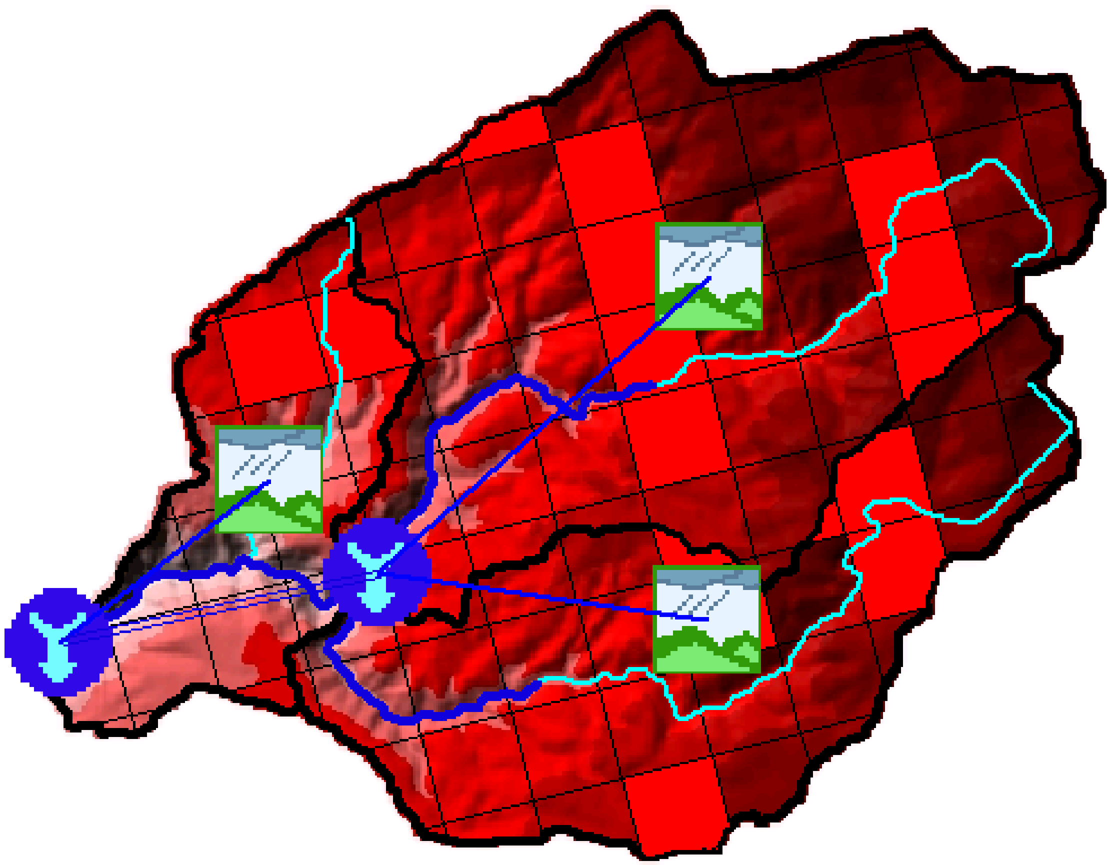
US Army Corps
of Engineers
Hydrologic Engineering Center

Geospatial Hydrologic Modeling Extension

HEC-GeoHMS



User's Manual

Version 1.0

July 2000

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13. ABSTRACT *(Maximum 200 words)*

The Geospatial Hydrologic Modeling Extension (HEC-GeoHMS) is a software package for use with the ArcView Geographic Information System. GeoHMS uses ArcView and Spatial Analyst to develop a number of hydrologic modeling inputs. Analyzing the digital terrain information, HEC-GeoHMS transforms the drainage paths and watershed boundaries into a hydrologic data structure that represents the watershed response to precipitation. In addition to the hydrologic data structure, capabilities include the development of grid-based data for linear quasi-distributed runoff transformation (ModClark), HEC-HMS basin model, physical watershed and stream characteristics, and background map file.

GeoHMS provides an integrated work environment with data management and customized toolkit capabilities, which includes a graphical user interface with menus, tools, and buttons. The program features terrain-preprocessing capabilities in both interactive and batch modes. Additional interactive capabilities allow user to construct a hydrologic schematic of the watershed at stream gages, hydraulic structures, and other control points. The hydrologic results from HEC-GeoHMS are then imported by the Hydrologic Modeling System, HEC-HMS, where simulation is performed.

GeoHMS is available for Windows 95/98/NT/2000 operating systems.

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Geospatial Hydrologic Modeling Extension HEC-GeoHMS, User's Manual

The above information and the full License Agreement are presented for acceptance when the software is first used. That information is also provided in Appendix E of this manual for reference.

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Foreword

The Hydrologic Engineering Center's (HEC) recent developments in Geographic Information System (GIS) tools for hydrologic and hydraulic modeling result from many years of interest in geospatial data usage. The earliest work was begun in the mid 1970's when HEC developed software based on the concepts developed in the Harvard University's School of Landscape Architecture, Honey Hill Project. That early work culminated with the development of the Spatial Analysis Methodology (HEC-SAM) which included a grid-cell data bank and analysis software for hydrologic and flood damage calculations. That early work had the same concepts as those of today, but the limitations in the computer hardware, GIS software, and data availability made widespread engineering applications difficult.

The current development builds on those early experiences and takes the technology to several practical engineering products including HEC-GeoHMS. HEC resurrected its earlier efforts by reviewing current GIS capabilities in association with Professor David Maidment from the University of Texas. HEC and Dr. Maidment formulated a watershed data structure that would link GIS and hydrologic models. From that time, the definition and content of the GIS and hydrologic data structures evolved into a hydrologic GIS preprocessor, PrePro. Taking advantage of the wealth of terrain and geographic data readily available over the Internet and from government agencies, PrePro delineates streams and watersheds and builds the hydrologic model structure for HEC-HMS. PrePro was the predecessor to HEC-GeoHMS.

The development of PrePro at the University of Texas was partially supported by HEC via the Corps' Civil Works R&D program. The effort also received substantial support from the Texas Department of Transportation as well as support from other national and international agencies. PrePro development at the Center for Research in Water Resources at the University of Texas has been directed by Dr. Francisco Olivera. GeoHMS has been developed by HEC and ESRI as a component of a Cooperative Research and Development Agreement between those two organizations. Dr. Maidment, Dr. Olivera, and others at the Center for Research in Water Resources have provided valuable assistance for the development of GeoHMS.

Other GIS products that have been released or are under development by HEC include HEC-GeoRAS, a GIS utility for use with the HEC-RAS river hydraulics program, and HEC-GeoFDA, a GIS utility for use with the HEC-FDA flood damage analysis package.

