

StormWISE Software Documentation - Version 1.0 August, 2007

1. Contents of Installed Package

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.

UNITS used in the BMPFIT data files:

Design_Rainfall - inches

Area_Served - acres

Cost_Coefficient - \$/square foot

Cost_Exponent - dimensionless - lower for BMP's with site-scale economies of scale.

L,U - fraction of subwatershed pollutant load typically removed by the BMP technology for this LANDUSE

(L = lower limit, U = upper limit, set L = U for initial analysis and then try U > L)

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-XXXXsum.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 portion 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. An example from Swarthmore College’s Springfield project is provided in this folder. 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.

Example: Notepad Springfield.inp

After exiting notepad, type:

npsopt_washoff PROJECT. POLLUTANT REDUCTION
where: POLLUTANT = the name of a specific pollutant as specified in the PROJECT.inp file
REDUCTION = the amount of pollutant reduction desired (in the same units used in the “.inp” file for pollutant loadings, such as Tons for sediment or pounds for nutrients)

Running “npsopt_washoff” will generate the file PROJECT.dat.

Example: npsopt_washoff springfield TSS-TON 50
will generate the file “springfield.dat”, and AMPL optimizer input file.

Now, type the command:

ampl PROJECT.run

Example: ampl Springfield.run

Note: the ampl program is included in the example folder. If extensive use is made of the command line programs, users should download the full ampl program from <http://www.ampl.com> and install it in a location that appears in the computer’s “Path” environment variable.

The file PROJECT.run must be edited to contain the name of the correct data file, PROJECT.dat. 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 is 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 StormWISE data input (“.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. This is done by entering a value in the “Desired Reduction” column in the upper right corner of the StormWISE window. (Note: “Desired Reduction” must be less than the amount indicated for “Maximum Reduction”) 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.

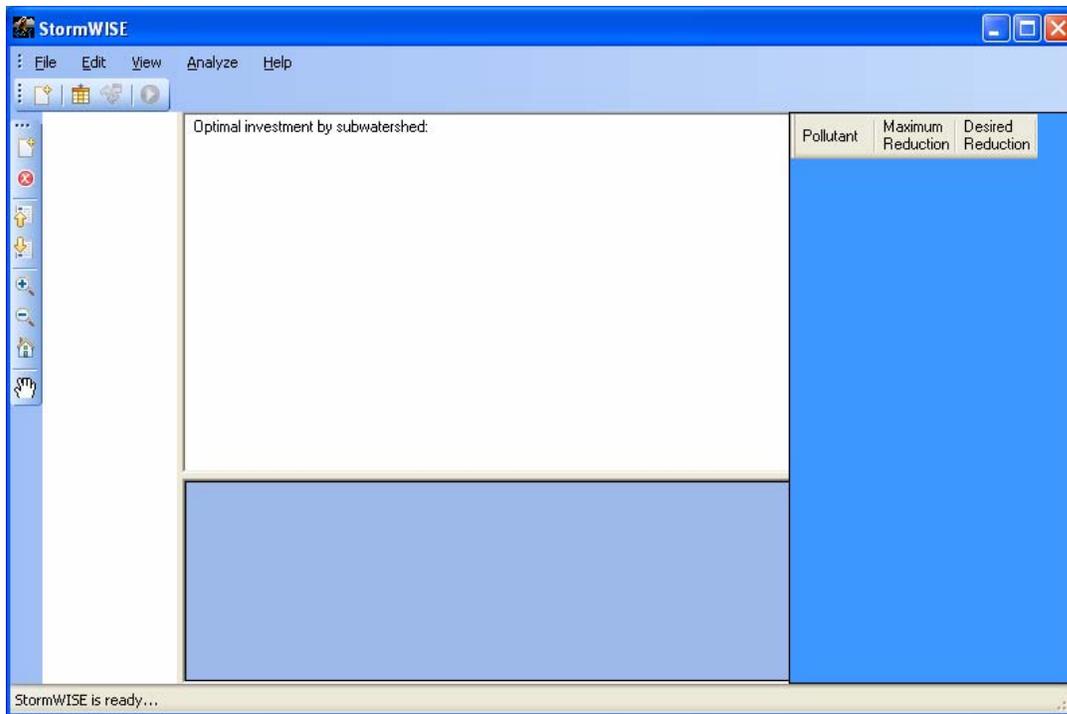
BEFORE INSTALLING STORMWISE. StormWISE graphical and GIS interface requires that Microsoft “DotNET 2.0” be installed on the users computer. The DotNet modules may already be installed to support other software installed on the computer. If not, download the Microsoft .NET Framework Version 2.0 Redistributable Package (x86) from the Microsoft.com web site and install it. Also required is the MapWindow public domain GIS interface. Users of the EPA modeling system BASINS 4.0 may already have MapWindow installed. The MapWindow Active X control MapWinGIS can be downloaded for free from <http://www.mapwindow.com>. If you choose to install the entire MapWindow GIS software package, then the Active X control will also be installed automatically and no further MapWindow installation is required.

