CHAPTER 4. Model Interfaces for RAISON

As mentioned in the Introduction, attempts to improve NPS modelling capabilities need to be combined with the application of new technologies to resolve problems associated with ease of model use. This will allow the user to track the decision-making processes through the model to obtain a better understanding of the simulation. An integrated approach is achieved in this research with the linkage of the selected models, AGNPS and WATFLOOD with the water quality component added, within the RAISON decision support system with GIS capabilities.

4.1 RAISON as the GIS and SDSS Platform

Interactive programs were created to assist in processing data, initiating model simulations, and analyzing model results. Exploiting the capabilities of RAISON, graphical interfaces were built to allow interaction with the models by intercepting input and output and to connect them to the database in the system. Work was done to create communication links between the AGNPS model and RAISON. The pre-processing tools provide easy data compiling for the models. Using topography, soil type, and land use maps in vector formats, procedures are designed to automate as much input data as possible. With minor changes, the same tools were applied to create input files for WATFLOOD and for the water quality model developed as part of this research.

Design of a control panel for model operation helps in the setup and operation of the simulation process. Actually this also triggers the model to run by creating a shell that activates the model and controls the mode of operation. Post-processing for output data by means of graphical and statistical tools also assists with the interpretation of model results. Such a generic application is very useful for applying the models to different watersheds in order to validate the hydrologic and water quality components. It is worth mentioning that due to the modularity involved in the development of the subroutines and processes, if better ways of estimating nutrient and pesticide release and transport become available, little of the present work would be lost. The procedures and modules can be adapted to accommodate such improvements.

Finally different techniques, to analyze the sensitivity associated to the models, were evaluated and selected to be included in the system. Typically, the best use for nonpoint source models is for comparative analysis between different scenarios. This involves modifying parameters to account for the desired change in conditions. The capability to undertake rapid "what if" scenarios, in defining and managing future landuse, will be critical in maintaining the ecological function of urbanizing watercourses.

Providing a measure of the confidence limits that can be placed on the simulation results due to the uncertainties in values of input parameters is a crucial step in the simulation process. As a preliminary analysis of the sensitivity of the parameters on the model results, a sensitivity module was created that would allow interactive selection of parameters to perturb. This also involves possible selection of different precipitation input functions since it is known that runoff models are highly sensitive to rainfall intensity and duration. The technique for the sensitivity analysis is based on the normalized sensitivity coefficients, which indicate a percent change in the results for individual perturbations of the parameters. After creating the temporary files with the variation for the selected parameters, the models run in batch mode for all the different input files. Visual outputs of the normalized coefficients help in defining the importance of each parameter variation in the overall result. Comparison of different analysis can be made as a function of input rainfall function and spatial selection.

4.1.1 Description of RAISON

RAISON is a software package developed at Environment Canada's National Water Research Institute. It is a analysis toolkit that integrates database, spreadsheet and graphic interpretive tools with GIS and expert systems capabilities for microcomputers. The system provides an intuitive environment for displaying data and analysis results in the context of local geography. It was originally developed to facilitate access to watershed water quality data and to combine several models to evaluate the water resources at risk due to acid rain. Ongoing development of the system has led to a generic integrated set of tools for data analysis. It has evolved from practical concerns for an affordable working system that can help design environmental information systems and decision support systems (Lam and Swayne, 1996).

RAISON offers a friendly interface to integrate data, text, maps, satellite images, video, models and other knowledge input. The system provides a library of functions to design customized applications. The database component is the core of the system and has to work with other modules such as GIS, expert systems, statistics, models, graphics and analysis tools. RAISON is not a full GIS nor a stand alone database but it provides enough functionality to link them. It accepts files from most commercial GIS and database systems and allows the customization of the software for any specific application. The geographic linking is provided with background maps that are produced from vector files or imported directly into RAISON from a variety of commercial file formats.

Data stored in UTM and Latitude/Longitude coordinates may be used interchangeably. For example, data in UTM coordinates may be displayed on a map defined in Lat/Lon coordinates. Maps may be customized and color coded using external graphic applications that support bitmap or metafile formats. One of the important RAISON features used in this work is its capability to incorporate modelling tools into the system by building interfaces that interact with existing models intercepting input and output to the database in the system.

4.1.2 Layers and Grids

The way in which RAISON handles geo-referenced information for different attributes is through the use of databases. A layer database is a collection of spatial polygons (objects) with an attached attribute. RAISON supports three types of layers: i) spatial layers of points, lines or polygons, ii) grids as a network of squares with associated spatial coordinates, iii) grid layers as data associated with the grid but without spatial information. The last two layer types work in conjunction, linking the object geo-reference with the data attached to it. The grid layer feature in RAISON was designed to be used by models that use a regular grid and collect or process information related to individual grid cells. In this way, data can be associated with the grid easily after it has been created. The grid is usually used to process information before a value for the grid layer is found. This is the case of the present interface for the agricultural model where, for example, the land slope is calculated by intersecting digital elevation model data with the grid and then attached to the grid layer.

For each layer range, legends or characteristics tables can be assigned to draw the layer and graphically identify the different attributes according to the data values. This feature allows spatial display of grid data (model input or results). The communication with RAISON is through dynamic data exchange (DDE) as an established protocol for exchanging data through active links between applications that run under windows. Most of the functions used in the interface are available in the layer dynamic-link library (DLL), which is a library of routines loaded and linked into applications at run time. The LAYER.DLL includes routines for standard application tasks such as initializing database files and structuring tables, creating grid layers, retrieving and changing database values, drawing maps and handling user actions. All the tables that handle the data required by the models follow the RAISON layer data structure:

i) layer summary table holding the information about the tables from layer database,

ii) type table that holds all the information for the spatial objects such as number of vertices and kind of object (point/line/polygon),

iii) position table that holds the coordinates information for each spatial object.

4.2 Integration of the Models

This section describes in detail how the interfacing to the models from the RAISON system is achieved through the use of relational databases. The data requirements and structure of the tables for the database are described for the two models. The variables to be automatically extracted are defined and the extraction process for the different digital sources is presented.

4.2.1 Data Requirements and Structure

As described in Chapter 3, data needed for the AGNPS model are classified in two categories: watershed and cell data. The first includes information applying to the entire watershed such as size, number of cells, storm intensity, etc. Cell data include information on the approximately 20 parameters based on topography, soil type, land use and management practices within the cell. Additional data are required if the cell is selected for fertilizer or pesticide application. It also handles point sources, impoundment data and additional erosion. The input data and output results for the AGNPS model have been organized in Table 4.1.

Table 4.1a. AGNPS Model Input

Table Name	*No.*	*Variables*
Watershed Data	A1	14
General Cell	A2	20
Soil	A3	9
Fertilizer	A4	4
Pesticide	A5	17
NonFeedlot	A6	5
Feedlot	A7	58
Add Erosion	A8	6
Impoundment	A9	3
Channel	A10	21
Totals		157

Table 4.1b. AGNPS Model Output

Table Name	*No.*	*Variables*
Watershed Summary	A11	17
Sediment Analysis	A12	42
Hydrology	A13	7
Sediments	A14	30
Nutrients	A15	14
Pesticide	A16	13
Landuse Summary	A17	8*
Sources and Deposition	A18	44
Totals		175

*Depends on number of classes

Similarly, WATFLOOD requires general watershed information and cell data. Table 4.2 shows the structure for the data input. Appendix A has details on the variables assigned to each table, sample values, units and descriptions.

Table 4.2. WATFLOOD Model Input

Table Name	*No.*	*Variables*
Watershed Data	A19	24
General Cell	A20	13
Soil	A21	15
Fertilizer	A22	4
Pesticide	A23	17
Totals		73

In terms of GIS data, some of the variables in both models are related to topography, soil type or land use. The automatic extraction of map data uses a Digital Elevation Model (DEM) file and Map files with soil type and landcover layers. Tables 4.3 and 4.4 present a summary of the variables dependency for both models.

Table 4.3 AGNPS Variables as Function of DEM and MAP

Variable	*DEM*[1]	*LU*[2]	*S*[3]
Receiving Cell Number	●		
Receiving Cell Subdivision	●		
Flow Direction	●		
SCS Curve Number		●	●
Land Slope	●		
Overland Manning's		●	
K - Factor			●
C - Factor		●	
P - Factor (1 all cases)		●	
Surface Condition Constant		●	
COD Factor		●	
Soil Texture ID			●

[1]Digital Elevation Model; [2]Landcover layer: [3]Soil type layer

Table 4.4 WATFLOOD Variables as Function of DEM and MAP

Variable	*DEM*[1]	*LU*[2]	*S*[3]
River Elevation	●		
Drainage Area	●		
Drainage Direction	●		
River Classification	●		
Contour Density	●		
Channel Density	●		
Routing Reach Number	●		
Land Classes[4] (6, 10, etc.)		●	
Soil Textures[5] (12 types)			●

[1]Digital Elevation Model; [2]Landcover layer: [3]Soil type layer: [4]Percentage of area for each land cover; [5]Percentage of area for each soil texture.