For several years, HEC has developed a number of GIS modules for specific tasks, such as processing terrain for drainage path, generating grid-based rainfall, etc. Those modules required users knowledgeable of UNIX, ArcInfo, hydrology, and a number of miscellaneous sub-programs. HEC-GeoHMS combines the functionality of those ArcInfo programs into a package that is easy to use with a specialized interface. With this ArcView capability and a graphical user interface, the user easily accesses customized menus, tools, and buttons instead of the command line interface in ArcInfo. With GeoHMS, users who are new to GIS have access to powerful GIS operations.

GeoHMS uses readily available digital geospatial information to construct hydrologic models more expediently than using manual methods. Also, development of basic watershed information will aid the engineers in estimating hydrologic parameters. After gaining adequate experience with using GIS-generated parameters, users can take steps to streamline the process of hydrologic parameter estimation.

Acknowledgements

This HEC-GeoHMS software implementation of GIS technology for hydrologic engineering has benefited from many years of research and program development. From an institutional perspective, the University of Texas at Austin has contributed important research, development, and demonstration of concepts. Having that basis for the technology, HEC and ESRI contributed extensive software development and documentation through a Cooperative Research and Development Agreement (CRADA) to engineer technology into commercial software. The individuals involved are listed below.

From the Research Division of HEC, Mr. James H. Doan is a co-developer of HEC-GeoHMS and an author of this user's manual. Dr. Thomas Evans provided extensive input and guidance. A number of HEC staff helped in the testing and usage of the program. Mr. Arlen Feldman, Chief of Research Division, contributed valuable management and review of the program and documentation.

From ESRI, Dr. Dean Djokic, Dr. Zichuan Ye, and Mr.Sreeresh Sreedhar contributed valuable software insight, development, and programming in conjunction with HEC.

From the University of Texas at Austin, Dr. David Maidment, Dr. Francisco Olivera, and several graduate students contributed valuable research effort, time, and expertise.

Mr. Darryl W. Davis, Director of HEC, and Mr. Jack Dangermond, President of ESRI, established the CRADA. Mr. Davis was the Director of HEC during the development of HEC-GeoHMS.

CHAPTER 1

Introduction

In recent years, advances in the Geographic Information Systems (GIS) have opened many opportunities for enhancing hydrologic modeling of watershed systems. With an openness to share spatial information via the Internet from government agencies, commercial vendors, and private companies, coupled with powerful spatial algorithms, the integration of GIS with hydrologic modeling holds the promise of a cost-effective alternative for studying watersheds. The ability to perform spatial analysis for the development of lumped hydrologic parameters can not only save time and effort but also improve accuracy over traditional methods. In addition, hydrologic modeling has evolved to consider radar rainfall and advanced techniques for modeling the watershed on a grid level. Rainfall and infiltration are computed cell by cell providing greater detail than traditional lumped methods.

These advanced modeling techniques have become feasible because the consuming data manipulations can now be generated efficiently with GIS spatial operations. For example, the ability to perform spatial overlays of information to compute lumped or grid-based parameters is crucial for computing basin parameters, especially grid-based parameters. HEC-GeoHMS has been developed as a geospatial hydrology tool kit for engineers and hydrologists with limited GIS experience. The program allows users to visualize spatial information, document watershed characteristics, perform spatial analysis, delineate subbasins and streams, construct inputs to hydrologic models, and assist with report preparation. Working with HEC-GeoHMS through its interfaces, menus, tools, buttons, and context-sensitive online help, in a windows environment, allows the user to expediently create hydrologic inputs that can be used directly with the Hydrologic Modeling System, HEC-HMS.

Chapter 1 discusses the intended use of HEC-GeoHMS and provides an overview of this manual.

Contents

- Technical Capabilities
- Program Features
- Intended Application of HEC-GeoHMS
- User's Manual Overview
- Documentation conventions

Technical Capabilities

Hydrologic modeling has evolved to represent the subbasin in more detail that the traditional lumped approach where hydrologic parameters are averaged over the basin. With the availability of radar rainfall and spatial data, hydrologic modeling on a grid level has introduced a more detailed representation of the basin. This distributive modeling approach utilizes the ModClark (Peters and Easton, 1996; Kull and Feldman, 1998) hydrograph transformation method, which tracks infiltration and excess rainfall on a cell by cell basis. To meet the needs of both the traditional lumped and distributed basin approaches, HEC-GeoHMS has the capability to develop HMS input files that are compatible for both approaches.

The current version of HEC-GeoHMS creates a background map file, lumped basin model, a grid-cell parameter file, and a distributed basin model. The background map file contains the stream alignments and subbasins boundaries. The lumped basin model contains hydrologic elements and their connectivity to represent the movement of water through the drainage system. The lumped basin file includes watershed areas, and reserves empty fields for hydrologic parameters. To assist with estimating hydrologic parameters, tables containing physical characteristics of streams and watersheds can be generated. If the hydrologic model employs the distributive techniques for hydrograph transformation, i.e. ModClark, and grid-based precipitation, then a grid-cell parameter file and a distributed basin model at the grid-cell level can be generated.

Program Features

HEC-GeoHMS is a public-domain extension to the ArcView GIS and Spatial Analyst extension. ArcView GIS and its Spatial Analyst extension are available from the Environmental Systems Research Institute, Inc., ESRI. HEC-GeoHMS runs on the Windows 95/98/NT platforms. The following program features illustrate GeoHMS's functionality and ease of use.

Data Management

GeoHMS performs a number of administrative tasks that help the user manage GIS data derived from the program. The data management feature tracks thematic GIS data layers and their names in a manner largely transparent to the user. Prior to performing a particular operation, the data manager will offer the appropriate thematic data inputs for operation, and prompt the user for confirmation. Other times, the data management feature manages the locations of various projects and also performs error checking and detection.

Terrain Preprocessing

GeoHMS allows users to perform terrain preprocessing in a step-by-step fashion or in batch mode. In the step-by-step process, the user often has the opportunity to examine the outputs and make corrections to the data set, as appropriate. However, if the user has performed the terrain preprocessing a number of times, then batch processing will allow terrain preprocessing to be performed unattended.

Basin Processing

The emphasis of the subbasin delineation, processing, and manipulation capability is on flexibility, ease of use, and user interactivity. As the user subdivides a basin or merges many smaller subbasins together, the results of the operation are displayed immediately for users confirmation. The ability to perform basin processing interactively is powerful because the results are presented quickly for the user to make a modeling decision instead of having to reprocess the data. For example, the user can obtain a stream profile and look for significant grade breaks. If a basin subdivision at a grade break is desired, the user just clicks on the profile at the grade break. Other tools allow the user to delineate subbasins in a batch mode by supplying a data set of point locations of desired outlets.