INSTALLING STORMWISE. The StormWISE installer is downloaded in the form of a compressed “.zip” file. Extract the contents of this file and run the file “setup.exe”. This will invoke the StormWISE installer program that runs under Microsoft Windows Installer. You will have the option of specifying where StormWISE program files should be stored on your computer. The installer will automatically create a “StormWISE” folder in your “My Documents” folder containing at a minimum the “Empty Project” and “StormWISE_Documentation” folders. You will also be able to choose whether or not to install the following additional components in the “StormWISE” folder: (1) “Auxiliary Command Line Programs” (BMPFit, GWLF_Postprocessor, and NpsOpt_washoff), (2) “Sample_Projects” (Springfield and Tacony), and (3) StormWISE source code.

STORMWISE EXAMPLES. Start the StormWISE program using either the StormWISE entry on the Start/All Programs menu or the program icon on the Desktop. If the installation was successful, you will be greeted by a splash screen showing the StormWISE owl and the main screen, shown below. 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.

Springfield Example. The Springfield example is ready to run. From the File menu, choose “Select INP file”. A window pops up allowing you to navigate to My Documents\StormWISE\Sample_Projects\Springfield\Input_Data_Tables. Select “Springfield.inp” and click “Open”. View the data in the tables, if you like, and then click

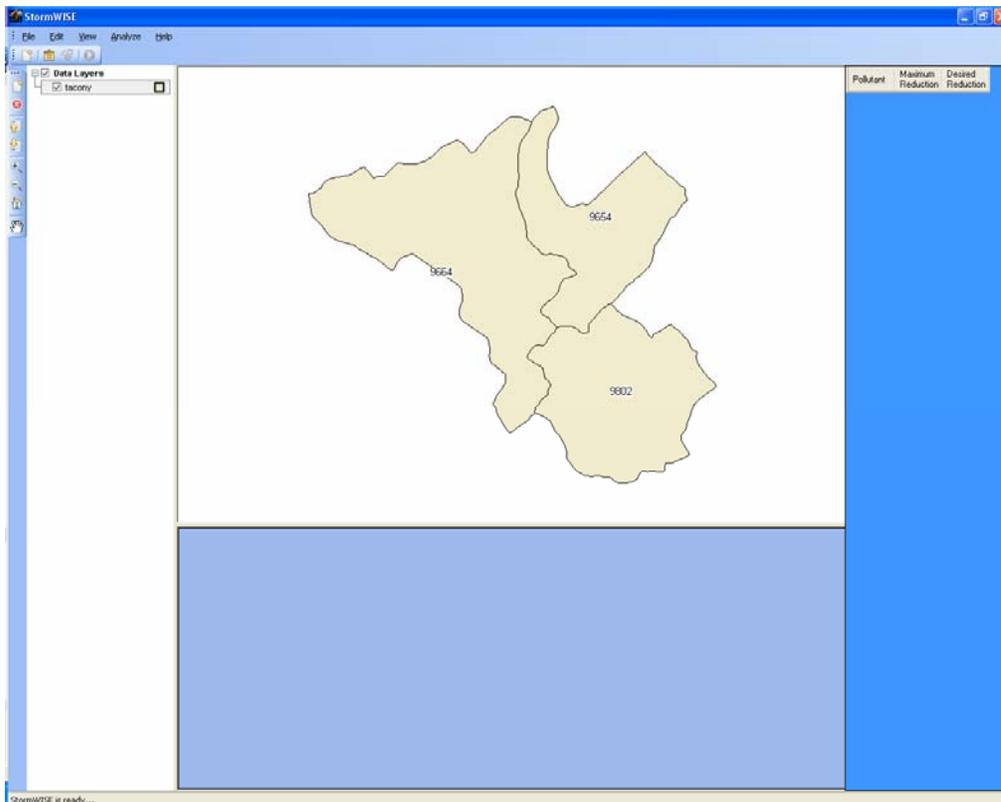
“OK”. Enter pollutant reductions in the “Desired Reduction” column (eg. 50 tons of TSS-TON which is sediment). From the Analyze menu, select “Run”. The output table should fill with numeric results and a pie diagram should appear. Now, view the results using a GIS map display. From the File menu, select “Add GIS Layer” and navigate to My Documents\StormWISE\Sample_Projects\Springfield\GIS_ShapeFiles and select “Springfield_main_subbaisns_clip.shp” then click “Open”. The pie diagram is replaced by a map. Again, from the “Analyze” menu, choose “Run” and the subwatersheds on the map will display in different colors showing the relative priorities of the different subwatersheds for BMP investments, with green being lowest priority and red being highest priority. To view a color map associating colors with optimal investment levels (in \$1000), click the “+” next to “Springfield_main_subbasins_clip” in the Data Layers column on the left. The width of this column can be adjusted if necessary. Now, you may print the results by selecting “Print” from the “File” menu. More details on the StormWISE menus and toolbars are provided in the Tacony example, below.



