMPs. Whether a BMP acts additively or multiplicatively is a property of the BMP that is understood and imposed by the GISHydro program – this is not a decision or property that the analyst needs to make or specify. Also, the mathematics of BMP application differ depending on this additive or multiplicative property as described and illustrated below.

How BMPs are modeled – equations

Nutrient loading is modeled in GISHydro2000 in a manner consistent with and based upon the land uses and loading rates defined by the CBPO. Annual nutrient loads are calculated according the equation:

$$L_{i,j,k} = A_i \cdot R_{i,j,k} \qquad (1)$$

Where *L* is the nutrient load (in lbs/year), *A* is the area of land in land use, *i* (in acres), and *R* is the loading rate [in lbs/(acre-year)]. The subscripts in the equation are *i* (denoting land use), *j* (denoting the spatial county segment, referred to as a "cosegment"), and *k* (denoting the specific nutrient: nitrogen, phosphorus, or sediment). Calculations in GISHydro2000 are organized such that any unique polygon being analyzed resides in only one cosegment, *j*, but may include multiple land uses, *i*. Calculations are performed for all three nutrients. If a user has specified a polygon that resides in more than one cosegment, that polygon will be split into two or more polygons, each of which resides in only a single cosegment.

BMPs act to reduce nutrient loading according to the following general equation:

$$\gamma_{i,k} = \alpha_{i,k} \cdot \beta_{i,k} \qquad (2)$$

where γ is the total BMP reduction multiplier, α is the aggregate additive BMP factor and β is the aggregate multiplicative BMP factor. The α and β values correspond to the "alpha" and "beta" values, respectively, that appear as "BMP Efficiencies" in Table 6-1 and are also shown in the dialog box in Exercise 6. The "alpha" (a) values correspond to additive BMPs indicated by a trailing "(+)" at the end of the BMP text definition while the "beta (b) values correspond to multiplicative BMPs indicated by a trailing "(x)" at the end of the BMP text definition. For instance, an α value of 0.40 corresponds to the nitrogen reduction efficiency of the BMP "Stormwater Management – New" symbolized by "SWM-New(+)". A β value of 0.30 0.30 corresponds to the nitrogen reduction efficiency of the BMP "Nutrient Management Plan Implementation" symbolized by "NMPI(x)". (Please see Table 6-1 to locate these entries.) As with nutrient loading rates, BMP factors, and thus the overall BMP reduction factor, are a function of land use category and nutrient type.

The new loading achieved with the BMPs in place is simply the product of the BMP reduction multiplier and the loading calculated in equation 1:

$$(BL)_{i,j,k} = L_{i,j,k} \cdot \gamma_{i,k} \tag{3}$$

where *BL* is the BMP mediated loading and the other terms are as defined earlier. It is necessary to define how the aggregate additive and multiplicative factors are determine. The additive factor, α, is calculated as:

$$\alpha_{i,k} = 1 - \sum_{m=1}^{n} \frac{\left(A_{B,i}\right)_m}{A_i} \cdot (\varepsilon_{i,k})_m \tag{4}$$

where $(A_{B,i})_m$ is the area of the m^{th} BMP applied to land use, *i*, (in acres), $(\varepsilon_{i,k})_m$ is the efficiency of the m^{th} BMP applied to land use, *i*, for nutrient, *k* (as a decimal fraction between 0 and 1), and *n* is the total number of additive BMPs applying to the particular land use. Similarly, the multiplicative factor, β, is calculated as:

$$\beta_{i,k} = \prod_{m=1}^{n} \left(1 - \frac{\left(A_{B,i}\right)_m}{A_i} \cdot (\varepsilon_{i,k})_m \right) \tag{5}$$

where *n* is now the total number of multiplicative BMPs applying to the particular land use.