HMS Model Support

GeoHMS produces a number of hydrologic inputs that are used directly in HMS. In addition, the program supports the estimation of hydrologic parameters by providing tables of physical characteristics of the streams and watersheds. While working with HEC-GeoHMS, the user can toggle HEC-GeoHMS on/off in order to bring in other ArcView extension programs to perform spatial operations and develop additional parameters for populating the hydrologic model.

Intended Application of HEC-GeoHMS

HEC-GeoHMS is intended to process watershed data after the initial compilation and preparation of terrain data is completed. The assembly of GIS data can be performed using standard GIS software packages that support ARC Grid format. Even though this user's manual provides some guidance and discussions on the proper approach for assembling data, HEC-GeoHMS is not intended as a tool for data assembly. When assembling data, it is important to understand how to use GIS software to put data of different types and formats into a common coordinate system. A few examples of required data are a digital elevation model, digital stream alignments, and stream gage locations. The most important data, and often the most difficult, is a "hydrologically corrected" digital elevation model, DEM.

When the data assembly is complete, HEC-GeoHMS processes the terrain and spatial information to generate a number of hydrologic inputs. It is intended that these hydrologic inputs provide the user with an initial HMS model. The user can estimate hydrologic parameters from stream and watershed characteristics, gaged precipitation, and streamflow data. In addition, the user has full control in HMS to modify the hydrologic elements and their connectivity to more accurately represent field conditions.

User's Manual Overview

This manual provides detailed instructions for using the HEC-GeoHMS ArcView extension to develop hydrologic inputs for HEC-HMS. Documentation conventions are used to make the manual easier to read. The manual is organized as follows:

Chapter 1 - introduction to HEC-GeoHMS

Chapter 2 - instructions for installing the HEC-GeoHMS and getting started

Chapter 3 - overview of the major steps in using HEC-GeoHMS

Chapter 4 - data collection

Chapter 5 - issues related to data assembly, especially the terrain data

Chapter 6 - terrain preprocessing

Chapter 7 - basin processing

Chapter 8 - physical characteristics extracted for streams and watersheds

Chapter 9 - input files for HMS

Chapter 10 - example application of HEC-GeoHMS

Appendix A - references

Appendix B - HMS background map file format

Appendix C - grid-cell parameter file format

Appendix D - Standard Hydrologic Grid (SHG) specifications

Appendix E - program license agreement

Documentation Conventions

The following conventions are utilized throughout the manual to describe the windows and screens in the program interface. Window and screen titles are *shown in **bold and italics***. Menu names, menu items, and button names are **shown in bold**. Menus are separated from submenus with the right arrow ⇒. Data to be typed into an input field on a window or screen is `shown in the courier font and` within "double quote". A column heading, tab name, field title, and name of tables, files, or themes name are "shown in double quotes". Names of tables, files, or themes are not case sensitive, but certain letters are capitalized for readability.

CHAPTER 2

HEC-GeoHMS Installation

This chapter discusses the hardware and software requirements and installation procedures for HEC-GeoHMS. Prior to installing this software, ArcView GIS and the Spatial Analyst extension should be installed using their installation guides. The following installation procedures apply to computers running the Windows 95/98 and NT/2000 operating systems. After HEC-GeoHMS is installed, guidelines will be provided to load it within ArcView.

Contents

- Hardware and Software Requirements
- Installation of HEC-GeoHMS
- Loading HEC-GeoHMS

Hardware and Software Requirements

The minimum hardware and software requirement for using HEC-GeoHMS are similar to those of ArcView GIS. However, when working with GIS, it is important to take into account the size of the data sets as well as the complexity of the analysis when determining adequate computer resources. Even though the program will still work on a slower machine, the user will often experience long computing times. To assure that performance is not being compromised, the following hardware recommendations should be considered with the idea that more computer resources, in terms of central processing unit (CPU) speed, memory, and hard drive space, are always better.

Recommended Hardware Specifications

The recommended hardware specifications are as follows:

CPU: Pentium II 300Mhz

Memory: 256 MB

Hard Drive Space: The hard drive space availability should be at least 20 times the size of the terrain data. For example, if the terrain data takes up about 50 MB, then the available hard drive space should be about 1 GB. In many cases, having ample hard drive space available will improve performance because the spatial operations often generate many temporary intermediate files and repeatedly perform files caching.

Required Software Specifications

The required hardware specifications are as follows:

Operating System:	Windows 95/98/NT/2000
Pre-installed software:	ArcView GIS 3.1 or later
	Spatial Analyst 1.1 extension or later

Installation of HEC-GeoHMS

The installation of HEC-GeoHMS will copy program files and sample data sets to the location of ArcView and Spatial Analyst. HEC-GeoHMS can be installed with the following methods: Automatic or Manual Installation.

Automatic Installation

- Place the CD in the CD-ROM drive
- If the setup program does not start, then select **Start ⇒Settings ⇒ Control Panel. Open the Add Hardware/Software** icon
- Follow the steps displayed in the message box to complete the installation.

Manual Installation

The manual installation of HEC-GeoHMS consists of copying GeoHMS files to where ArcView was installed. Typically, ArcView is installed in C:\esri\Av_gis30\Arcview\ or otherwise referred to as $AVHOME\. Copy the following files to the specified ArcView sub-directories. These files are saved under the **Manual Installation** directory on the CD-ROM.

Program Files	**Specified Locations**
HEC-GeoHMS.avx	$AVHOME\ext32
G2i.dll	$AVHOME\bin32
DirRemove.exe	$AVHOME\bin32

Geohms.hlp	$AVHOME\help
Geohms.GID	$AVHOME\help
Geohms.CNT	$AVHOME\help
Hmspoint.avp	$AVHOME\symbols
Hmsmarker.avl	$AVHOME\symbols
Hmsline.avl	$AVHOME\symbols
Hrap_alb.shp	$AVHOME\tools
Hrap_alb.shx	$AVHOME\tools
Hrap_alb.dbf	$AVHOME\tools
GeoHMS_readme.txt	$AVHOME\ext32

Loading HEC-GeoHMS

Once HEC-GeoHMS is installed, it can be loaded within ArcView. To do this, open ArcView. ArcView extensions are loaded through the **File** menu on the main ArcView window.

- Select the **File** ⇒ **Extensions**… menu item.
- In the ***Extensions*** dialog that appears, scroll down until the **HEC-GeoHMS** is visible.
- Click on the name label **HEC-GeoHMS** to access the **About** information as shown in Figure 2–1.
- Check the box to turn it on.
- Press **OK** to close the dialog and watch the lower portion of the window for the installation notes.