4.2.2 DEM and MAP files

A Digital Elevation Model (DEM) is a digital representation of the continuous variation of relief over space. A DEM consists of a sampled array of elevations for ground positions that are normally spaced at regular intervals. The 30 arc-second DEM file used in this project are based on GTOPO30 arc-second DEM data for the entire world. These data are publically available from the U.S. Geological Survey's EROS Data Center.

Prior to the DEM utilization, a conditioning processes must be made to the file, for example using the Easy/Pace PCI software. This includes drainage watershed conditioning (DWCON), a program that is a conditioning phase that prepares the data prior to drainage and watershed analysis. This conditioning involves a cleanup of the elevation data and generation of flow direction and flow accumulation values. The results of the conditioning phase are:

1. A Depressionless DEM: Depressions present a significant problem in flow prediction models for two reasons; they are often data errors introduced during the DEM interpolation process and depressions confuse flow direction models and must be filled before flow can continue.

2. A Flow Direction Channel: Water at any given pixel location will flow into one of its eight adjacent neighboring pixels. This value indicates the neighboring direction of flow for each DEM element. The direction is calculated so it follows a continuous downhill path.

3. A Flow Accumulation Channel: This value represents the number of DEM elements whose water flows into its location. Examination of this channel by level thresholding can provide much information (ie. the drainage river system in the watershed).

After the conditioning phase, the resulting values can be exported as ASCII text files and then combined in a comma separated value (CSV) file to be imported into the RAISON map system. Each attribute will be imported as a field in the point layer database that will later be used to extract the information related to topography.

In relation to the Map files, the source of information can be a digitized map with attributes that are the soil type for each of the polygons in the soil layer. For the landuse layer, a supervised classification process can be made to a remote sensing image. The results, either from the digitization or polygon classification should be exported to ArcInfo Shape files that can be imported by RAISON and stored as spatial layers in the database. When importing polygons into the RAISON database layer, an optimization process to reduce the numbers of points that describe each polygon has been implemented. Figure 4.1 shows an example of the digital data using RAISON to display it.

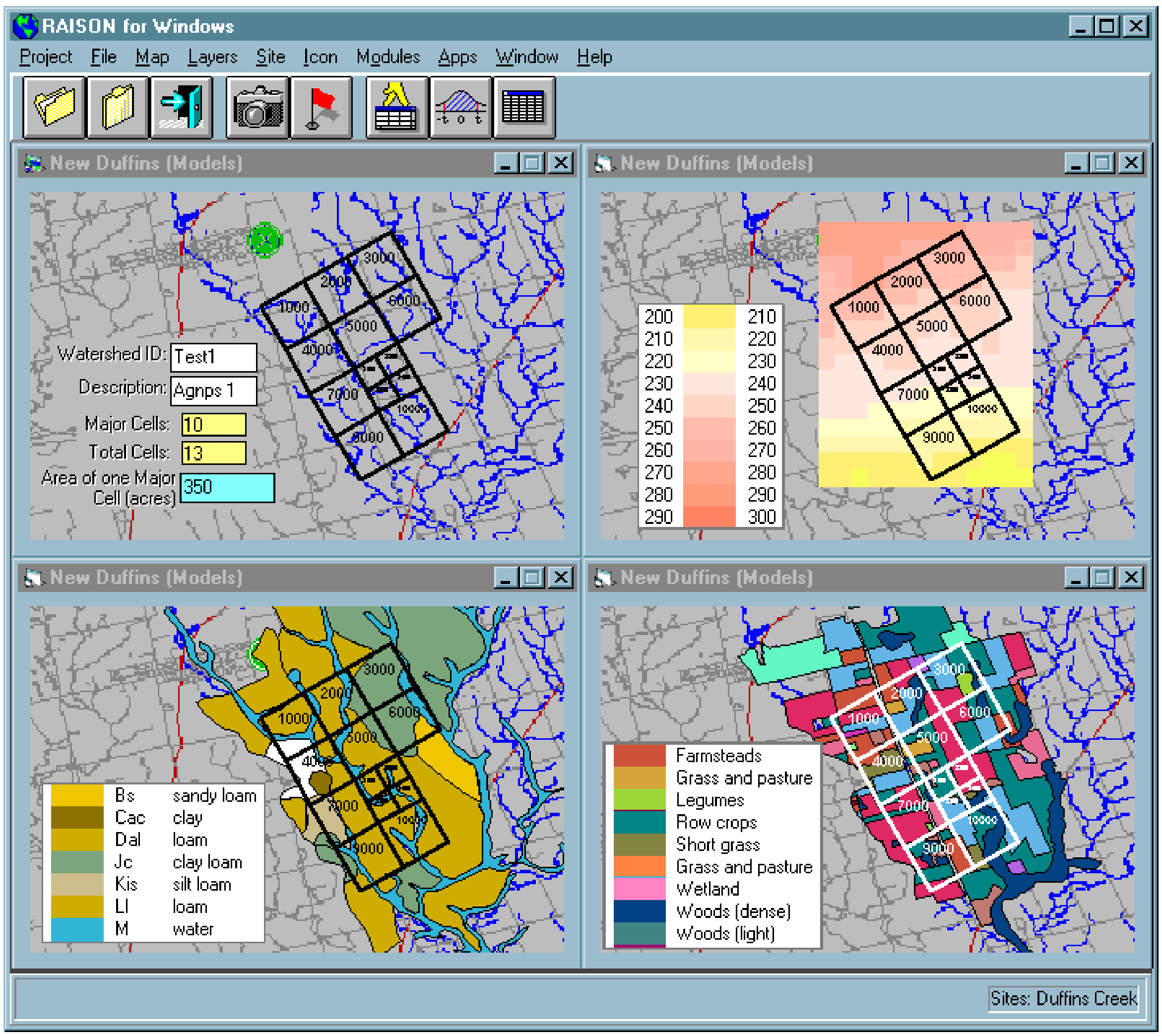


Figure 4.1 Input sources displayed in RAISON. From top left in clockwise direction: a) AGNPS test file with the grid aspect, b) DEM file (elevations) for study area., c) landcover layer and d) soil texture layer.

This reduction is based on angle variation from a sequence of vectorized points. This is done by comparing the direction in two adjacent points with the direction that results from the first point and the next one in the sequence. If the change in direction is significant (compared with a preset tolerance) then the point is maintained; if the change is not significant it can be removed. In some cases the optimization of points to be included can result in a reduction of almost 50% of the original dataset.

4.2.3 Extraction of DEM and Map Data

The major asset of the GIS approach is to automatically extract the required information to calculate the model data. Depending on the topography of the watershed and the configuration of the grid, some variables are topographically related. Others are functions of the soil type and landcover. The process of extracting data from map sources has been divided into two major sections: i) topography related data using the DEM file, ii) soil type and landcover data using the Map file.

Prior to the extraction process and in order to speed up the display and calculations, some optimization is achieved and auxiliary files are created that contain only the polygons that fall inside a container box of the grid or the cell. The first step is to search for the four corners of a box (minimum and maximum latitudes/longitudes) that contains the grid. For each polygon, the corresponding corners of a bounding box that accommodate the polygon are read from the type table of the layer database. Comparing the vertices with the ones from the box will result in deciding whether or not to copy the polygon in the temporal file.

Following the same idea, in order to speed up the calculations a bounding box created at run time is used to select the DEM or polygon points that fall inside each cell. To give an idea of this optimization and the final performance of the extraction process, the elapsed time, based on a Pentium 90Mhz, for different stages of the development is presented in Table 4.5.

Table 4.5 Optimization of Extraction Times. a) First stage, no optimization made. b) Reducing files and creating auxiliary files. c) Narrowing to bound box at run time.

a) Full DEM & MAP files for all the elements on the grid

Grid Size	DEM Ext		MAP Ext (h:m:s)	Total Ext (h:m:s)
3x3(9)	0:12:00	*Soil*	0:09:20	
		Landuse	0:28:30	0:49:50
7x7(49)	1:29:15	*Soil*	0:52:55	
		Landuse	2:32:50	4:55:00
12x12(144)	4:19:12	*Soil*	2:35:31	
		Landuse	7:29:18	14:24:01

b) Reduced DEM & MAP files for all the elements on the grid

Grid Size	DEM Red	DEM Ext	Total DEM		MAP Red	MAP Ext	Total MAP	Total Ext
3x3(9)	0:00:50	0:01:55	0:02:45	*Soil*	0:00:10	0:02:15	0:02:25	
				Landuse	0:00:25	0:05:35	0:06:00	0:11:10
7x7(49)	0:01:35	0:10:24	0:11:59	*Soil*	0:00:21	0:06:25	0:06:46	
				Landuse	0:00:50	0:15:50	0:16:40	0:35:25
12x12(144)	0:03:51	1:14:11	1:18:02	*Soil*	0:00:45	0:29:20	0:30:05	
				Landuse	0:01:31	1:10:15	1:11:46	2:59:53

c) Full DEM & MAP bounded for each cell on the grid (reduction optional for display)