StormWISE main screen

Tacony Example. The example from Tacony Creek in northeast Philadelphia demonstrates how a user can start from a basic pollutant loading analysis using the AVGWLf model (from Pennsylvania State University: <http://www.avgwlf.psu.edu/>). The three drainage analysis from the “Tacony” example is shown below. Separate analyses were run for three subwatershed areas numbered 9654, 9664, and 9802 in the AVGWLf Pennsylvania database. The output text files in comma separated value (csv) format were copied from the AVGWLf output directories for each analysis and are installed by the StormWISE installer in:

My Documents\StormWISE\Sample_Projects\Tacony\AVGWLF_Postprocessor_&_Example.



Tacony GIS shapefile generated by AVGWLF

The GIS shape files generated by ArcVIEW while running the example in AVGWLF are installed in the GIS_ShapeFiles subfolder of the Tacony folder. Any ShapeFiles generated by ESRI ArcView can be loaded directly into StormWISE for viewing. However, in order for StormWISE to display its results in the GIS display as a color ramp, the names of the drainage areas in the StormWISE input file must agree exactly with the names used in the GIS ShapeFile database file under the “ID” field. For example, if you open the GIS “Attribute Table” file Tacony\GIS_ShapeFiles\tacony.dbf using Microsoft Excel, you will see the numeric names of the subwatersheds assigned by AVGWLF in two columns, the “NAME” field and the “ID” field. StormWISE reads only the “ID” field to match drainage area names with subwatersheds in the ShapeFile. This example simply sets the drainage area names in the StormWISE input file to the exact numeric names assigned by AVGWLF to the subwatersheds.

