APPENDIX - A

StormWISE Software Documentation

1. Contents of CDROM

A. Stormwise_Distribution – executable programs and example data files

1. BMPFIT –

a. AMPL run, model, and data files to implement multipoint cost calibration to obtain StormWISE parameter HALF_COST_PER_AREA. This is a console program. At the command prompt, type

ampl xxx.*run*

where "xxx" stands for a land use category,

for example:

ampl commercial.run

to display results for commercial land use category to the screen.

BMP performance and cost data can be changed by editing the file xxx.*dat* for each different land use category.

b. BMPFIT.xls – a template file for Microsoft Excel which, when used with the Excel "solver" add-in, will perform a multi-point cost calibration to obtain StormWISE parameter HALF_COST_PER_AREA and also plot the results.

2. GWLF_postprocessor – a console program to read comma separated value (.csv) files containing output from the AVGWLF pollutant load simulation model (sediment, nitrogen, and phosphorous loadings) and generate an input (.inp) file for use by StormWISE. AVGWLF .csv files containing summary data have the form

PROJECT-XXXX*sum.csv*

where PROJECT is the name of the AVGWLF project and

XXXX is a code for the drainage area generated by AVGWLF.

After generating such an output file for each of the subwatershed drainage areas in your analysis, copy them into your StormWISE project folder and at the command prompt, type

```
gwlf_postprocessor  PROJECT XXX1 XXX2 XXX3 …
```

where XXXx names each of the different drainage areas to include in the StormWISE analysis. An example of the use of this program is provided in the StormWISE_Examples folder in the StormWISE directory, and is described further below. NOTE: the file BMP.inp must be present in the same directory when running GWLF_postprocessor, which contains a protion of the StormWISE .inp file related to BMP technologies and costs. BMP.inp can be edited to change cost and performance assumptions for BMP technologies. The source code for GWLF_postprocessor in the "C" programming language, and it can be recompiled from the provided source code to run on almost any computing system. Also, this program can be modified by users with C programming experience to parse the output files of other nonpoint pollution loading simulation programs.

3. npsopt_washoff – a console program with similar capabilities to the StormWISE graphical interface program. It can read StormWISE .inp files generated manually, by GWLF_postprocessor, and also by the StormWISE graphical interface program, described below. The .inp files contain pollutant loading and cost data. The output is an AMPL ".dat" file that is read by the optimization module in file npsopt_washoff.mod. The sequence of commands is as follows:

Notepad PROJECT.*inp*

to create or edit a StormWISE input file,
where

"PROJECT" is the name of the current project, which is usually the name of the larger watershed being analyzed.

After exiting notepad, type:

npsopt_washoff PROJECT.*inp*

to generate the file PROJECT.*dat* which is read by AMPL when the command:

ampl PROJECT.*run*

is typed at the console. The file PROJECT.*run* must be edited to contain the name of the correct data file, PROJECT.*dat*. An example from Swarthmore College's Springfield project is provided in this folder. The AMPL output, containing optimal investment levels by land use category and subwatershed drainage area, is displayed to the screen by default. Output can be redirected to a file as follows:

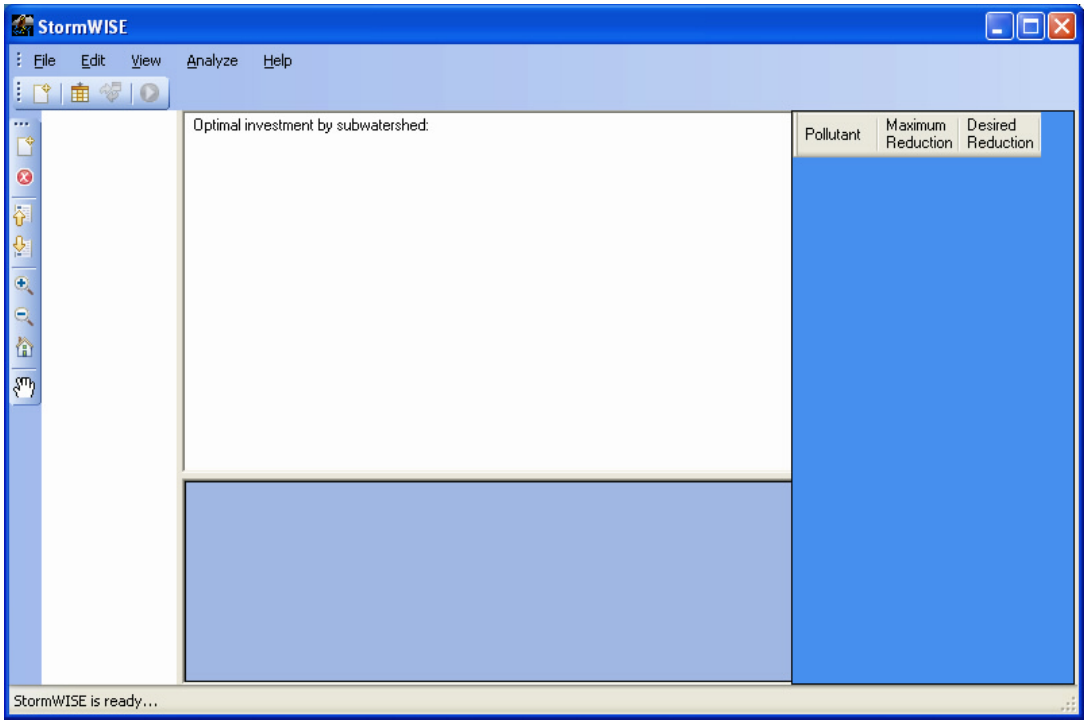
ampl PROJECT.*run* > PROJECT.*txt*.