Grid Size	DEM Ext	Total DEM		MAP Ext	Total MAP	Total Ext
3x3(9)	0:01:02	0:01:02	*Soil*	0:01:35	0:01:35	
			Landuse	0:01:42	0:01:42	0:04:19
7x7(49)	0:03:35	0:03:35	*Soil*	0:03:45	0:03:45	
			Landuse	0:04:20	0:04:20	0:11:40
12x12(144)	0:10:55	0:10:55	*Soil*	0:10:05	0:10:05	
			Landuse	0:11:21	0:11:21	0:32:21

For the DEM extraction, the calculations are performed in two steps. For the flow direction the DEM elements that intersect the borders of each cell in the grid are identified. Using the flow accumulation values of the DEM, the element with the highest drainage value that intersects one of the four borders of the grid cell is used to calculate the flow direction. If the selected DEM element falls within the current cell, the angle for the flow direction is calculated between the center of the cell to the center of the DEM element. If the DEM element falls in the receiving cell, then the angle for the flow direction is calculated between the center of the current cell to the center of the receiving one. Figure 4.2 shows an example of the intersection of the DEM file elements with the grid cells. The second step is to calculate the land slope within each grid cell. This is done by first calculating the maximum slope between each DEM element and its immediate neighbors and then averaging the results for the grid to define the internal overland slope. Figure 4.3 shows an example of the slope calculations.

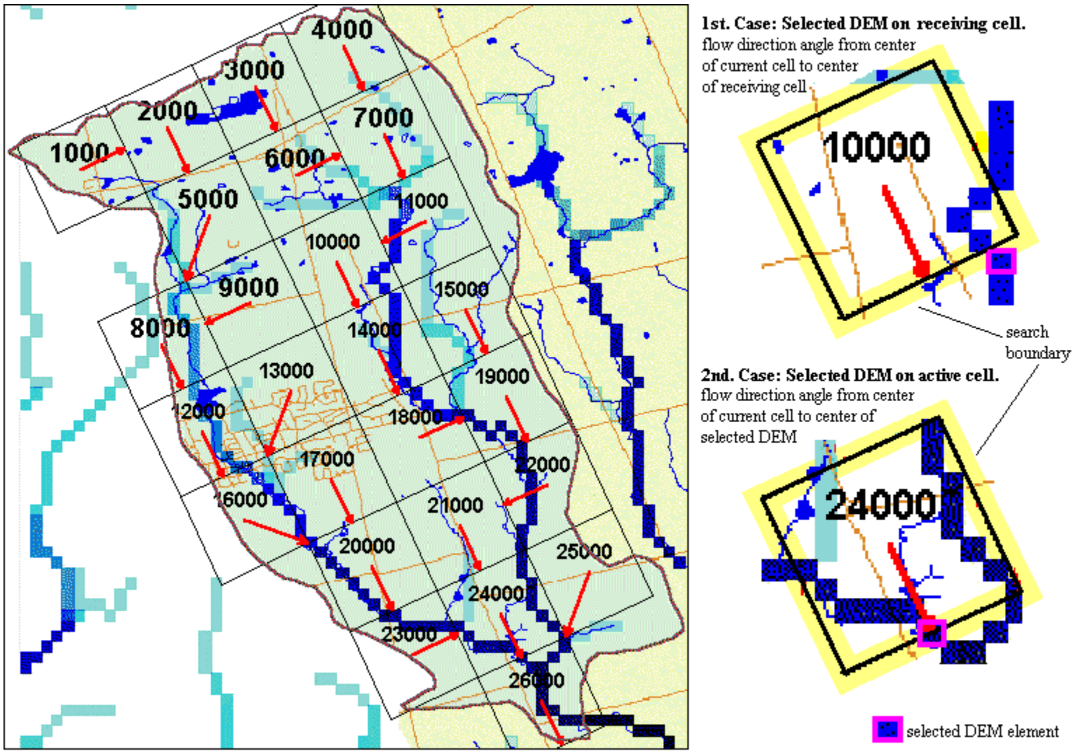
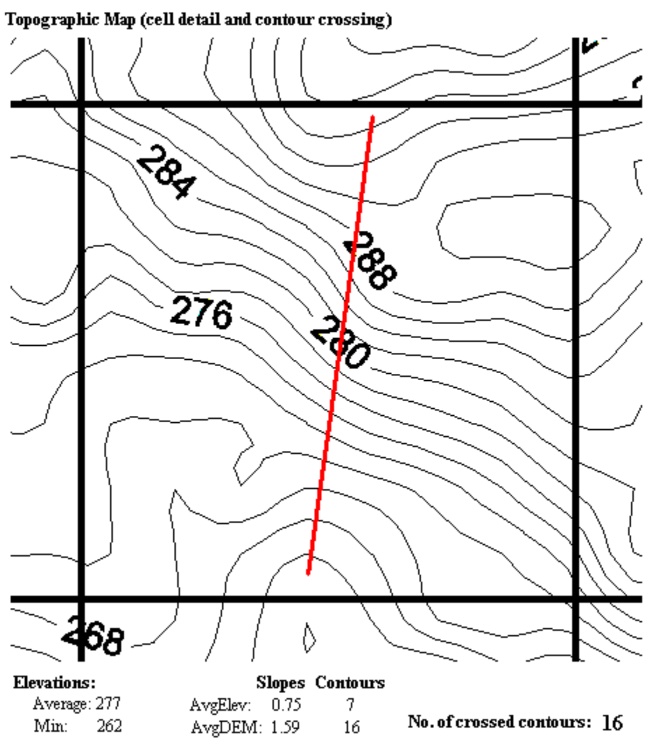


Figure 4.2 - DEM extraction example for grid flow direction



DEM elevations

282	287	289	291	296	296	294	294	293	292
280	281	285	288	290	290	290	289	289	288
279	279	282	283	286	289	290	290	290	289
279	275	278	278	281	287	289	288	289	286
273	272	272	273	277	281	282	283	285	283
272	270	270	270	272	275	277	279	282	282
271	270	268	270	268	269	271	274	278	280
270	270	268	266	264	266	269	270	273	280
268	269	268	265	262	264	268	269	269	274
264	266	266	264	262	262	260	264	263	266

DEM element slope

0.80	2.33	2.67	2.00	2.67	2.00	1.67	1.67	1.67	1.33
0.33	0.67	2.00	2.00	2.33	1.33	0.33	0.00	0.33	1.33
1.33	1.33	2.33	1.67	2.67	2.67	1.00	0.67	1.33	2.33
2.33	1.00	2.00	2.00	2.67	3.33	2.67	2.00	2.00	2.33
1.00	0.67	0.67	1.00	2.33	3.00	2.33	2.00	2.00	1.33
0.67	0.67	0.67	0.67	1.33	2.33	2.67	2.67	2.67	1.33
0.33	0.67	0.67	2.00	1.33	1.67	1.67	1.67	2.67	2.33
1.00	0.67	1.00	1.33	0.67	1.33	1.67	0.67	1.33	3.67
1.67	1.67	1.33	1.00	0.00	1.33	2.67	3.00	2.00	3.67
1.67	2.00	1.67	1.33	2.00	3.00	2.33	3.67	2.67	3.67

Figure 4.3 - DEM extraction example for grid overland slope

The contour density value for WATFLOOD deserves special mention. In this case, extracted from a topographic map, the number of contours crossing a straight line perpendicular to the flow direction are the input data for the model. Though this is the recommended value, internal slope may provide a different way to calculate it. Using the same procedure to calculate the slope as described above, and assuming a certain value for the contour interval, the number of contours was estimated from internal slope.

The same data were also estimated by performing a Kriging interpolation to get the contours using the DEM elevations and counting the number of times a line perpendicular to the flow direction crosses a contour object. Figure 4.4 presents the results comparison for estimated contours and map derived values. At the same time calculations were done to test the values for the channel slope by averaging DEM elevation values. As can be noted, the channel slope values, calculated with the average elevations, correlates quite well with but underestimates the measured contours.