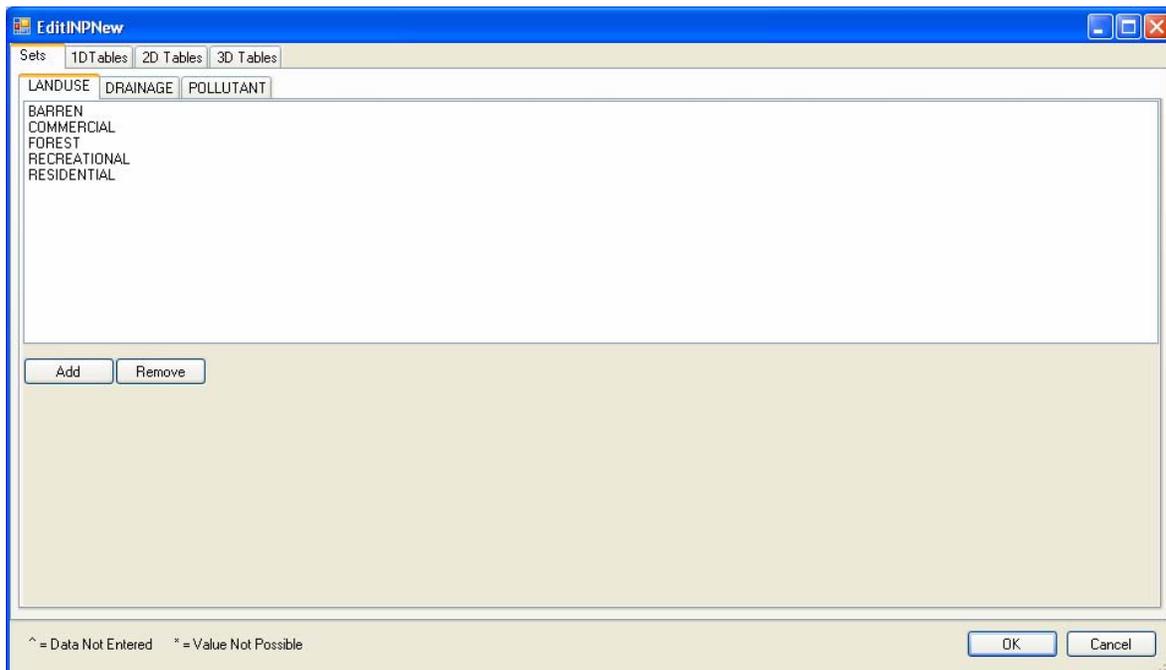
You can use Excel to edit the entries in the ID field to make them more meaningful, but you must use only UPPERCASE letters, numbers, and the underscore “_” character in the names, and do not use spaces. If you do edit these names, then you must also change them in the StormWISE input file either from within StormWISE or directly in the “.inp” file using a text editor. Note that the drainage area names appear as SET definitions at the top of the input file and in the Pollutant_Load 3-D table farther down in the file, and the names are repeated for each pollutant. Also note, that StormWISE currently has no ability to simply rename items on the “Sets” tab, such as drainage areas. These can only be deleted and added. When you delete a drainage area, all pollutant load data associated with that drainage is lost, and when you add a drainage area, all pollutant load data must be entered before the new data file can be saved.

Generating a StormWISE Input File from multiple AVGWLF Output Files. 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 are used with GWLF_postprocessor to automatically generate an input file for StormWISE. Also, “gwlf_postprocessor” expects to find a file “BMP.inp” provided by the StormWISE user containing data on BMP performance and cost parameters. You can open the provided file with a text editor to view or edit the values used in this example.

To generate the StormWISE input data file, open up a command prompt (console) window and navigate to the Tacony folder. Enter:

```
gwlf_postprocessor tacony 9654 9664 9802
```

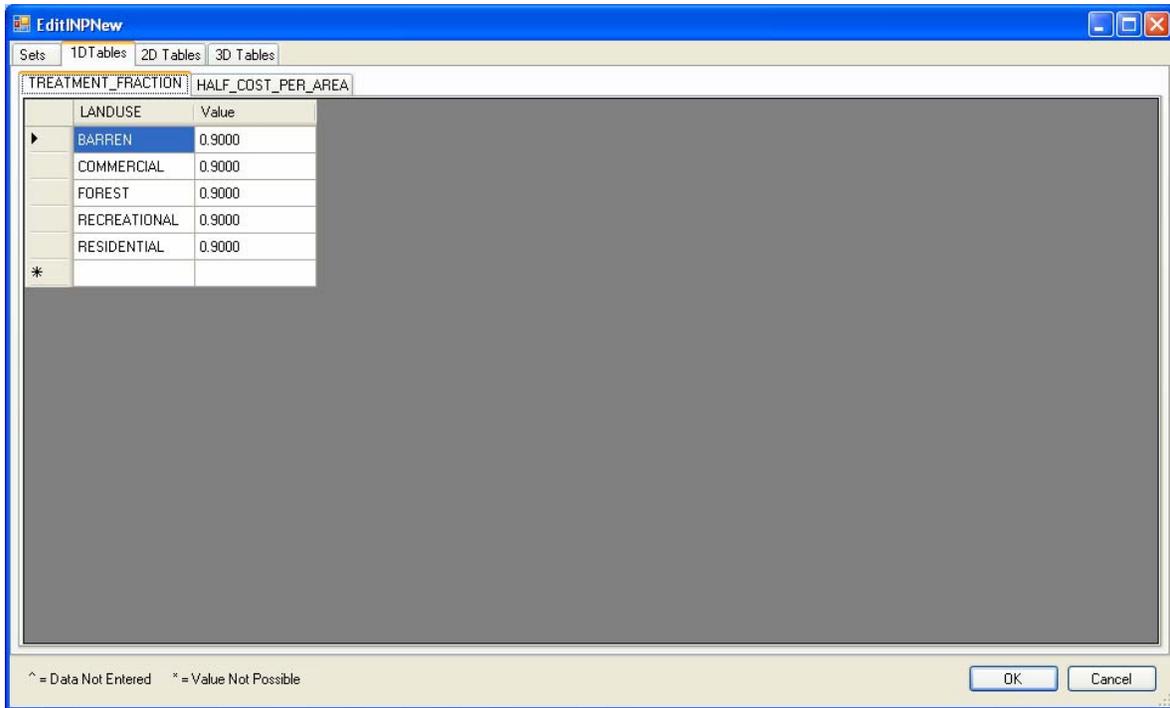
This will generate a file called “tacony.inp” which can be loaded by StormWISE using the menu sequence “FILE/Select INP file” (or by clicking on the select INP tool) and navigating to the Tacony folder. The data editing screen below appears:



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.



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.

^ = Data Not Entered * = Value Not Possible

	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
*					

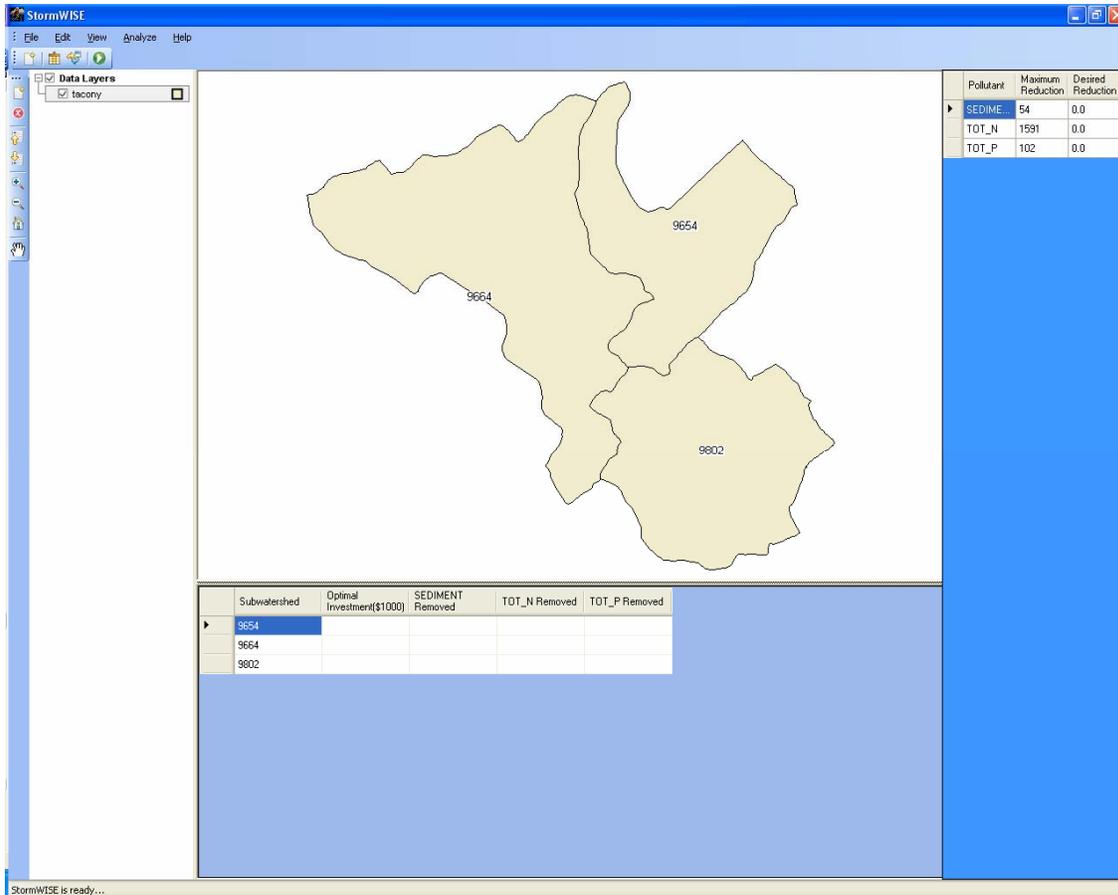
Finally, clicking on the 3DTables tab shows a single three-dimensional table for POLLUTANT_LOAD having a layer for each pollutant, and a two-dimensional table showing loadings, in appropriate pollutant loading units (such as Tons for sediment and Pounds for nutrients). The loadings, in Tons, for Sediment 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.