How BMPs are modeled – an example

First, let's consider BMPs on the "Pervious Urban" land use, specifically the "Stormwater Management – Recent (SWM – Recent)" and "Erosion and Sediment Control (E&S Control)" BMPs which have efficiencies of 33 and 40 percent, respectively, for the reduction of nitrogen loads. Both of these BMPs act additively. Let's assume 1000 acres of pervious urban land on which the SWM – Recent BMP is applied to 300 acres and the E&S Control BMP is applied to 700 acres. Applying equation 4 to determine the α value for nitrogen reduction on pervious urban land we get:

$$\alpha_{pervious\_urban,nitrogen} = 1 - \left[\frac{300}{1000} \cdot 0.33 + \frac{700}{1000} \cdot 0.40 \right] = 0.621 \quad (6)$$

Note that the sum of BMP acres of pervious urban land (300 + 700 = 1000 acres) equals the total amount of pervious urban land use acres available. While it is possible for the total BMP acres to be less than the total acres available, the opposite is not allowed. Because of the understanding of how additive BMPs work, it is not allowable to have two different BMPs to be applied simultaneously to the same piece of land. This might be more obvious by simply scanning Table 6-1 and noting that the sum of all the reduction efficiencies in many additive BMPs for a given land use exceeds 1 (e.g the sum of the four pervious urban efficiencies is 1.39). As an extreme case, it should be clear that if all four of these BMPs were allowed to be applied to all pervious urban acres available, the resultant α value from equation 4 would be α = -0.39 which is clearly nonsensical.

Returning to the example shown in equation 6, since there are no multiplicative BMPs considered here for pervious urban land, we note that β = 1 for this land use type and, therefore, from equation 2 the overall BMP reduction coefficient for pervious urban land in this example is:

$$\gamma_{pervious\_urban,nitrogen} = \alpha_{i,k} \cdot \beta_{i,k} = (0.621) \cdot (1) = 0.621 \quad (7)$$

Now, let's consider BMPs on the "Hi Till" land use, specifically the "Nutrient Management Plan Implementation (NMPI)" and "Cover Crop (CC)" BMPs which have efficiencies of 30 and 58 percent, respectively, for the reduction of nitrogen loads. Both of these BMPs act multiplicatively. Let's assume 1000 acres of high till land on which the NMPI BMP is applied to 900 acres and the CC BMP is applied to 700 acres. Applying equation 5 to determine the β value for nitrogen reduction on hi till land we get:

$$\beta_{hi\_till,nitrogen} = \left(1 - \frac{900}{1000} \cdot 0.30\right) \cdot \left(1 - \frac{700}{1000} \cdot 0.58\right) = 0.434 \quad (8)$$

Note that the sum of BMP acres of hi till land (900 + 700 = 1600 > 1000 acres). This implies that there must be overlap of the two BMPs on at least 600 acres of hi till land. Unlike for additive BMPs, multiplicative BMPs *do* allow for two different BMPs to be applied simultaneously to the same piece of land. Because of the structure of equation 5, the lower limit to β, if an infinite number of multiplicative BMPs were applied, is 0. Returning to the example shown in equation 8, since there are no additive BMPs considered here for hi till land, we note that α = 1 for this land use type and, therefore, from equation 2 the overall BMP reduction coefficient for hi till land in this example is:

$$\gamma_{hi\_till,nitrogen} = \alpha_{i,k} \cdot \beta_{i,k} = (1) \cdot (0.434) = 0.434 \quad (9)$$

Finally, we note in Table 6-1 that only the "pasture" land use has both additive and multiplicative BMPs defined for it. "Stream protection with fencing (SPWF)" has a nitrogen reduction efficiency of 75 percent acting additively. "Stream protection without fencing (SPWOF)" has a nitrogen reduction efficiency of 38 percent acting additively. Lastly, "Soil conservation and water quality plan implementation

(SCWQPI)" has a nitrogen reduction efficiency of 12 percent acting multiplicatively. Let's assume 1000 acres total of pasture land. With 700 acres of the SPWF BMP, 300 acres of the SPWOF BMP, and with the SCWQPI BMP acting on all 1000 acres. Using equation 4, let's first calculate α:

$$\alpha_{pasture,nitrogen} = 1 - \left[\frac{700}{1000} \cdot 0.75 + \frac{300}{1000} \cdot 0.38 \right] = 0.362 \tag{10}$$

Likewise, β is only a function of the SCWQPI BMP:

$$\beta_{pasture,nitrogen} = \left(1 - \frac{1000}{1000} \cdot 0.12 \right) = 0.88 \tag{11}$$

Therefore the overall reduction value, γ, value in this final example is:

$$\gamma_{pasture,nitrogen} = \alpha_{i,k} \cdot \beta_{i,k} = (0.362) \cdot (0.88) = 0.319 \tag{12}$$

Thus, in this last example we arrive at the result that the application of all three of these pasture land use BMPs on the acreages as defined, leads to an ultimate loading of just under 32 percent of the total, unmitigated loading that would have resulted in the absence of any BMPs.