This file can be opened by Notepad and printed, if desired, or copied and pasted into a word processing document.

4. StormWISE – a graphical and GIS user interface program containing all of the functionality of npsopt_washoff with an easy to use interface and the option to display results on a map showing the subwatershed drainage areas. Editing of .inp files can be accomplished using data grid tables similar to a database or spreadsheet program. If GIS "shape" files are not available containing maps, a "pie" chart is automatically generated to display results graphically. A data grid table displays optimization model results in both cases. The user can easily modify assumptions and data such as the amount of pollutant reduction desired. Typically the user will generate a sequence of results, each for a different level of pollutant load reduction, and the cost implications of each selection will be displayed. The color-ramp output on the GIS map or the pie chart helps the user to quickly identify those subwatershed drainage areas that should be targeted to locate BMP implementation sites.

NOTE: StormWISE graphical and GIS interface requires that Microsoft "DotNET 2.0" be installed on the users computer. The DotNet modules may already be installed to support other software installed on the computer. Also required is the MapWindow public domain GIS interface. Users of the EPA modeling system BASINS 4.0 may already have MapWindow installed. Installation programs "DotNET Installer.exe" and "MapWinGIS Installer.exe" are included in the StormWISE folder. Before running StormWISE, the entire StormWISE folder should be copied to the user's computer to a hard drive location such as drive C:\ for a permanent installation, or perhaps to the user's desktop for simply testing capabilities of the software. Installing StormWISE itself does not require running a special installation program.

Start StormWISE by double clicking on the StormWISE.exe file in the StormWISE folder. A shortcut to this file can be placed on the desktop or on the Program menu, if desired. The user is greeted by the opening screen, shown below.

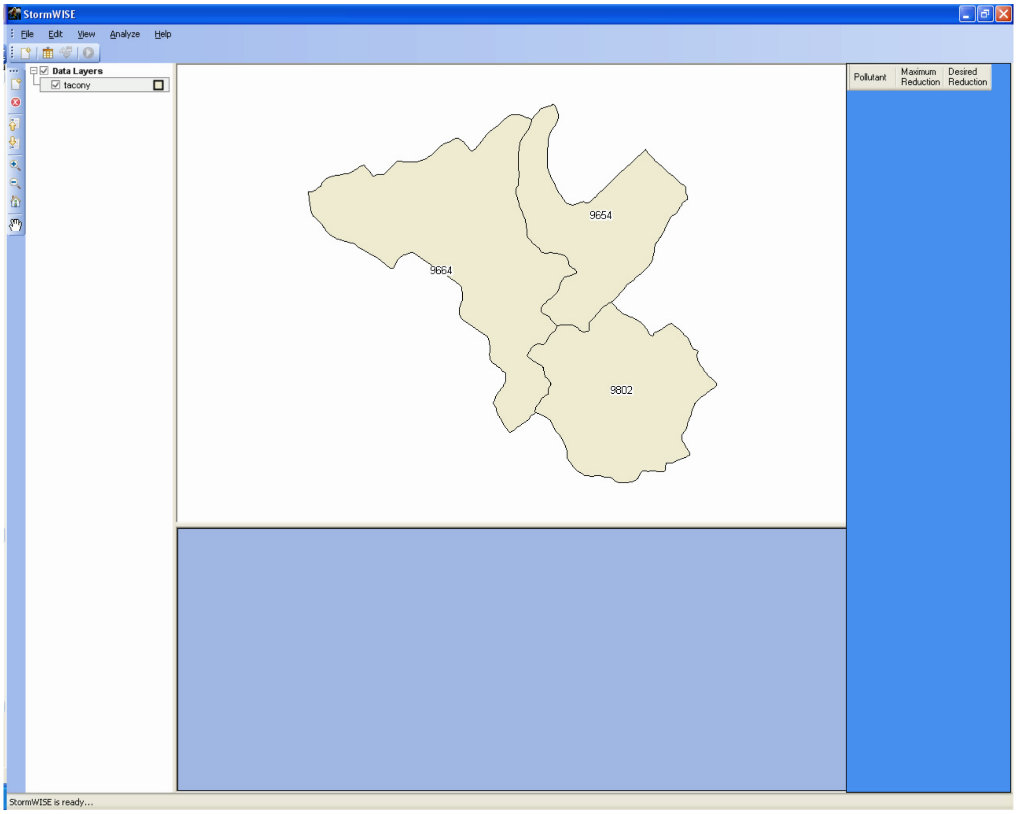


Optimal investment by subwatershed:

Pollutant	Maximum Reduction	Desired Reduction

StormWISE is ready…

An array of menu options and tool bar shortcuts is provided along the top. Along the left is a tool strip for the GIS displays. Using File/Add GIS Layer, or clicking on the Add Layer tool allows the user to navigate to the location of a GIS "shape" file containing a map of the drainage areas. The three drainage analysis from the "Tacony" example is shown below.