^ = Data Not Entered * = Value Not Possible

	BARREN	COMMERCIAL	FOREST	RECREATIONAL	RESIDENTIAL
SEDIMENT	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.

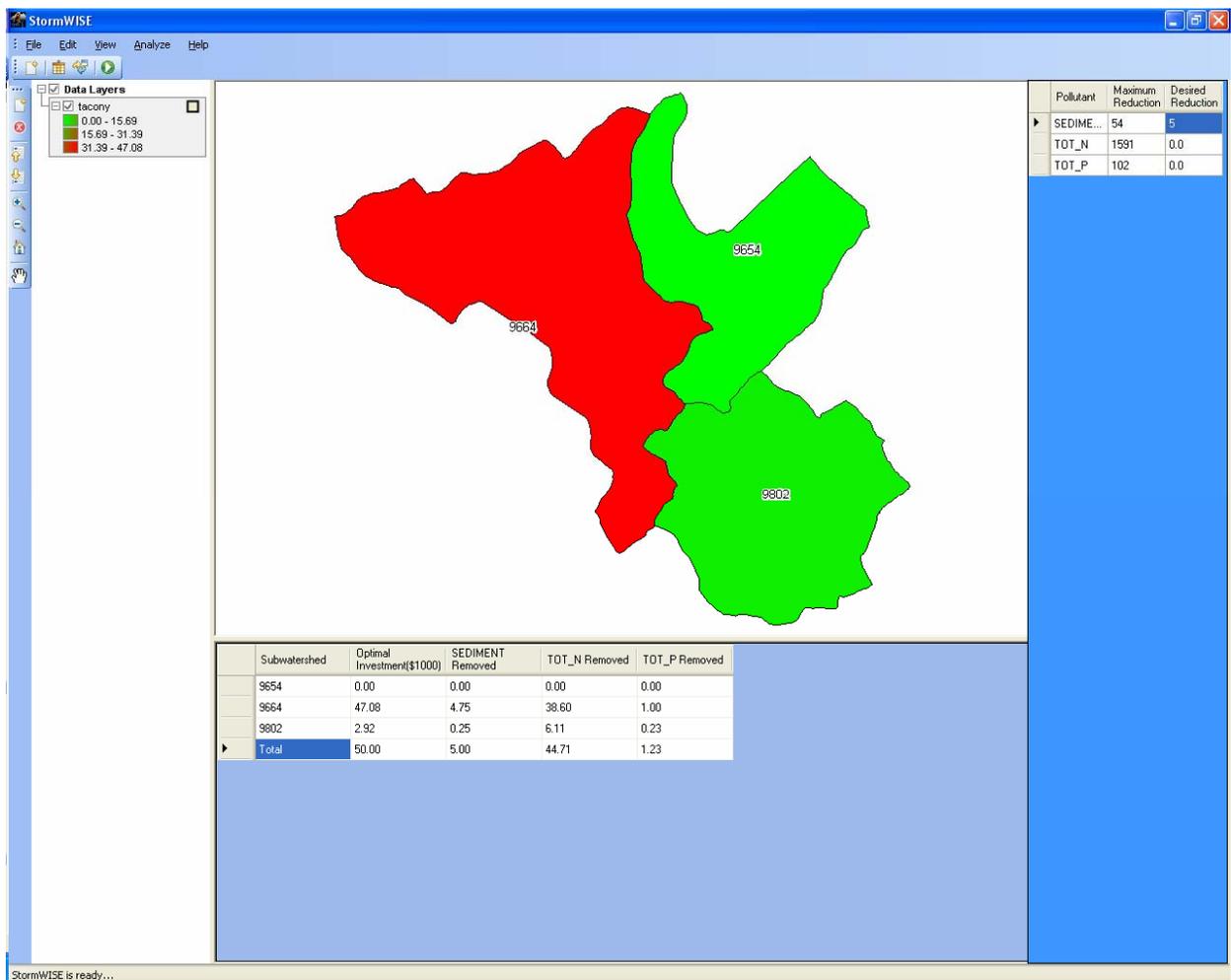
If all data fields are valid, then clicking the “OK” button in the lower right corner of the edit view will update the model with the data and return to the main screen, as shown below.