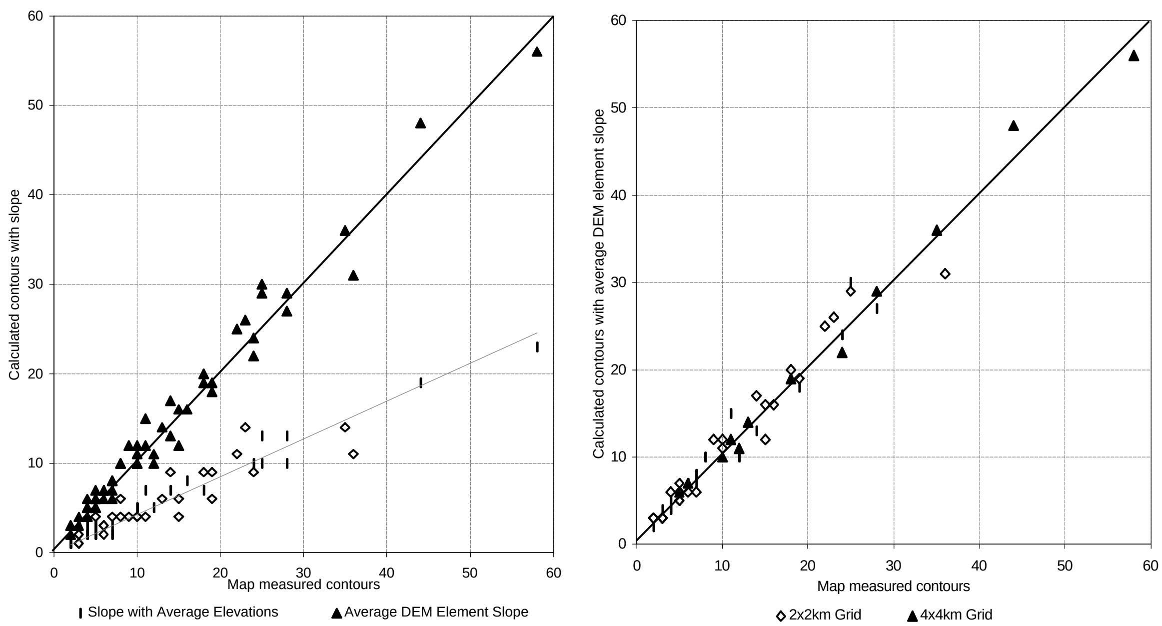


Figure 4.4 Number of contours. Comparison with contouring and slope calculations.

In fact, the process using the DEM elements directly to calculate the slope may be accurate enough. With this procedure, determining the number of contours is less time consuming and leads to a consistent way of calculating the internal slope required by WATFLOOD. It is worth mentioning that the scale ratio between the size of the DEM elements and the grid cell size was maintained approximately constant in a 1:100 relation for all the tests.

For the variables that depend on soil type and landuse information, a different process is used to perform the calculations for the selected grid according to an active lookup table (LUT) for soil type and landuse characteristics. These include the relational indexes that link the code map with the data values and are summarized in Appendix B. For the AGNPS extraction, the process will start browsing the layer file looking for the intersection with every cell in the grid file, calculating the area for each attribute (ie. soil type) and its percentage with respect to the total area of the cell. With this percentage, it retrieves the values for the selected field in the LUT and calculates the weighted value for the cell. The general expression used in the extraction process to weight the parameters is:

$$Weighted\ Parameter = \sum_{i=1}^{n} \frac{A_i}{A_T} Parameter_i \tag{4.1}$$

where A_i/A_T is the percentage of area for the ***i*** soil type or landcover, and $Parameter_i$ is the value from the lookup table for the soil type or landcover attribute. An exception is the value for soil texture that is assigned directly from the dominant class within the cell. As an example of the extraction process where polygon information is converted into model grid input data, Table 4.6 presents the detailed process for a variable dependent on the soil type field. It shows the calculations for two arbitrary cells in order to estimate the *K* factor for the USLE method. The map code is the original field variable in the soil layer map file. Using this code and reading the values from the LUT, the soil class and the K factor are retrieved from the database file. Weighting the values according to the percentage of each soil type within the cell (Equation 4.1) and accumulating these values, gives the representative parameter value for the cell as accurately as it can be done.

Table 4.6 Example Calculations for the K-factor Using Soil Map Information.

Cell Number	Soil Type (fraction)	Map Code	Soil Class in the Lookup Table (LUT)	K factor in LUT	Weighted K factor	Accumulated K factor
1000	0.1411	B.L.	Bottom Land : water-alluvial	0	0.000	0.000
1000	0.0274	Pec	Peel : clay loam	0.29	0.008	0.008
1000	0.1074	Ml	Milliken : loam	0.31	0.033	0.041
1000	0.0294	Wol	Woburn : loam	0.31	0.009	0.050
1000	0.2248	Ml	Milliken : loam	0.31	0.070	0.120
1000	0.1816	Kis	King : silt loam	0.37	0.067	0.187
1000	0.1287	Ml	Milliken : loam	0.31	0.040	0.227
1000	0.0422	Cac	Cashel : clay	0.20	0.008	0.236
1000	0.0664	Kis	King : silt loam	0.37	0.025	0.260
1000	0.0243	Wol	Woburn : loam	0.31	0.008	**0.268**
2000	0.1644	B.L.	Bottom Land : water-alluvial	0	0.000	0.000
2000	0.1322	Pec	Peel : clay loam	0.29	0.038	0.038
2000	0.2760	Pec	Peel : clay loam	0.29	0.080	0.118
2000	0.0009	Pec	Peel : clay loam	0.29	0.000	0.119
2000	0.1218	Brsl	Brighton : sandy loam	0.14	0.017	0.136
2000	0.1402	Ml	Milliken : loam	0.31	0.043	0.179
2000	0.1676	Brsl	Brighton : sandy loam	0.14	0.023	**0.203**

For the WATFLOOD model, the areal extraction is exactly the same as described, but after obtaining the percentages of soil type and land use, no further calculations are required. The only additional process is to group the soil and land classes according to the classification groups defined in the lookup tables. With these procedures in place, all the cell data are automatically extracted and stored in the grid layer.

As previously mentioned, the AGNPS model can accommodate specific cell data, for example, if the cell is selected for fertilizer or pesticide application. Also there is the possibility to attach point sources (ie. feedlots and non-feedlots), impoundment data and additional erosion. All these additional data are captured through the use of input forms.

4.3 Interfaces for RAISON

4.3.1 Conceptual Design

The main objective of this work is to include diffuse pollution models in a Spatial Decision Support System (SDSS) with common interfaces and Geographic Information System (GIS) capabilities. An integrated approach is developed involving the linkage of the AGNPS and WATFLOOD models with RAISON to form the SDSS to deal with NPS modelling. Figure 4.5 shows a schematic representation of the linkage between the models and RAISON through the use of interfaces.

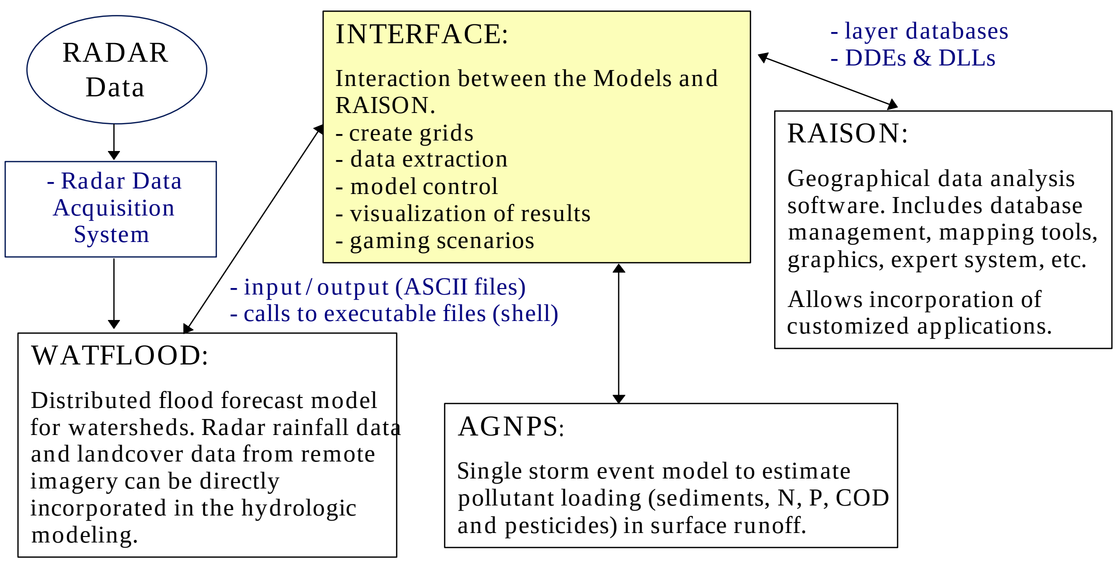


Figure 4.5 Schematic representation of the linkage between the models and RAISON.

In order to create such interfaces, interactive programs were written to assist in processing data, initiating model simulations and analyzing model results. Building up graphical interfaces by exploiting the capabilities of RAISON, allows interaction with the models by intercepting input/output data and connecting them to the database. The design of the interface consists of a main window that controls the access to the different available toolbars. The toolbars group different tasks or procedures to be performed in order to create/edit the grid, collect/edit the required data, run the model and display results.

Table 4.7 shows the conceptual design of the interfaces. Communication links between the interfaces and RAISON were established by using the DLL for the layer functions. The interaction between the interfaces and the models is done through interchange of data via ASCII files and calls to executable files. The pre-processing tools provide easy data compiling for the models. Using topography, soil type and land use maps in vector formats, procedures were developed to automate as much data input as possible as described previously. Design of a control panel for model operation helps in the setup and simulation. This also triggers the model to run by creating a shell that activates the model. Post-processing for output data by means of graphical tools assists with the interpretation of model results.

Table 4.7 Conceptual Design of the Interfaces.