Pollutant	Maximum Reduction	Desired Reduction

StormWISE is ready…

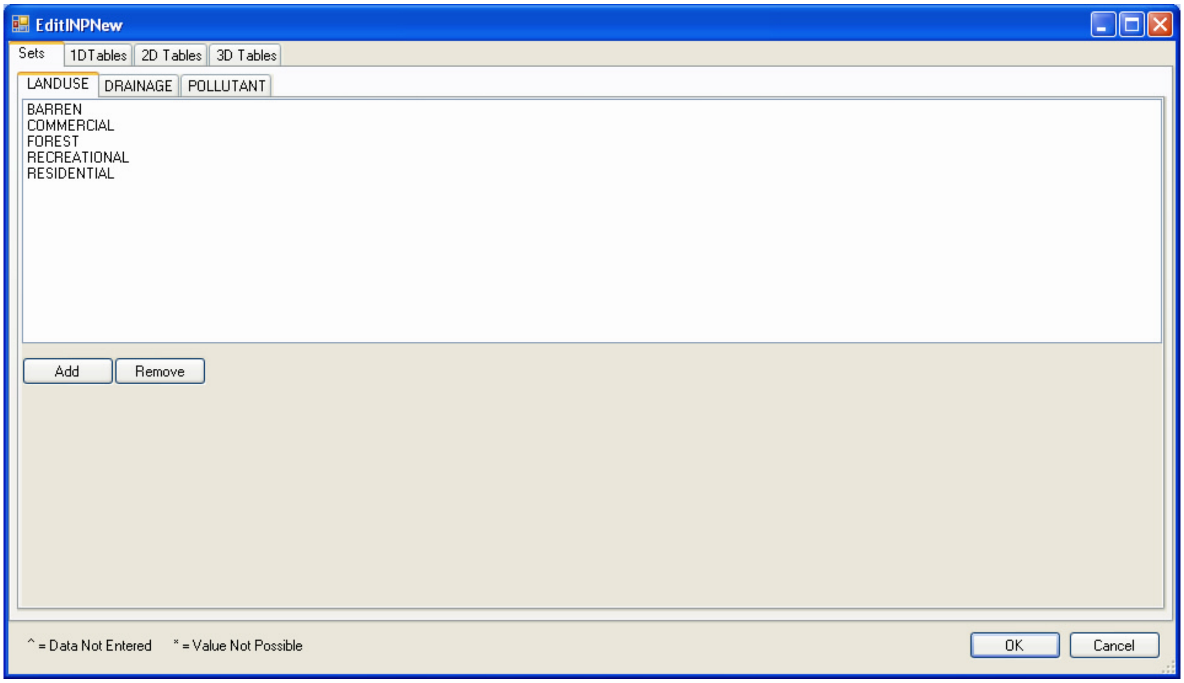
The GIS shape files are found in the folder Tacony_GIS in the StormWISE_Examples\Tacony folder.

Next, an input file is loaded. This file can be created manually using a text editor, or it can be generated automatically by GWLF_postprocessor. Also, an empty input file, “empty.inp” is provided in the StormWISE_Examples folder. If it is loaded, then the model data must be entered using the data grid table editing capabilities of StormWISE. The resulting input table can then be saved for future use. Data fields that have not yet been entered are indicated by the caret “^” character. StormWISE will not allow the user to solve the model until all data fields containing “^” have been replaced with valid numeric data.

Continuing with the Tacony example, “csv” files from an AVGWLF analysis of three subwatershed drainage areas (labeled 9654, 9664 and 9808) are supplied in the folder. These can be used with GWLF_postprocessor to automatically generate an input file for StormWISE. Open up a command prompt (console) window and navigate to the Tacony folder. Enter:

```
gwlf_postprocessor tacony 9654 9664 9802
```

This will generate a file called “tacony.inp” which can be loaded by StormWISE using the menu sequence “FILE/Select INP file” (or by clicking on the select INP tool) and navigating to the Tacony folder. The data editing screen below appears:

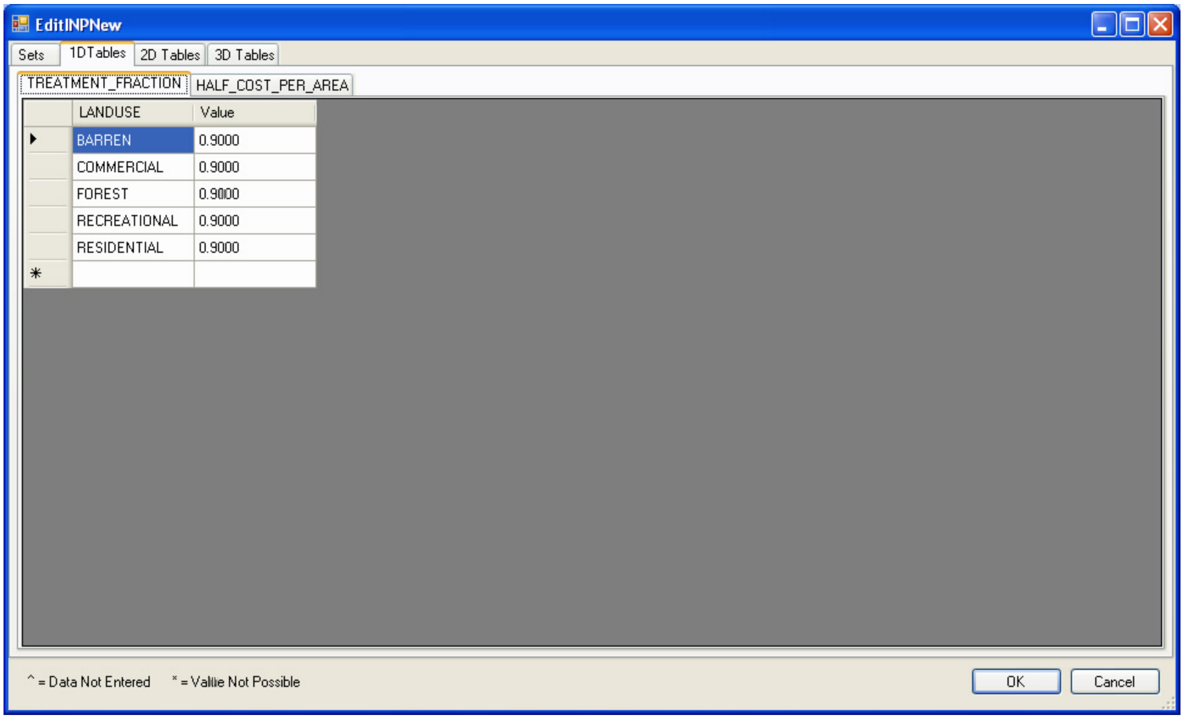


BARREN
COMMERCIAL
FOREST
RECREATIONAL
RESIDENTIAL

^ = Data Not Entered   * = Value Not Possible

The tabs on this screen show the four different model components of all StormWISE projects: Sets, 1DTables, 2DTables, and 3DTables. There are three different sets, LANDUSE, DRAINAGE, and POLLUTANT. LANDUSE contains the names of the landuse categories used in the current project. DRAINAGE contains the names of the subwatershed drainage areas, which are 9654, 9664, and 9802 in this case. POLLUTANT contains the names of the pollutants to be included in the analysis, in this case SEDIMENT, TOT_N (total nitrogen) and TOT_P (total phosphorous).

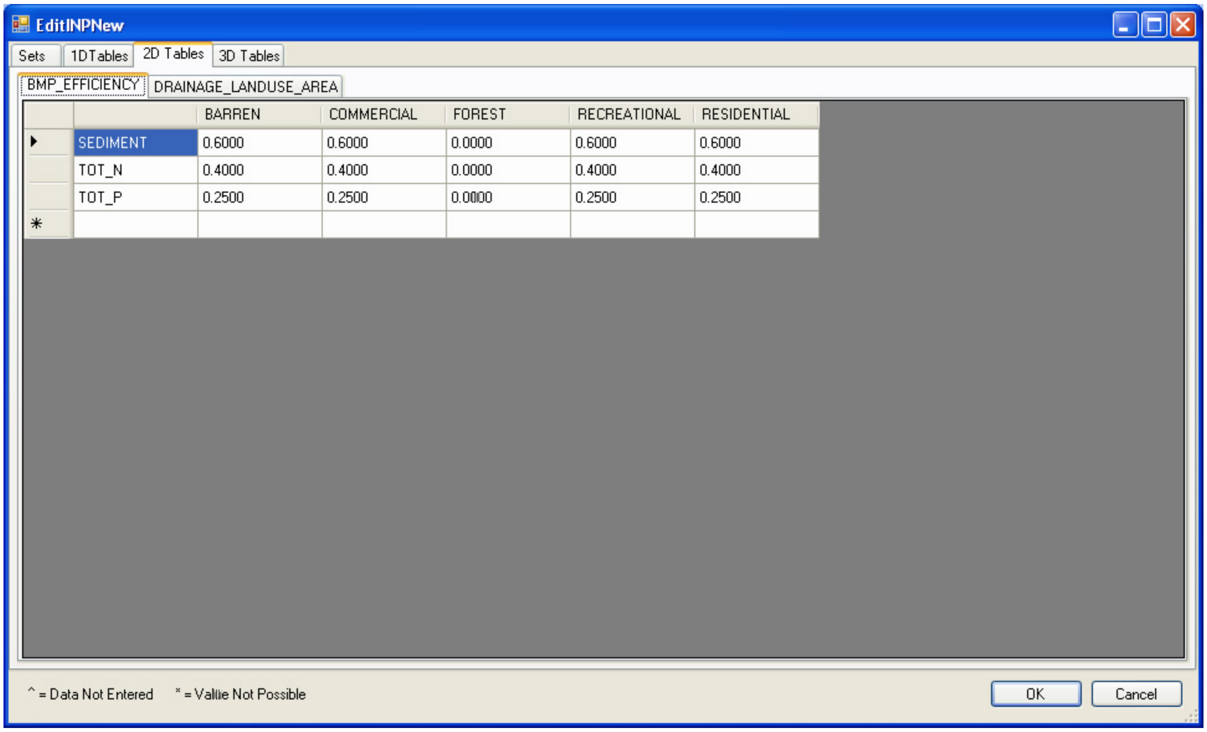
Clicking on the 1DTables tab shows subtabs for the two one-dimensional tables which contain numeric entries for the "TREATMENT_FRACTION" and the "HALF_COST_PER_AREA," as shown below. The first is the fraction of the runoff that is captured by the water quality BMP, typically 90%. The second is the BMP cost per acre of drained area for each managed land use category. This "marginal cost" increases with the fraction of the entire acreage treated. The HALF_COST_PER_AREA is the marginal cost at the point where half of the acreage in a particular land use category is managed by BMP's. Estimates of this cost parameter are estimated from site-specific BMP cost data using the BMPFIT program, described earlier.