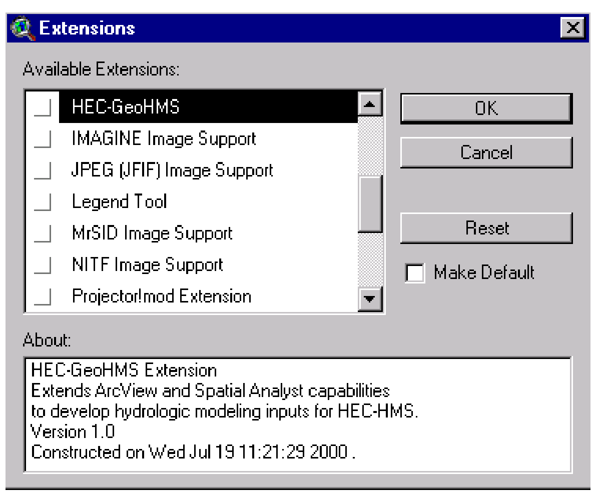


Figure 2–1. Extensions window with HEC-GeoHMS.

In is not necessary to load the Spatial Analyst extension because GeoHMS will automatically load it. When properly installed and loaded, HEC-GeoHMS will create two document types, ***MainView*** and ***ProjView***, as shown in Figure 2–2.

HEC-GeoHMS Document Types

ArcView Standard Document Types

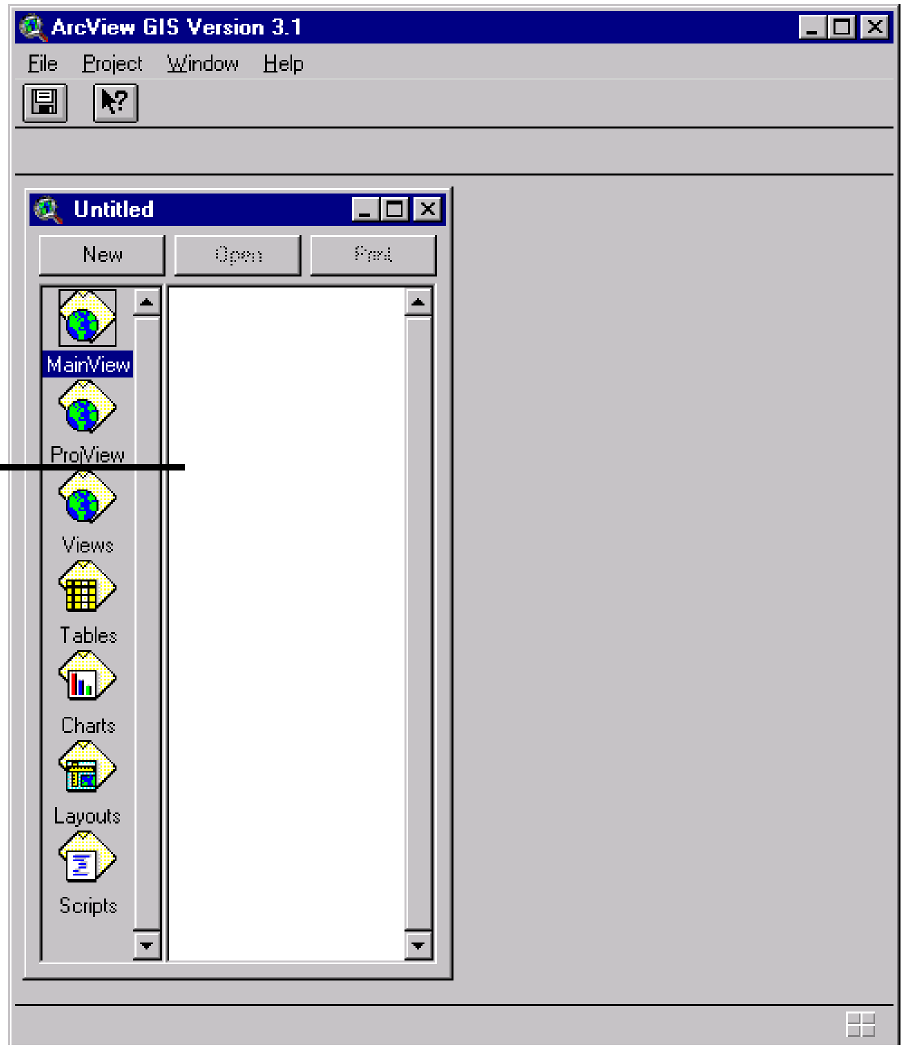


Figure 2–2. HEC-GeoHMS loaded within ArcView

CHAPTER 3

Working with HEC-GeoHMS – An Overview

HEC-GeoHMS is a set of ArcView scripts developed using the Avenue programming language and Spatial Analyst. It includes integrated data management and a graphical user interface (GUI). Through the GUI, which consists of menus, tools, and buttons, the user can analyze the terrain information, delineate subbasins and streams, and prepare hydrologic inputs.

The relationship between GIS, HEC-GeoHMS, and HEC-HMS is illustrated in Figure 3–1. The GIS capability is used for heavy data formatting, processing, and coordinate transformation. The end result of the GIS processing is a spatial hydrology database that consists of the digital elevation model (DEM), soil types, land use information, rainfall, etc. Currently, HEC-GeoHMS operates on the DEM to derive subbasin delineation and prepare a number of hydrologic inputs. HEC-HMS accepts these hydrologic inputs as a starting point for hydrologic modeling. With the vertical dashed line separating the roles of the GIS and the watershed hydrology, HEC-GeoHMS provides the connection for translating GIS spatial information into hydrologic models.