Toolbar	Tool/Procedure	Description
Make/Edit Grid	Initialize Database	Initialize the database file and create the basic file structure.
	Create Grid	Create a basic grid and save to an existing database file.
	Create Tables	Create the required tables and structure for the models.
	Edit Grid	Edit the grid by adding, deleting, and/or subdividing cells.
Collect/Edit Data	Initial Data	Capture the initial watershed data.
	Collect Data	Extract data as function of topography, soil type, and landuse.
	Edit Flow Direction	Edit the flow directions and receiving cells.
	Cell Editor	View and edit the general cell data.
Run Model	Write ASCII File	Utility to convert the database to an ASCII file for the model.
	Run Model	Run the model for the selected file(s).
Display Input/Output	Create/Edit Ranges	Create and edit ranges for the selected variable.
	Display I/O	Using the layer view, display the available input/output.
	Tabular Results	Using the tabular view, display the output (model results).
	Trace Contributions	Account for various sources in any given cell.
Analysis/Scenarios	Duplicate Grid	Duplicate grid and copy data under a new grid name.
	Modify Landuse	Change percentage of landcover and recalculate parameters.
	Summarize Runs	Display summary of the different runs in a database.
	Sensitivity Analysis	Perform sensitivity analysis and ranking.

4.3.2 Description of the Interface

The main windows for the AGNPS and WATFLOOD interfaces, that control the access to the different sections of the interfaces are showed in Figure 4.6. Each button accesses a different toolbar. The same toolbars can be selected from the tools menu. The bar beneath the buttons is the status bar that gives a short description of what each tool will activate.

When a main button is selected, the specific toolbar is displayed and the different options for the active procedure are enabled. The sequence of the procedures and tools are arranged to encourage a proper order in the creation of a specific scenario. Following is a very brief explanation for the toolbars. More detailed description of the different sections of the interface is presented in Appendix C, where all the options are explained and the windows mentioned in the next section are shown with more detail and full explanations.

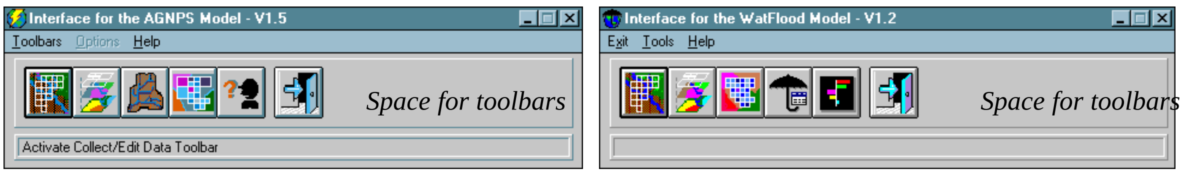
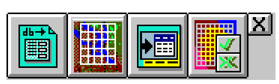


Figure 4.6 Main interface windows for AGNPS (left) and WATFLOOD (right).

In both interfaces, the different buttons will activate the *Make/Edit Grid* toolbar, the *Collect/Edit Data* tools, the *Run Model (AGNPS or WATFLOOD)* toolbar, the *Display Input/Output* tools and the *Analysis Scenarios* toolbar. When any of the procedures is selected, the available options for each tool are displayed in a form of a graphical toolbar together with the respective popup options menu. This toolbars where developed as navigational aids through the interface but their main objective is to access the different modules of the program.

The Make/Edit toolbar:

 (*AGNPS*)  (*WATFLOOD*)

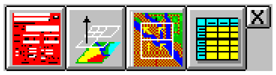
[Initialize Database] - Initialize the database file. It will open a *File Dialog Box* asking for the name of the file to create. After inputting the name, the program will proceed to create the basic file structure for the database.

[Create Grid] - Create a basic grid and add it to an existing database. It will open the *Grid Maker* window to create a basic grid and save it in an existing database file.

[Create Tables] - Create the required tables and database structure for the models. It will open the *Create Tables* window and allows to generate the structure to hold the data for the model.

[Edit Grid] - Modify the basic grid by adding, deleting and/or sub-dividing cells in AGNPS or selecting and deselecting cells for WATFLOOD. It will open the *Grid Editor* window and allow modifications to the basic grid.

The Collect/Edit Data toolbar:

 (*AGNPS and WATFLOOD*)

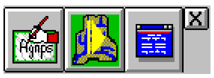
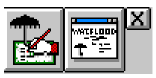
[Initial Data] - Capture the initial watershed data. It will open the Initial *Watershed Data* window that allows required data input.

[Collect Data] - Collect cell data from Soil and Landcover Maps. It will open the *Collect Data* window that allows calculation of the data as a function of topography, soil type, and landcover maps. It will also facilitate the display of the DEM file and the soil and landcover maps.

[Flow Direction] - Edit the flow directions and receiving cells. It will open the *Flow Direction Editor* that will help the user in the selection of the flow directions and receiving cells.

[Cells Editor] - View and edit the general cell data in summary form. It will open the *Cell Editor* in order to facilitate the view and editing of the different grid parameters.

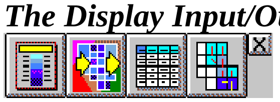
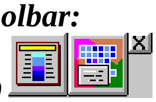
The Run Model toolbar:

 *(AGNPS)*  (*WATFLOOD*)

[Write ASCII File] - Access the export utility to convert the data stored in a database file to an ASCII file that the model can understand. It will open the *Export ASCII* window to export into a specified ASCII file.

[Run Model] - Run the models for the selected file(s). It will open the *Run Model* window to select the file and grid to use for running the model.

The Display Input/Output toolbar:

 *(AGNPS)*  (*WATFLOOD*)

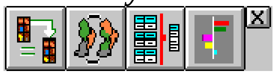
[Edit Ranges] - Create or edit the table for the ranges to be used when displaying the input data or output results. It will open the *Create/Edit Ranges* window to create or edit the ranges.

[Graphic Display I/O] - Spatially display the input data or the model results. It will open the *Graphic Display* window that allows the user to spatially display the input data or the model results in the database file for the selected grid.

[Tabular Results] - (Only for AGNPS) View the model results in tabular form. It will open the *Tabular Display* window that allows the user to view the model results in a spreadsheet tabular form.

[Trace Contribution] - (Only for AGNPS) Activates the source accounting options. It will open the *Trace Contribution* window that allows the user to see the various sources of pollution in any given cell..

The Analysis/Scenarios toolbar:

 *(AGNPS)*

[Duplicate Grid] - Duplicate grids in the database file. It will open the *Duplicate Grid* window that allows the user to replicate a specific grid with a new grid name.

[Modify Landuse] - Modify land coverage percentages. It will open the *Landuse Editor* that allows the user to change the amounts of land coverage for the different land classes.

[Summarize Runs] - (Only for AGNPS) Display the summary of the different runs. It will open the *Summary Runs* window to view a summary of the differents runs.

[Sensitivity Analysis] - Perform the sensitivity analysis. It will open the *Sensitivity Analysis* tool that will allow the user to select the variables to perturbe, perform the sensitivity and display the results.

4.3.3 Online Help File

The AGNPS and WATFLOOD interfaces have been developed in an object oriented environment using a graphical user interface. The main interface windows contain a status bar to provide a quick and easy way of identifying the different sections. As the mouse pointer is moved over the various buttons, information about the object appears in the status bar. Additionally, an *Online Help File* has been created as a reference to get more information about the variables from the model.

In fact the online help files are a very comprehensive and fully functional Windows help system developed around the AGNPS and WATFLOOD Interfaces. In order to access them, from the *Help* menu in the main window, choose *Contents* to bring up the help contents page. Figure 4.7 shows the table of contents from the AGNPS and WATFLOOD interface help files.

The hypertext help files were created with the help compiler for windows using a rich text format (RFT) source document. Help topics include:

AGNPS and WATFLOOD Interface: Includes the main interface description, providing hyperlinks to the different sections (toolbars).

Toolbars: Presents all of the details on the toolbars and links to the different windows are provided by clicking in the respective buttons.

Input/Output Description: Outlines the data requirements for the models and the results obtained from running it. Describes the dependency of the variables on the different map files and provides information on the database structure and detailed information on the variables.

Creating Model Grids: Explains the methodology for starting the database file and creating/editing the required grids.

Collecting and Editing Data: Explains the methodology to input the initial watershed data and how to automatically collect data from the maps and its subsequent editing.

Running the Model: Provides the available running procedures for the models.

Displaying Data/Results: Describes the visualization tools for spatially displaying the input data and/or the model results.