LANDUSE	Value
BARREN	0.9000
COMMERCIAL	0.9000
FOREST	0.9000
RECREATIONAL	0.9000
RESIDENTIAL	0.9000

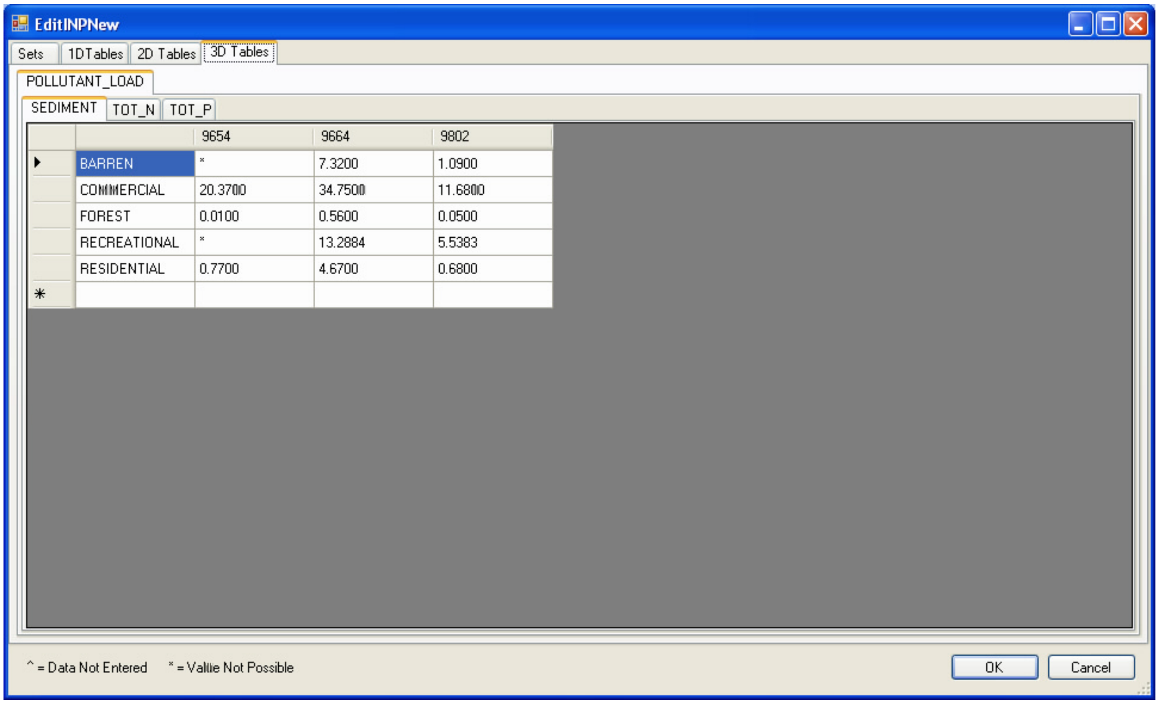
^ = Data Not Entered   * = Vallie Not Possible

Clicking on the 2DTables tab shows subtabs for two two-dimensional tables which contain numeric entries for BMP_EFFICIENCY, as a fraction, by pollutant and land use category, and DRAINAGE_LANDUSE_AREA, which shows the land area, typically in acres, for each drainage area (as columns) and each land use category (as rows). Note that to exclude a particular land use category from consideration for BMP installation, simply enter zero for the BMP_EFFICIENCY, as shown in the Tacony example, below.



	BARREN	COMMERCIAL	FOREST	RECREATIONAL	RESIDENTIAL
SEDIMENT	0.6000	0.6000	0.0000	0.6000	0.6000
TOT_N	0.4000	0.4000	0.0000	0.4000	0.4000
TOT_P	0.2500	0.2500	0.0000	0.2500	0.2500

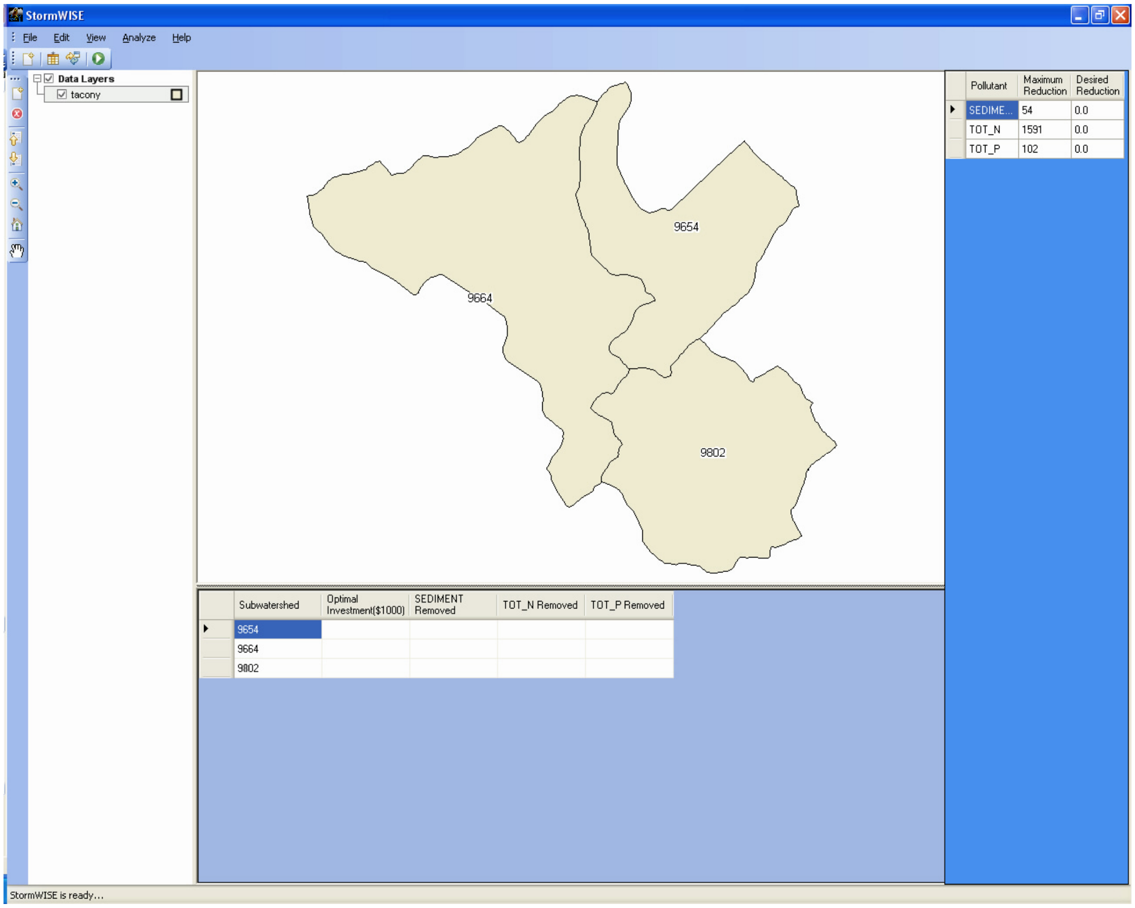
Finally, clicking on the 3DTables tab shows a single three-dimensional table for POLLUTANT_LOAD having a layer for each pollutant, and a two-dimensional table showing loadings, in appropriate pollutant loading units (such as Tons for sediment and Pounds for nutrients). The loadings, in Tons, for Sediment in the Tacony example are shown below. Note that when a particular land use does not exist in a subwatershed drainage area, a "*" character indicates that the loading value is not possible.