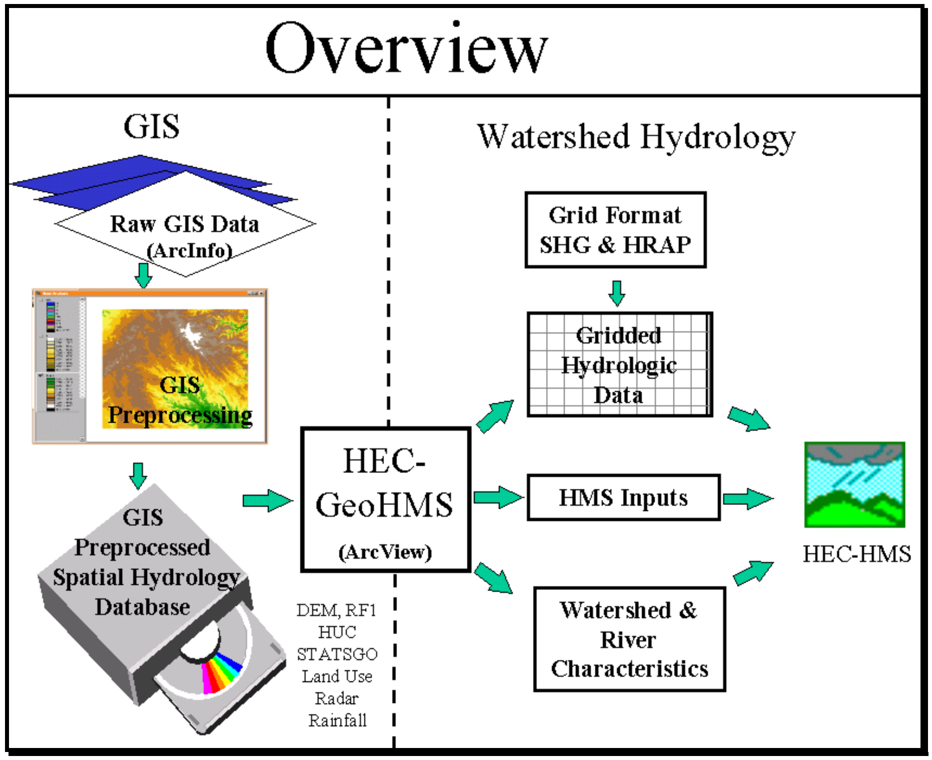


Figure 3–1. Overview of GIS and hydrology programs

The following contents describe the major steps in starting a project and taking it through the GeoHMS process.

Contents

Data Processing

Data Collection

With the volume of spatial data available, it is important to identify the data that will meet project needs. Spatial data comes in many formats, resolutions, intended uses, quality, and prices. Prior to collecting data, the project specifications should be thoroughly reviewed for any recommendations. When the project does not specify a particular data set, review the project's goals and objectives to help define acceptable data in terms of data storage, resolution, and accuracy. In addition, economic factors should be considered to determine the cost effectiveness in collecting and assembling the data or purchasing the data from a vendor. Whether the data are collected or purchased, the metadata must also be acquired to provide necessary documentation for the data. Data collection is discussed in greater detail in Chapter 4.

Data Assembly

The data assembly often requires efforts of an experienced GIS user. Because GIS data have many forms and formats, users often need to convert the data into a common format and then into a common coordinate system. For example, data describing the terrain should be in ESRI's ARC Grid format and vector data, such as stream alignments and streamflow gage locations, should be in the shapefile format. By having a common coordinate system, these data sets can be overlaid and spatial operations can be performed on them. Often times, these data sets are provided in rectangular portions. When assembling data, especially the terrain, special efforts are required to ensure that data are continuous along the edges. Terrain data assembly is discussed in Chapter 5.

Terrain Preprocessing

Using the terrain data as input, the terrain preprocessing is a series of steps to derive the drainage networks. The steps consist of computing the flow direction, flow accumulation, stream definition, watershed delineation, watershed polygon processing, stream processing, and watershed aggregation. These steps can be done step by step or in a batch manner. Once these data sets are developed, they are used in later steps for subbasin and stream delineation. It is important to recognize that the watershed and stream delineation in the terrain preprocessing steps is preliminary. In the next step - basin processing, the user has the capability to delineate and edit basins in accordance with project specifications. Terrain preprocessing is performed in ***MainView*** document and is discussed in greater detail in Chapter 6.

The ***MainView*** document is generally responsible for terrain preprocessing and spatial database setup. Figure 3–2, Table 3-1, Table 3-2, and Table 3-3 show the menus, buttons, and tools added by HEC-GeoHMS when the ***MainView*** document is activated.

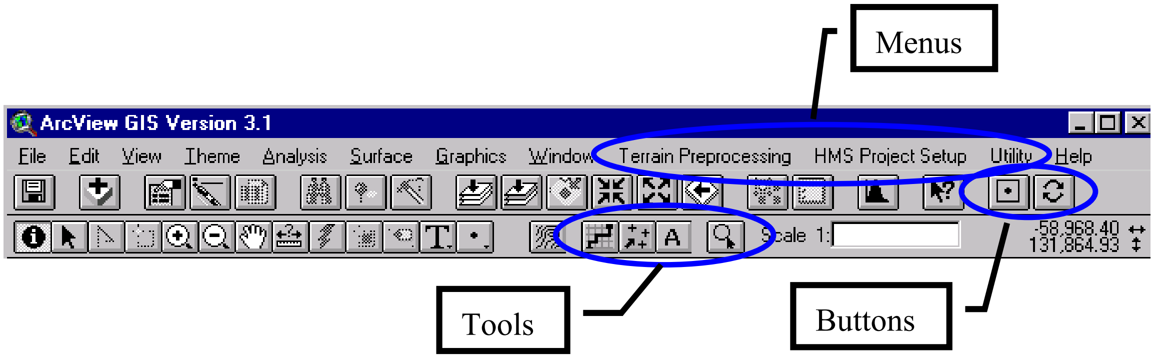


Figure 3–2. MainView GUI with GeoHMS extensions features.

Table 3-1. MainView menus.

Menus	Descriptions
Terrain Preprocessing Data Management Fill Sinks Flow Direction Flow Accumulation Stream Definition Stream Segmentation Watershed Delineation Watershed Polygon Processing Stream Segment Processing Watershed Aggregation Full Preprocessing Setup	The **Terrain Preprocessing** menu is used to process and analyze the terrain. It has the capability of processing the terrain in two ways: step by step or batch processing. It also has data management capability for tracking data sets as they are derived. (Chapter 6)
HMS Project Setup Start New Project Generate Project New Threshold for Selected Project Remove Selected Project	After the terrain has been processed, the **HMS Project Setup** menu is used to extract the processed terrain information from the ***MainView***. The extracted information will be placed in a separate view called the ***ProjView***. There are several options for extraction of terrain information. (Chapter 6)
Utility Display Theme Tags Set Theme Tag Value Remove a Theme Tag Key View to Image Shaded DEM to Image	The **Utility** menu contains miscellaneous tools dealing with assigning roles for data sets and developing graphical output. Most users should not use this menu except for the graphic generation in the last two menu items.

Table 3-2. MainView buttons.

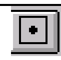
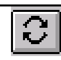
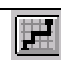
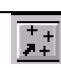
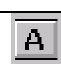
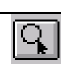
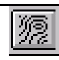
Buttons	Names	Descriptions
	Find Area	Find a number of locations that have the closest, but not exceeding, drainage area to the user-specified area. This tool provides many candidate points. In order to narrow the number of candidate points, the tool should be used when zoomed into the area of interest.
	Toggle GeoHMS	Toggle the HEC-GeoHMS tools ON/OFF. When it is in the ON position, HEC-GeoHMS tools are enabled. When it is in the OFF position, tools from other extensions are enabled.
	Help	Access context sensitive online help on any tools or menus. Select the tool and Press it on any tools for online help.