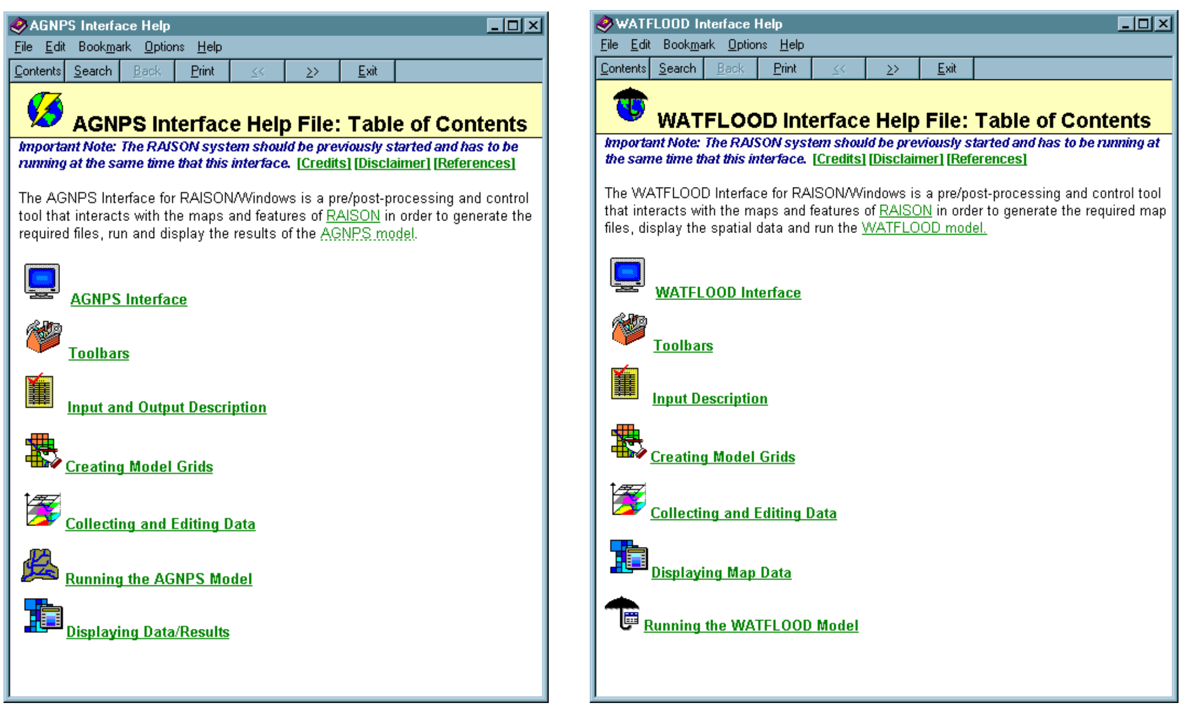


Figure 4.7 Table of contents from the AGNPS and WATFLOOD interface help files.

Almost all of the information contained in the help file was created in order to explain the different components of the interface. The input and output descriptions was elaborated using the text information delivered with the documentation of the models. Several levels of help are available at any moment while running the interface by pressing the F1 function key. For example, when the user is in the *Flow Direction Editor* window and the F1 key is pressed, the help file is opened exactly in that section. Most of the help images are clickable, providing links that allow further topics to be accessed.

As an example of the flow direction editor, Figure 4.8 shows the help file with the *Flow Direction Editor* topic opened in the screen. If the user clicks on the *Grid* or *Flow* buttons, the respective window topic will open with the description displayed. The same applies to the description of the variables. When a window with variables is open, the user can click on most of the variables names and get additional information about the desired parameter. The help system is structured in such a way that is intended as a brief tutorial that will describe how to do a NPS simulation using the AGNPS or WATFLOOD interface for RAISON.

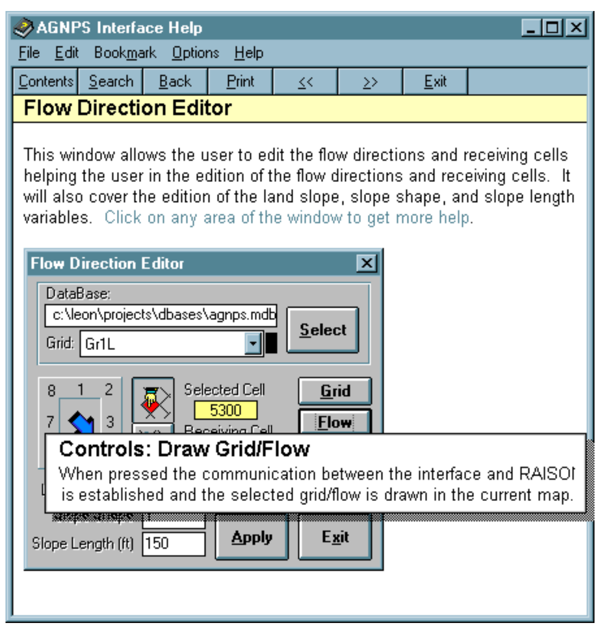


Figure 4.8 Flow direction editor help with further controls explanation.

4.4 Example: Use of the Interface

This section describes how to do a NPS simulation using the AGNPS Interface for RAISON. In the example, it is assumed that RAISON is already started with the project of interest (background map - snapshot) displayed. Also the DEM and MAP files are assumed to be previously imported into the RAISON layer database structure. For the following example, the snapshot and map files are from the Duffins Creek area. All of the datasets (except for the maps) used in the example have been generated for demonstration purposes only. They are mock datasets and do not represent any real simulation on the Duffins Creek watershed. Real data and simulations are presented in the application section.

4.4.1 Creating Grids

All the data required for the model are stored in a database file that can contain several grids. So the first step is to prepare a file and create the grids for the model. This is done from the *Make/Edit Grid* toolbar. Selecting the *Initialize Database* button a *File Dialog Box* will open asking for the name of the database file to create. The program will then proceed to create a basic file for the database. If the file name already exists, an option exists to overwrite the file.

After creating the database file, the next step is to generate the grid. This task is performed through the *Create Grid* option that allows a basic grid to be generated and saved in an existing database file. Allow interaction with RAISON by clicking with the mouse in the map where the upper left corner of the grid will be positioned. At this point, the grid properties (number of rows, columns, width of the cell, color and orientation) are introduced.

When the appearance of the basic grid is satisfactory, it can be stored in the database file. Once the grid is saved, the next step is to build the structure of the database. This is achieved with the *Create Tables* procedure. If the program detects that the tables were already created, no action can be taken other than exit. Otherwise a message will appear in order to perform the creation of the tables following the structure described above.

Finally, the form of the grid can be edited by adding/deleting or subdividing cells. Figure 4.9 shows an example of how a grid is created and edited to match the topology of the watershed to be simulated. The main interface window is displayed, together with the *Create Grid* and *Edit Grid* tools that help with the its creation and edition by adding, deleting and subdividing cells.

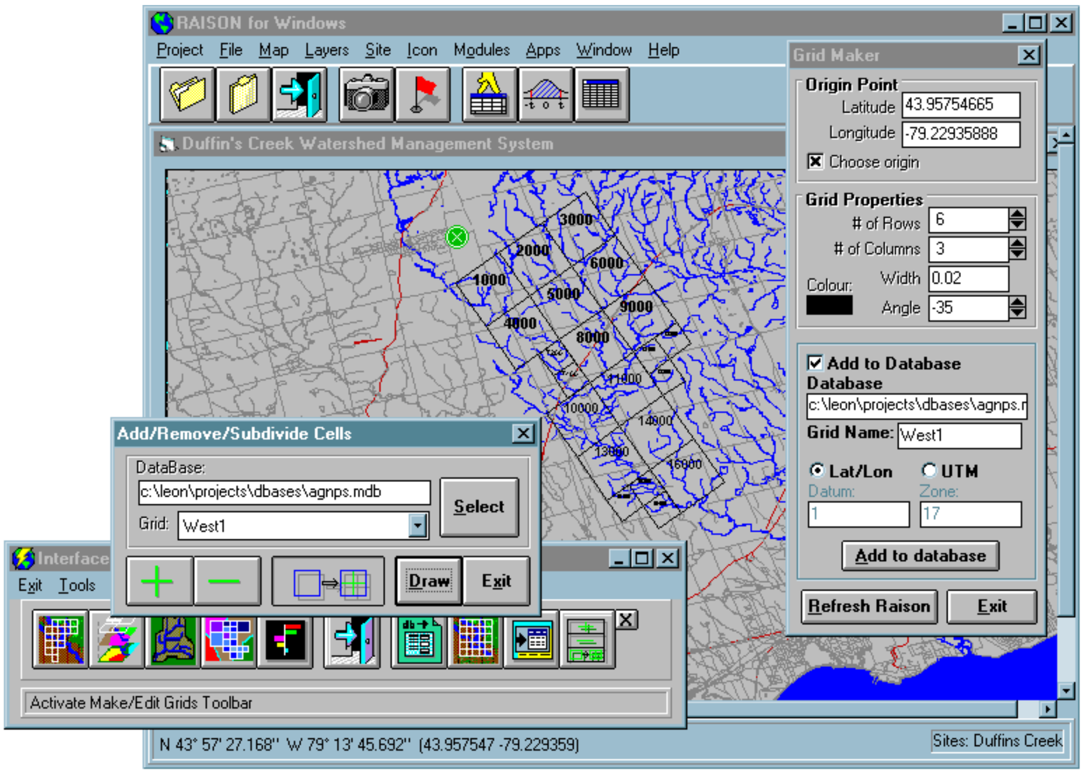


Figure 4.9 Example of the creation and editing of a grid for the AGNPS model.