	9654	9664	9802
BARREN	*	7.3200	1.0900
COMMERCIAL	20.3700	34.7500	11.6800
FOREST	0.0100	0.5600	0.0500
RECREATIONAL	*	13.2884	5.5383
RESIDENTIAL	0.7700	4.6700	0.6800

All data fields can easily be changed by simply editing the numeric fields. But the user should NOT edit any of the name fields in this format. Changes to name fields must be made by clicking on the "Sets" tab, selecting the Set to be edited, and then clicking the "Add" button to create an additional landuse, drainage area, or pollutant, or by highlighting one of the existing names and clicking the "Remove" button to eliminate it from the model (be sure to highlight a name before clicking "Remove"). If a set name is added, then numeric data must be entered in all tables where that name appears in a row or a column.

If all data fields are valid, then clicking the "OK" button in the lower right corner of the edit view will update the model with the data and return to the main screen, as shown below.

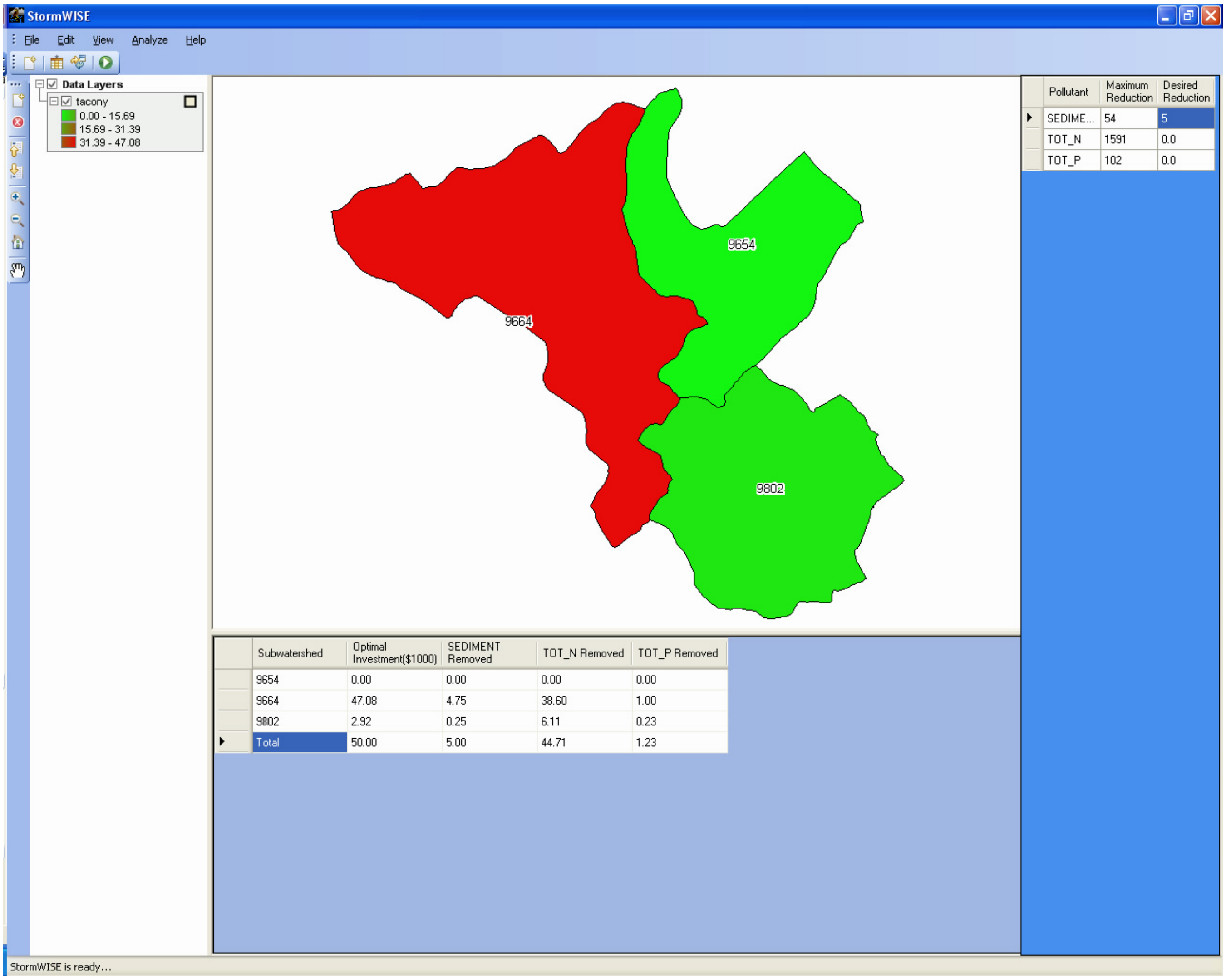


Pollutant	Maximum Reduction	Desired Reduction
SEDIME...	54	0.0
TOT_N	1591	0.0
TOT_P	102	0.0