Table 3-3. MainView Tools

Tools	Names	Descriptions
	Flow Trace	Trace the flow path downstream of a user-specified point (for visualization purposes).
	Point Delineate	Delineate the watershed contributing to a user-specified point.
	Identify Area	Identify contributing area in units as specified in the View's properties "distance unit" field.
	Specify Project Point	Specify the downstream outlet and/or upstream source point for extraction of terrain information.

	Contour	This is an ArcView tool that is useful in HEC-GeoHMS. This tool draws contours at the user-specified point.

Hydrologic Processing

Hydrologic processing is performed in the ***ProjView*** document, which is generally responsible for hydrologic model construction and setup. The tools available in the ***ProjView*** GUI are shown in Figure 3–3, Table 3-4, Table 3-5, and Table 3-6. Typically, the user proceeds from **Basin Processing** (Chapter 7) to **Basin Characteristics** (Chapter 8) to **HMS** (Chapter 9) menus.

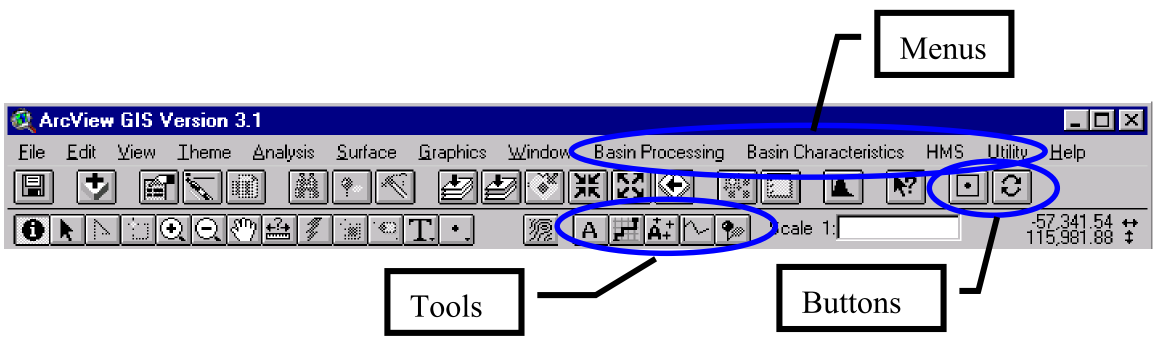


Figure 3–3. ProjView GUI with GeoHMS extensions features.

Table 3-4. ProjView Menus

Menus	Descriptions
Basin Processing Basin Merge River Merge River Profile Split Basin at Confluences Import Batch Points Delineate at Batch Points	This menu provides the user with interactive and batch processing capabilities to modify existing subbasins and delineate new subbasins. There are also several tools available for subdividing basins and preparing batch points for delineation. (Chapter 7)
Basin Characteristics River Length River Slope Basin Centroid Centroid Elevation Update Longest Flow Path Centroidal Flow Path	After the user finalizes the basin delineation, this menu develops the physical characteristics for both the streams and subbasins based on the terrain model. The stream characteristics will be stored in the stream's attribute table. Similarly, the basin characteristics will be stored in the subbasin's attribute table. These two tables can be exported for external computations. (Chapter 8)
HMS Reach AutoName Basin AutoName Map to HMS Units HMS Check Data HMS Schematic HMS Legend Add Coordinates Background Map File Lumped Basin Model Grid Cell Parameter File Distributed Basin Model	This menu performs a number of tasks related to HMS. These tasks include assigning default names for the reaches and subbasins, unit conversion, checking and creation of the basin schematic, and HMS files generation. (Chapter 9)
Utility Display Theme Tags Set View/Theme Tag Remove a Theme Tag Key View to Image Shaded DEM to Image	Same as those in the MainView

Table 3-5. ProjView Buttons

Buttons	Names	Descriptions
	Find Area	Same as those in the MainView
	Toggle GeoHMS	Same as those in the MainView

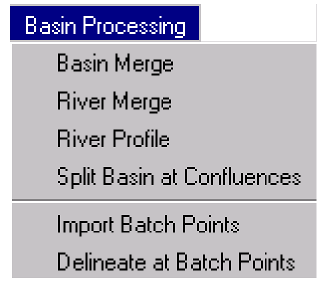
Table 3-6. ProjView Tools

Tools	Names	Descriptions
	Identify Area	Same as those in the MainView
	Flow Trace	Same as those in the MainView
	Basin Subdivide	Subdivide existing basin or create new basin at user-specified point
	Profile	Extract the stream profile with elevation based on the terrain model
	Batch Point	Create a batch point shapefiles layer based on the user-specified point
	Profile Subdivide	While the stream profile chart is opened, this tool allows the user to subdivide existing basin at user-specified point along the profile.

Basin Processing

In this step, the user is provided with a variety of interactive and batch-mode tools to delineate subbasins. In the interactive mode, the tools allow the user to see the delineation results, assess outcomes, and accept or deny the resulting delineation. The interactive tools should work quickly. For example, the user sees the result of the merger of smaller basins together or subdivision of a larger basin. When the user performs interactive basin processing, the program will prompt the user to confirm the results. A number of other interactive tools allow the user to delineate a basin from a stream profile, subdivide basin at a stream confluence, and create a basin where a stream does not exist. In the batch mode, the user can supply the outlet locations and the program will delineate subbasins at those locations, but without interaction to view and revise.

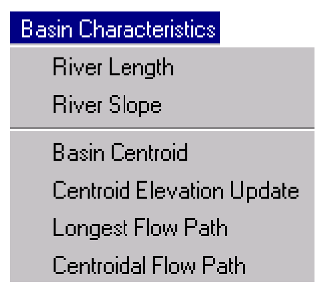
Basin processing is one of the responsibilities of the ***ProjView*** document and is discussed in greater detail discussed in Chapter 7.



Stream and Watershed Characteristics

When the streams and subbasins delineation have been finalized, the user can extract their physical characteristics. The stream physical characteristics, such as length, upstream and downstream elevations, and slope, are extracted from the terrain data and stored as attributes in the stream table. Similarly, the subbasin physical characteristics, such as longest flow lengths, centroidal flow lengths, and slopes, are extracted from the terrain data and stored as attributes in the watershed table. The current version of the program focuses on the extraction of physical characteristics instead of hydrologic parameters. These physical characteristic tables can be exported and used externally to estimate hydrologic parameters. When more experience is gained with applying GIS generated parameters, it is anticipated that the program will suggest ranges for hydrologic parameters, as appropriate.