4.4.2 Collecting Data

After the grid is generated and the required database structure is created in order to hold the data for the model, the next step is to start capturing the required data. As explained in the data requirements and structure section, the two categories of data, watershed and cell related, have to be captured for the selected grid, reviewed and, if needed, edited. The initial watershed data are captured directly into an input form that will verify if the data are valid and save them to the database. This is done through the *Initial Watershed Data* window.

The major asset of the GIS approach is the automatic extraction of the cell related data for the variables that depend on topography, soil type and landuse information. The extraction of the data from map files is achieved with the *Collect Data* procedure. This will perform the calculations described in the section about extraction of DEM and Map data. Figure 4.10 is an example of data extraction and display of the DEM file for the drainage characteristic (flow accumulation). It shows the original DEM file, the grid and the calculated flow directions.

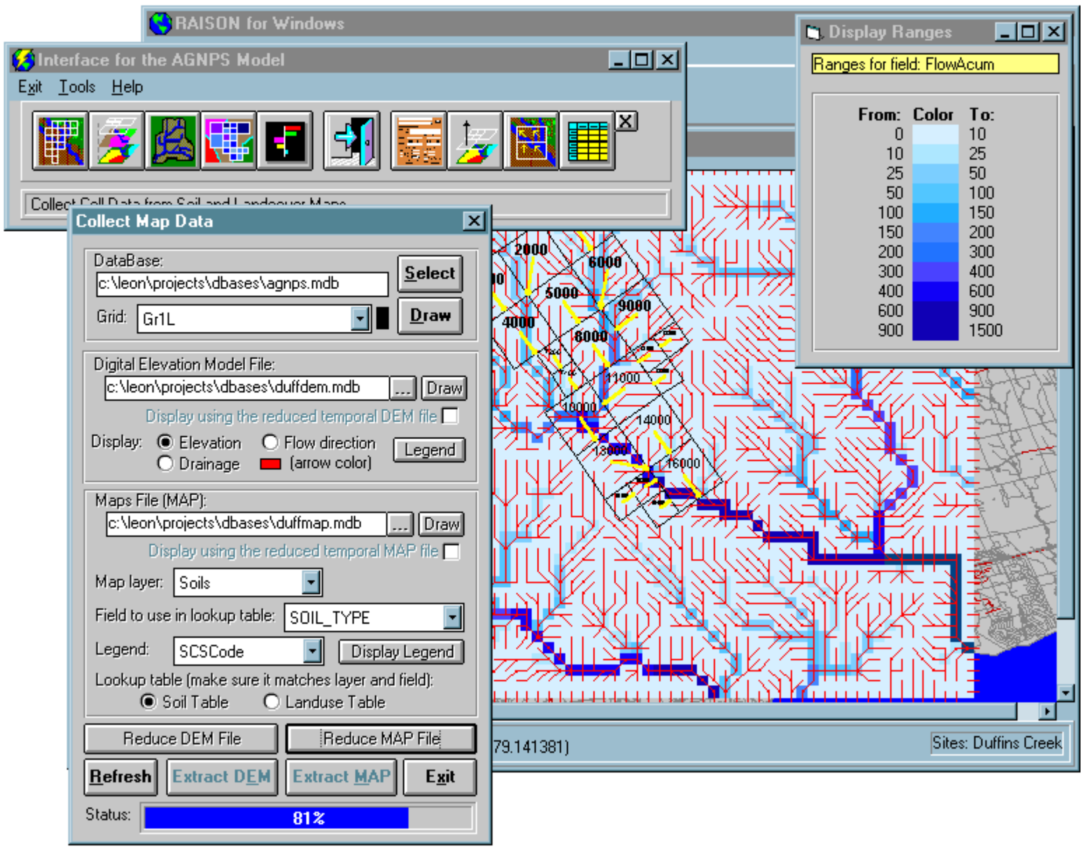


Figure 4.10 Example of DEM extraction and display of original DEM and flow direction.

To collect the information from the Map file, the process has to be made in two steps, first for the **soil layer** and the soil lookup table. Then the process should be repeated for the **landuse layer** and the landcover lookup table. When the extraction is completed, the resulting values can be reviewed and edited with the *Edit Flow Directions* or the *Cell Data Editor*. The *Flow Direction Editor* helps in editing and displaying flow directions and receiving cells.

To view and edit the general and additional cell data, the *Cell Editor* can be accessed. This editor will bring the cell data into a spreadsheet view where any value can be modified and automatically updated in the database. It is also possible to edit the additional cell related information, such as data for point sources, fertilizer and pesticide application. Figure 4.11 is an example of the cell editor tool with the results from the map data extraction. It can be noted that, in the background map, the soil type layer and its legend are displayed together with the arrows for the estimated flow direction for each cell.

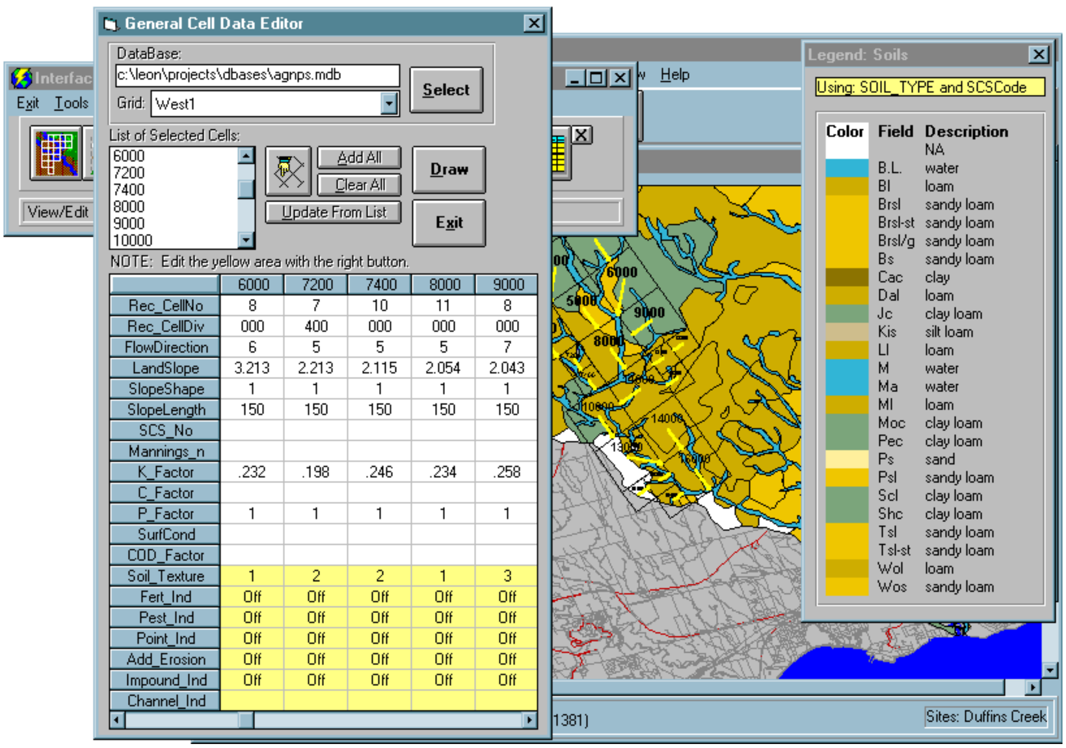


Figure 4.11 Example of the cell editor and display of the soil texture layer.

4.4.3 Running the Model

Once the data have been captured and/or automatically collected from the maps with the described procedures and stored in the database file, the next step is to run the model and visualize the results. In order to run the AGNPS model, the data stored in the database has to be exported to an ASCII file in the format that the model can understand.

This export and the running of the model can be done through the *Run AGNPS* toolbar. In this toolbar there are three procedures that write the ASCII file, run the model or activate a DOS shell that the AGNPS model provides to control the model. The recommended process to run the model from the interface is actually to select the *Run AGNPS Model* procedure.

This creates a temporal ASCII file, runs the model and extracts the results from the output file, storing them in the unique database file in the system. Witte *et al*. (1995) found that for large watersheds, the model should be run from outside the spreadsheet (DOS shell) program, so this is the approach used in this work to actually run the model.

The *Write ASCII File* option can be used to create an ASCII file for revision purposes. This will access the export utility to convert the data stored in a database file to an ASCII file that the model can understand. It will launch the *Export ASCII* procedure to export the data into a specified ASCII file. Note that this exported file is only for review purposes and will not be run within the interface.

An additional provision to access the DOS version of the model is available through the *AGNPS-DOS Shell* option. This will activate the AGNPS DOS Shell in a separate window and is left only for the user to take advantage of the check utility to verify the input data.

4.4.4 Displaying Data/Results

AGNPS, once run, gives detailed output, in fact a very large amount of data for analysis in even a small watershed. Graphical displays of the results have proven to be a more effective and efficient way of interpreting them than browsing through pages of numerical output. Visual tools have been created to display the spatial data in order to help with the analysis, interpretation and decision making processes. When the results are finally extracted from the output file and stored in the database, the *Display Input/ Output* toolbar can be selected to display the input data and/or the results from the simulation.