Subwatershed	Optimal Investment($1000)	SEDIMENT Removed	TOT_N Removed	TOT_P Removed
9654				
9664				
9802				

Two new tables have been added to the display: an empty table in the lower area which is prepared to receive the output of the optimization module, and a partially filled table in the upper right corner. This table invites the user to enter the pollutant reduction that is desired for the first run of the optimization screening model. If the model is run without editing this table, no pollutant reduction will occur, and no cost will be incurred. The maximum possible reduction is displayed. Entering any value larger than the maximum will also result in zero output.

The screen below shows the result when the user requests a reduction of 5 tons annually of sediment over the entire study area (i.e. from all three drainage areas). After entering a value of 5 in the "Desired Reduction" column, the user selects the menu option "Analyze/Run" or simply clicks the Run tool. The table now shows how much sediment reduction to pursue by installing BMP's in each of the three drainage areas. The optimal investment levels (in $1000 units) to direct towards each drainage area are shown as well as the amounts of pollutant removal achieved by that investment. Note that although the user made no request regarding the amount of TOT_N and TOT_P to reduce, some reductions in these pollutants are achieved anyway because BMP's that remove sediment also typically remove nutrients. Also, note that the total cost of achieving these pollutant reductions is estimated to be $50,000 and that most of it should be directed towards projects in drainage area 9664 and no projects should be pursued in drainage area 9654, if overall cost minimization is the only objective influencing the decision. In reality, the decisions regarding where to place BMP's depend on multi-objective considerations such as flood control, and other practical considerations. Thus, model results can not be interpreted strictly. On the other hand, these results can help watershed managers approach the very difficult problem of prioritizing projects in a way that achieves the greatest pollutant reduction for a certain level of investment. Another way of stating this result is that the model predicts that any alternative BMP investment strategy in this subwatershed would result in either a cost higher than $50,000 to achieve the same 5 tons annually of sediment removal, or sediment removal of less than 5 tons for the same investment of $50,000. Note that to display the color ramp on the left, the user must click on the legend at the "+" just left of "tacony."

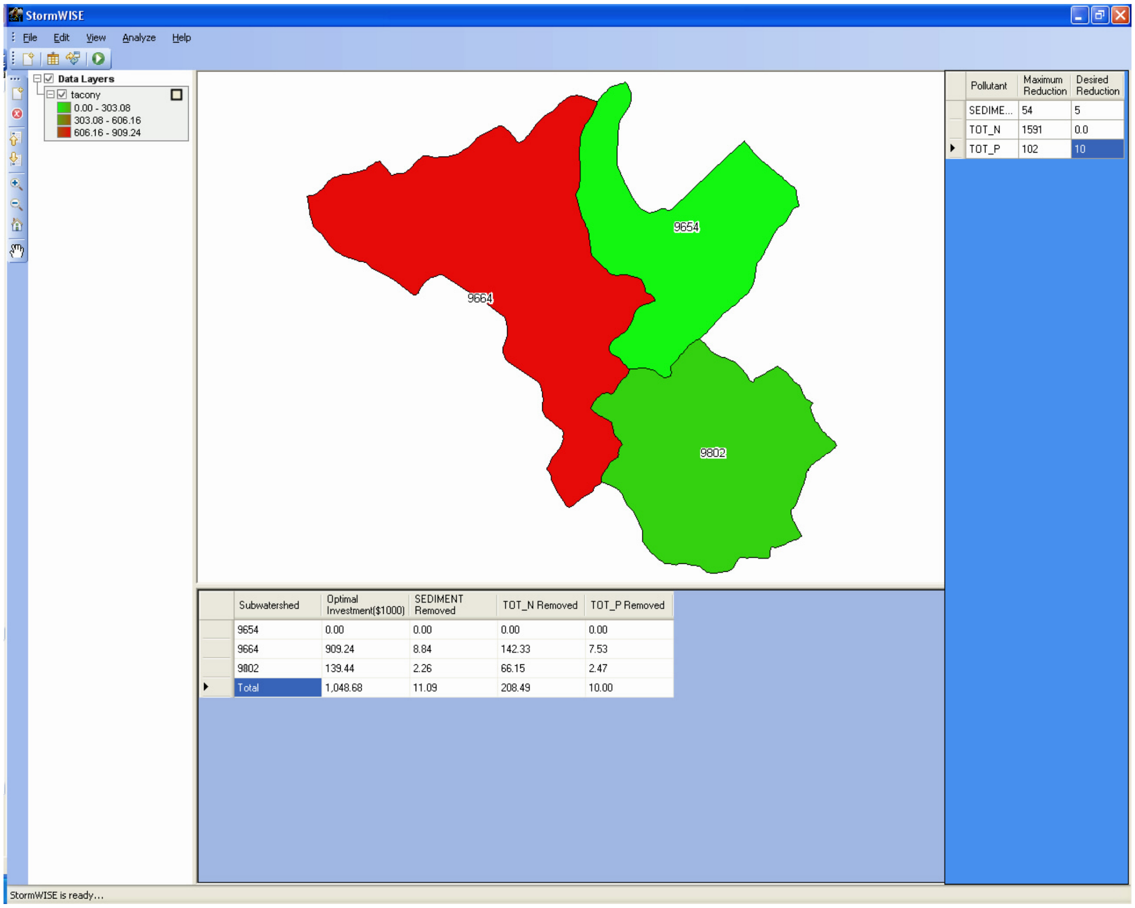


Pollutant	Maximum Reduction	Desired Reduction
SEDIME...	54	5
TOT_N	1591	0.0
TOT_P	102	0.0