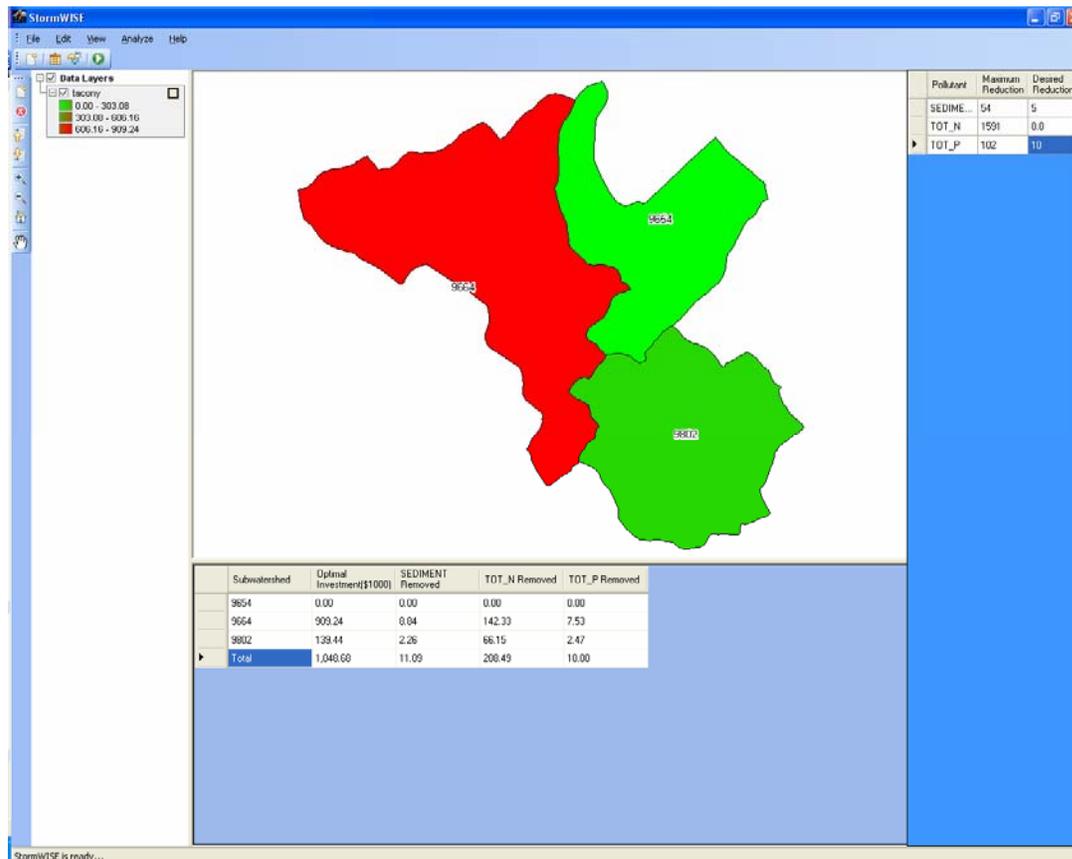
Two new tables have been added to the display: an empty table in the lower area which is prepared to receive the output of the optimization module, and a partially filled table in the upper right corner. This table invites the user to enter the pollutant reduction that is desired for the first run of 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. Always specify a desired reduction *less than* the maximum reduction. Entering any value larger than the maximum will 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."



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.



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.

Land Use Category Display of Results. In order to display the investment levels associated with a single land use category or groups of land use categories, use the "View" menu. There you will find checkboxes that enable you to display results for only those land uses that you have selected.

Empty Project. An empty input file, "empty.inp" is provided in the folder My Documents\StormWISE\Empty_Project. 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. The entires on the "Sets" table should be configured first. You can add or delete landuse categories, drainage areas, and pollutants modeled. Then, using 1DTables, 2DTables, and 3DTables, enter the required numerical values from data on your drainage areas and from the output of your pollutant load estimation model. StormWISE will not allow the user to save the changes or to solve the model until all data fields containing "^"

have been replaced with valid numeric data. If you are unsure about reasonable estimates for some of the numeric values, enter a temporary numeric “place holder” value such as 99.99 so that you can save the file and continue editing later.

Manual Editing of Data Input Files. 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.

B. StormWISE Source Code

Please Note: Distribution of source code from the StormWISE project is controlled by the Mozilla Public Software License Agreement, which users must accept before installing the software.

The StormWISE installer gives the user the option of installing source code. If this option is selected using the checkbox during installation, then source code folders will be installed in the “My Documents” folder. Source code is provided for 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.