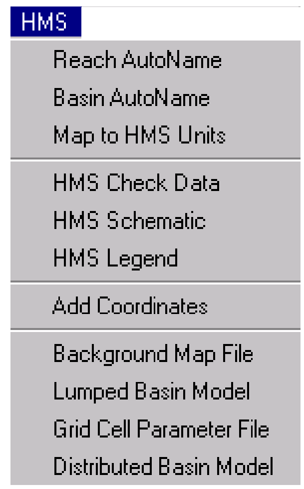
Computing stream and watershed physical characteristics under the **Basin Characteristics** menu as shown below is another responsibility of the ***ProjView*** document and is discussed in greater detail discussed in Chapter 8.



HEC-HMS Model Files

The program produces four files that can be used directly with HMS. If the lumped modeling approach is used, then the user can generate the background-map file and the lumped-basin file. If the distributed modeling approach is used, then the user can generate the background-map file, the grid-cell parameter file, and the distributed basin file.

Generating HEC-HMS model files under the **HMS** menu as shown below is another responsibility of the ***ProjView*** document and is discussed in greater detail in Chapter 9.



Hydrologic Parameters and HEC-HMS

When the GeoHMS-generated files are brought into HMS, the user has a partially completed HMS model. To complete the HMS basin model, hydrologic parameters need to be estimated and entered using editors provided in HMS. In addition, the user can add or remove hydrologic elements and their connectivity to reflect difficult modeling areas. Finally, the user needs to develop a Meteorologic Component to represent the precipitation and a Control Specifications Component to define the time window and other time-related specifications. With these three model components completed, the user can refer to the HMS manual to make a simulation run and calibrate the hydrologic model.

CHAPTER 4

Data Collection

The purpose of this chapter is to illustrate some of the ways spatial data are used in hydrology. By understanding how the data sets are utilized, the user can focus adequate time, effort, and attention on the appropriate data set. When collecting data, the user can assess the quality of the data and its metadata to meet project specifications. This chapter also provides a list of data types, descriptions, and their sources as a starting point for collecting data.

Contents

Data Usage

Spatial data are collected and used in a variety of ways. Understanding how data are used provides many important guidelines in data collection. When the data is intended as input in the program, it should be collected with attention given to its accuracy, resolution, validity of data source, and quality of documentation. Oftentimes when the best available data are not adequate, the appropriate course of action will be to develop data that meets project specifications instead of putting efforts in collecting "bad" data. In hydrology, the terrain data is critical because it is used to determining drainage paths and physical characteristics. When data are not used as input, they often serve many useful roles, such as reference information, documentation, and visualization, and should be collected.

Reference Information for Results Validation

For example, the stream alignments, hydrologic unit code, and streamflow gage with drainage area are useful published reference information for comparing and validating the GIS delineated streams and subbasins.

Documentation of Field Conditions

GIS data can be collected and used with existing spatial data to document field conditions. For example, photographs of drainage structures as shown in Figure 4–1 and other field conditions can be photographed and geographically located with the street data to more effectively document these facilities and show their spatial relationships.

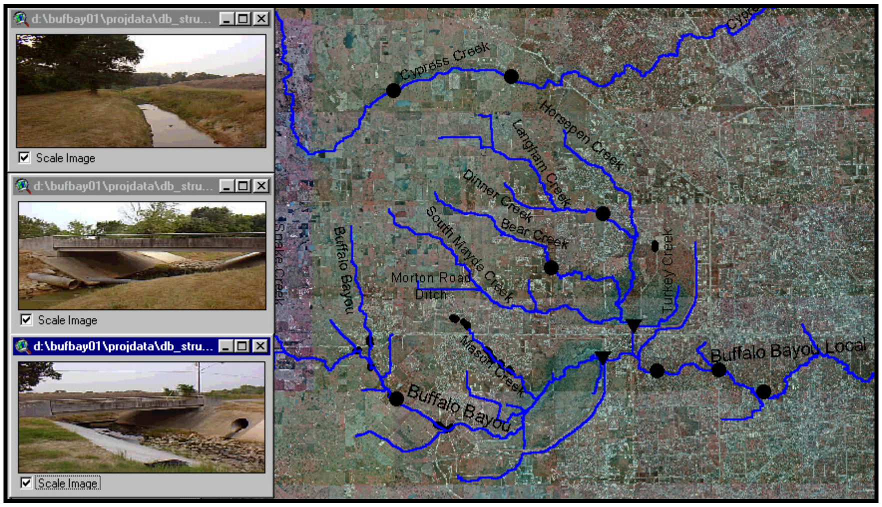


Figure 4–1. Field documentation with photographs

Data Visualization

GIS data can be used to visualize multiple data sets. For example, aerial images can be overlaid with subbasin boundaries to see land use patterns and variability.

Data Types, Descriptions, and Sources

The amount of GIS data available through governmental institutions and data vendor has grown greatly over the years. Some of these data are available for free while others are provided for a fee. Table 4-1 provides a starting point for collecting and searching for GIS data. The list provides brief descriptions of the data used in hydrology and their sources. Additional information on the data sets can generally be found at the respective institution's web site. Although the terrain data is the minimum data requirement to run HEC-GeoHMS, the other data sets are important information for constructing the hydrologic model. It is important to collect data for an area larger than your actual project region. Finally, metadata must also be collected for documentation.

Table 4-1. Data Types, Descriptions, and Sources

Digital Elevation Model (DEM) DEMs are originally generated from USGS maps and are available for resolutions ranging from meters to kilometer cell size. The availability of the finer DEM data may be scarce at this time. The DEM at 30-by-30-meter resolution is generally used for modeling the terrain because of their widespread availability. Source www.usgs.gov www.water.usgs.gov
Hydrologic Unit Code (HUC) The HUC contains the major watershed boundaries as published by the USGS. The HUC shows watershed boundaries at 4 levels of detail ranging from local to regional drainage area. Source www.usgs.gov
Digital Line Graph (DLG) In addition to line representation of transportation data, such as streets and railroads, the DLGs include water features, such as stream networks and irrigation ditches. The DLGs are maintained by the United States Geological Survey (USGS). Source www.usgs.gov

Stream Networks Stream networks are maintained by the Environmental Protection Agency (EPA). Many versions of the stream networks are available as the River Reach File (RF1), the River Reach File (RF3), and the National Hydrography Data set (NHD). Source www.epa.com http://nhd.usgs.gov
Streamflow Gage Data Although streamflow gage data are natively non-spatial, the latitude and longitude coordinates of the gage are provided most of time. The streamflow gage locations can be converted into a GIS data set by using the coordinate information. The majority of streamflow gages are maintained by the USGS, state governments, and flood control districts. The stream gages maintained by the USGS are organized by major basin names and the Hydrologic Unit Code. These gages often provide the historical daily peak flow values and/or annual peak flow values. Source www.usgs.gov
Digital Orthophoto Quarter Quads (DOQQ) Digital aerial photos with colors are available at various resolutions can be uses a background base map. Source Various governmental authorities and commercial vendors