Subwatershed	Optimal Investment($1000)	SEDIMENT Removed	TOT_N Removed	TOT_P Removed
9654	0.00	0.00	0.00	0.00
9664	47.08	4.75	38.60	1.00
9802	2.92	0.25	6.11	0.23
Total	50.00	5.00	44.71	1.23

StormWISE is ready...

Note that the solution above yields very little of the potential 102 pounds annually of phosphorous removal. If the user now enters the amount of 10 in the Desired Reduction column for TOTAL_P, and runs the model again, the result is shown below.



Pollutant	Maximum Reduction	Desired Reduction
SEDIME...	54	5
TOT_N	1591	0.0
TOT_P	102	10

Subwatershed	Optimal Investment($1000)	SEDIMENT Removed	TOT_N Removed	TOT_P Removed
9654	0.00	0.00	0.00	0.00
9664	909.24	8.84	142.33	7.53
9802	139.44	2.26	66.15	2.47
Total	1,048.68	11.09	208.49	10.00

More investments in BMP technology are required, both in subwatershed 9664 and 9802. Also, the amounts of SEDIMENT and TOT_N removed also increase because the BMP's installed to remove phosphorous also typically remove sediment and nitrogen.

At this point, the user can save the model data in data file having the same or a different name. Also, the GIS map and the data tables can be printed out using the File/Print menu.

First-time users should open up one or more of the ".inp" files using a text editor, such as Notepad to view the format of this file. It is very similar to the format of the data grid view tables in the graphical interface. Users can manually edit these data fields, if desired. The format of the ".inp" files is not rigid regarding delimiters (other than the semicolon and braces), capitalization, and white space. However, please note that the semicolon ";" at the end of each block of data is mandatory. Deleting a semicolon or failing to use one when manually generating a ".inp" file will lead to unpredictable results. Also, all of the data components (sets, 1-d tables, 2-d tables, and the 3-d table) must be present in the file, with the titles properly spelled.

Two other example files are provided: "Empty," described above, and "Springfield" which is based on Swarthmore College's Springfield Township study performed for the Pennsylvania

Coastal Nonpoint Pollution Program, with a report available online at http://watershed.swarthmore.edu.

B. StormWISE Source Code

All source code files are provided on the CDROM in the folder StormWISE_Source which contains a subfolder "source_090" indicating the current "pre-release" version 0.90 of the model. As soon as EPA's review of the software is completed, final revisions will be made, and the software will be released as version 1.0.

Four folders within the folder "source_090" contain Microsoft Visual Studio project files as well as the source code files. These are GWLF_PostProcessor, npsopt_washoff, npsoptclr, and StormWISE. An additional folder, "corecode" contains C++ source code files that are common to both the command line and graphical versions of the software.

GWLF_PostProcessor is self contained code written in standard C. The source code files can be extracted and compiled by a C compiler on any computing system.

"npsopt_washoff" is primarily a single "main.cpp" program written in standard C++. It calls functions in the "corecode" folder.

"corecode" contains modules "datablock.cpp" for structuring the input file data into blocks which are converted to sets, 1-D tables, 2-D tables, or 3-D tables by the "dataget.cpp" modules. The data structures are defined and implemented in "datacomponent.cpp". Finally, "npsopt.cpp" provides routines for editing and assuring consistency of all data blocks. The core code is all written in standard C++, and it makes extensive use of the extremely efficient standard template library. It can also be compiled on any computing system supporting a C++ compiler, and can be made functional using "npsopt_washoff" or another program written by future developers.

"npsoptclr" provides an interface for the core modules to the Microsoft ".NET" common language runtime (CLR) environment. It is written using Microsoft's "managed extensions" of the C++ language which enable easy access to C++ code by other managed languages, including C# (C-sharp), Visual Basic, and J# (Microsoft's implementation of the Java language). Microsoft's Visual C++ 2005 software is used to compile these modules. "npsoptclr" functions as a "wrapper" for the core code modules to enable them to interact with ".NET" managed code. It's output is a dynamic link library file, "NpsOptClr.dll" which must be present for the StormWISE program to function.

Finally, the StormWISE folder contains the code for the graphical/GIS interface. These modules are written in Microsoft Visual Basic and are compiled by Microsoft Visual Basic 2005, which is included along with Visual C++ 2005 in the suite Visual Studio 2005. Visual Basic was chosen primarily because the MapWindow GIS open source user community provides best support for programming the MapWindow environment through Visual Basic, and we were able to easily adapt modules that are distributed in the open source format for use in StormWISE. Also, the base of software developers with Visual Basic experience is quite large, so the prospects are good that this code can be used beyond the scope of the current project through distribution in the open source community.

Future revisions and extensions of the StormWISE source code will be distributed through Swarthmore College's Watershed web site: http://watershed.swarthmore.edu.