As an example of the graphical tools available, Figure 4.12 presents the spatial display of the *K* factor (input data) and the sediment erosion (model result). This feature uses part of the internal grid layer drawing commands of RAISON, showing the power of the system once all the information is stored as a database compatible with it.

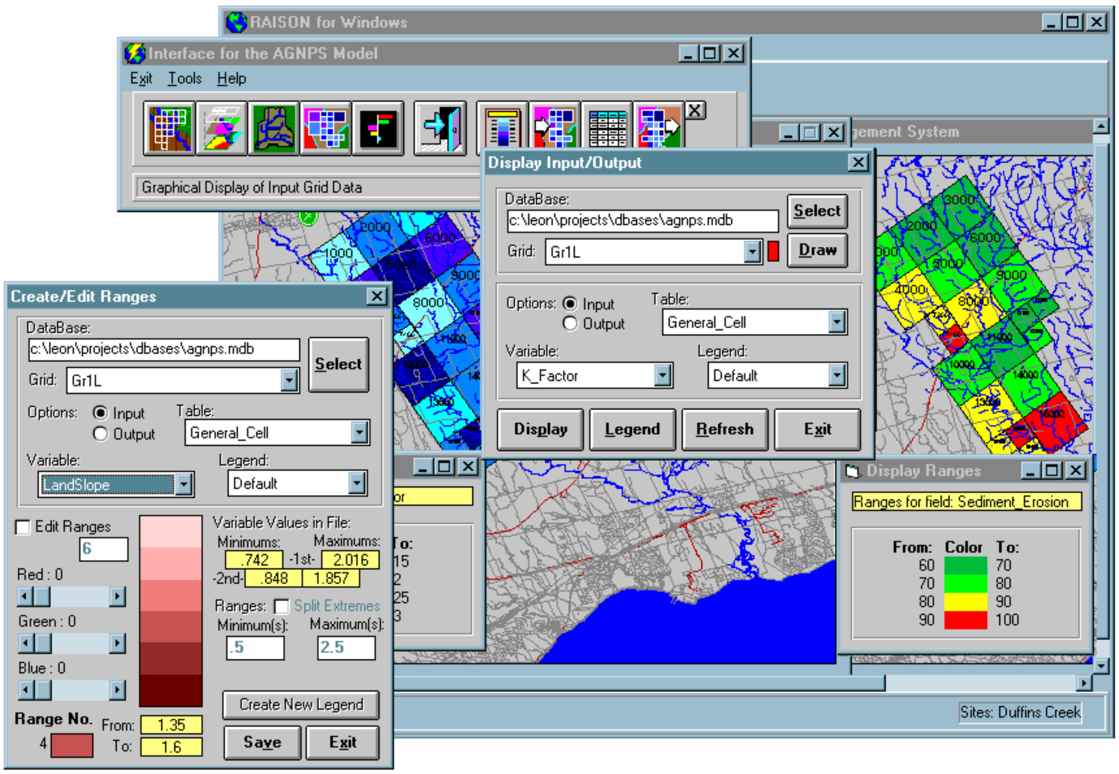


Figure 4.12 Example of graphical input/output display.

4.4.5 Modifying Scenarios

The AGNPS model can be used to simulate different scenarios (ie. best management practices) and its effects on runoff and pollutants loading. To provide support in the decision making process, the tools to duplicate a grid, modify the landcover percentages and recalculate the model parameters can be used to create the different scenarios. Once a basic set of data is extracted from the maps, the resulting gridded values can be copied and modified using the *Analysis/Scenario* options.

As an example of some of the available options, figure 4.13 presents two different runs on the Stouffville Creek watershed. A 500m cell size grid with 97 elements was generated to cover the area of interest. The precipitation was set to 2 inches and the energy intensity value to 15. The first scenario uses the land use coverage from a satellite image classification for 1983. The second one assumes that the top 30% of the watershed remained unchanged and the remaining 70% is developed as urban area with 25% of impervious area (streets, roofs, etc) with the rest having grass ground cover.

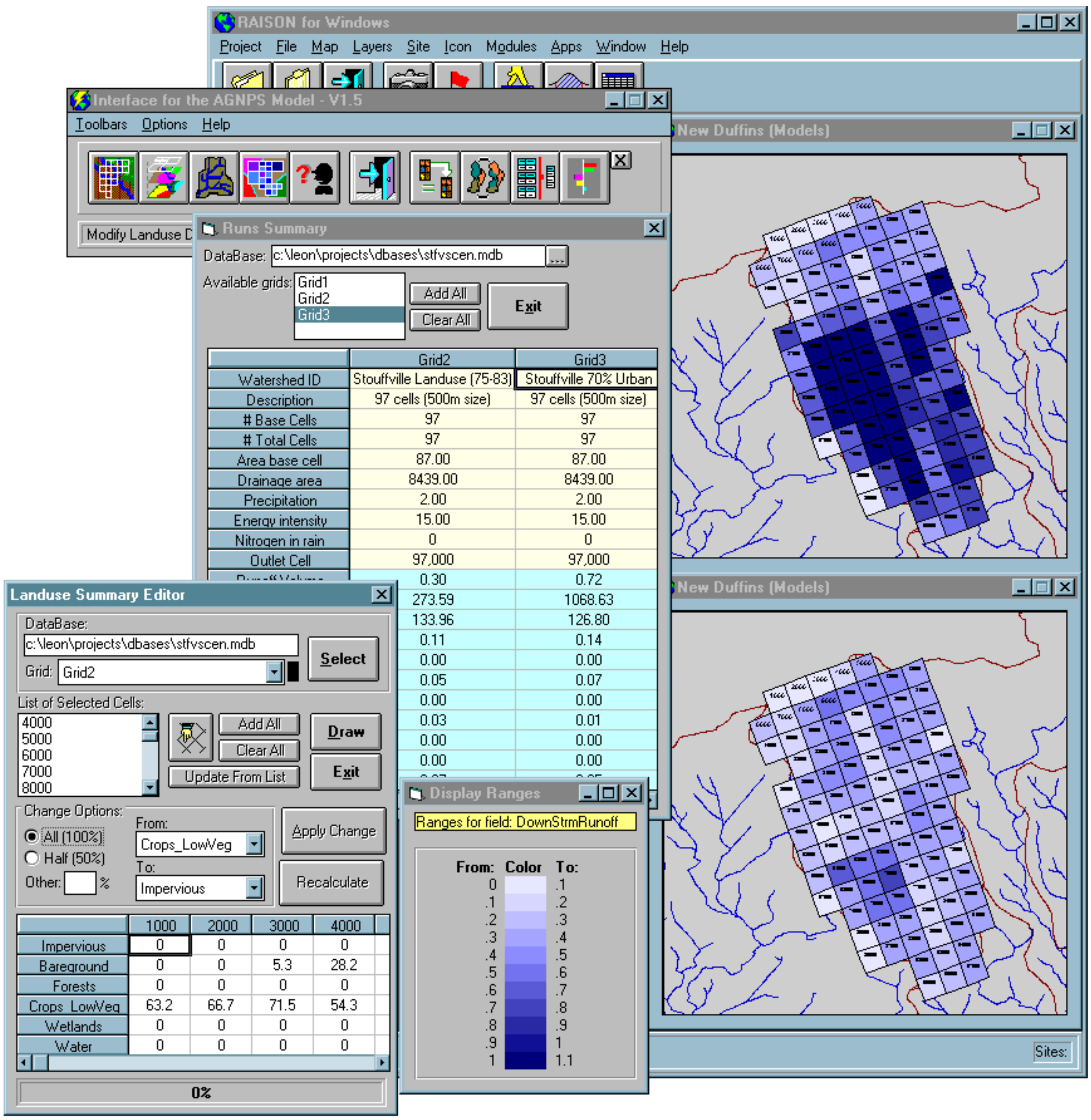


Figure 4.13 Example of different scenarios, modification and graphical output display.

4.5 Chapter Summary

This chapter presented the integral approach to include NSP models in a Spatial Decision Support System (SDSS) with a unique platform, common interfaces and Geographic Information System (GIS) capabilities. This consists of pre- and post-processing tools, model control panels gaming scenarios and sensitivity analysis for the parameters in the models. The construction of the interfaces, for the Agricultural Nonpoint Source (AGNPS) model and WATFLOOD, and their link with the decision support system RAISON (Regional Analysis by Ingelligent Systems On microcomputers) is described. First, a brief description of RAISON as the GIS and SDSS platform is presented. Some characteristics are outlined and the available tools used in this work for interfacing it with the models are mentioned. Finally, a detailed description about the AGNPS and WATFLOOD interfaces is presented. The conceptual designs are outlined and the interfaces presented in full detail, with highlights and explanations for all the commands and controls involved. The online help files are also briefly described, together with a brief example on how to use the interfaces.