Drainage Facilities Photographs Photographs can be taken of key drainage structures. The photographs often include the areas looking upstream and downstream of the structures as well as the faces of the structures. Source Field observations conducted by the engineers.
Street Data Street level data that is provided by the US Census Bureau often needs format conversion before it could be accessed though GIS software. A number of data vendors have performed the format conversion as well as putting value-added improvements. Source United States Census Bureau and commercial vendors
Soil Types Data The Soil Surveys Geographic Data Base (SSURGO) data contains good detail, but is limited in coverage. The State Soil Geographic Data Base (STATSGO) covers the entire USA, but in less detail. Source United States Department of Agriculture STATSGO and SSURGO CD- ROM www.ftw.nrcs.usda.gov/stat_data.html www.ftw.nrcs.usda.gov/ssur_data.html
Land Use/Land Cover The USGS Land Use Land Cover (LULC) provides good coverage but may be dated. Source http://mapping.usgs.gov http://edc.usgs.gov

CHAPTER 5

Data Assembly

The assembly of GIS data sets often requires conversion of file formats and coordinate systems, as well as geographical referencing of non-spatial data sets. For vector data, the industry-standard shapefile format is preferred when working with ArcView. Examples of vector data that require conversions are Digital Line Graphs for stream alignments and State Soil Geographic Data Base (STATSGO) data for the hydrologic soil types. For raster data, ESRI's ARC Grid format should be used. Examples of raster data that require conversions are the terrain data and radar rainfall. In addition to file formatting, data assembly often requires a number of map related transformations to ensure that vector and raster data are in proper alignment and map distortions are minimized. That is, they have the same datum, projection, and common coordinate system. These data sets can be overlaid for spatial analysis. In essence, a spot on the various data sets refers to the same point on the ground in all data sets. Some common map-related transformations are as follows.

- Projection
- Coordinate System
- Vertical and Horizontal Datum
- Units
- Resolution
- Accuracy
- Scales

When data are assembled with GIS software, the user should be aware of the distinctions between various spatial operations. For example, when the user joins various sized terrain tiles into a continuous terrain model, the ArcInfo grid "merge" and/or "mosaic" commands produce different results. The "merge" command will overwrite overlapping areas along the edges with the data that is merged last. However, the "mosaic" command will perform smoothing of data values along the overlapping areas. Recognizing the different approaches for combining terrain is crucial to prevent abrupt artificial changes in elevation along the edges of tiles that will affect drainage path determination. Other data assembly issues include combining various data sets of different resolution, filling data gaps as shown in Figure 5–1, and data re-sampling techniques.

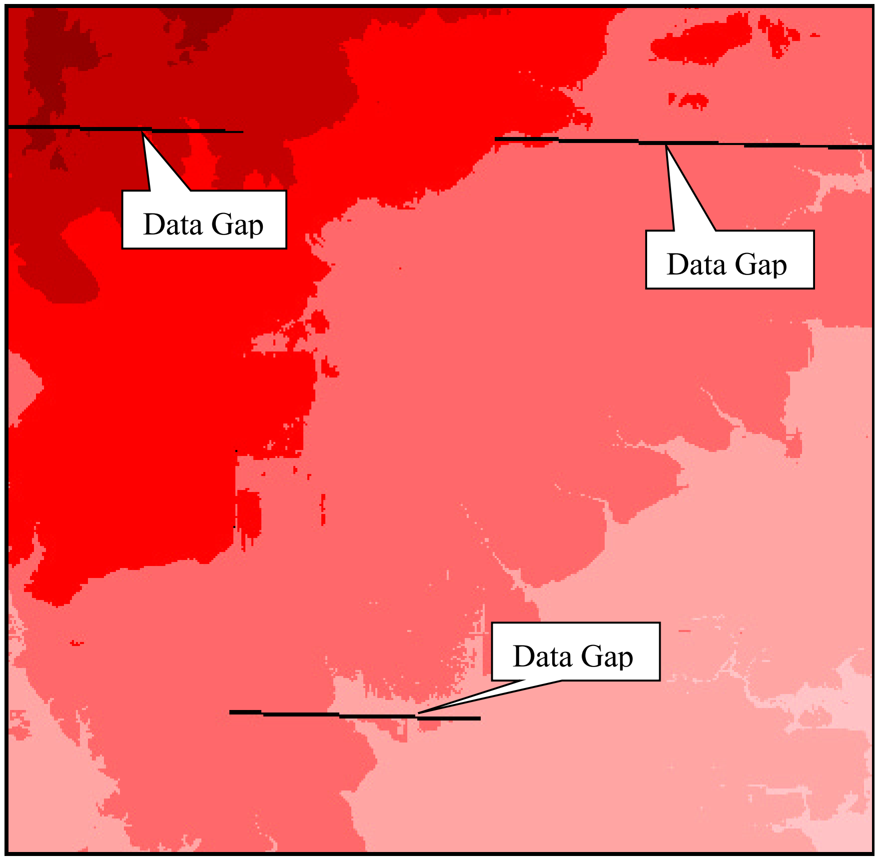


Figure 5–1. DEM model with data gaps.

Contents

Terrain Data Assembly

The assembly of quality terrain data for the study watershed consists of many important considerations. Ultimately, the quality of the results depends heavily on the terrain data. Typically, the continuous terrain data are assembled from joining tiles of terrain information as shown in Figure 5–2. Then, data gaps are filled in with interpolated elevation values from neighboring elevation values to make a continuous DEM model as shown in Figure 5–3. However, when terrain data are assembled in this typical manner, they often contain errors and problematic areas for computing drainage patterns from a hydrologic standpoint. Often, the terrain data undergo extensive editing to correct problematic areas. Automated routines are available to fill depressions in the DEM. The "depressionless" DEM may still not have streams located properly when compared to other map and photo resources. Extensive editing is usually required to create a "hydrologically corrected or conditioned" DEM. There are many issues surrounding terrain data assembly as discussed below.

Waller NW	Magnolia West	Magnolia East	Oklahoma	Tamina	Outlaw Pond	Splendora	Plum Grove
Waller	Hockley	Rose Hill	Tomball	Spring	Maedan	Moonshine Hill	Huffman
Hockley Mound	Warren Lake	Cypress	Satsuma	Aldine	Humble	Harmaston	Crosby
Brookshire	Katy	Addicks	Hedwig Village	Houston Heights	Settegast	Jacinto City	Highlands
Fulshear	Richmond Northeast	Clodine	Alief	Bellaire	Park Place	Pasadena	La Porte
Orchard	Richmond	Sugar Land	Missouri City	Almeda	Pearland	Friends-wood	League City

Figure 5–2. DEM tile quad names.

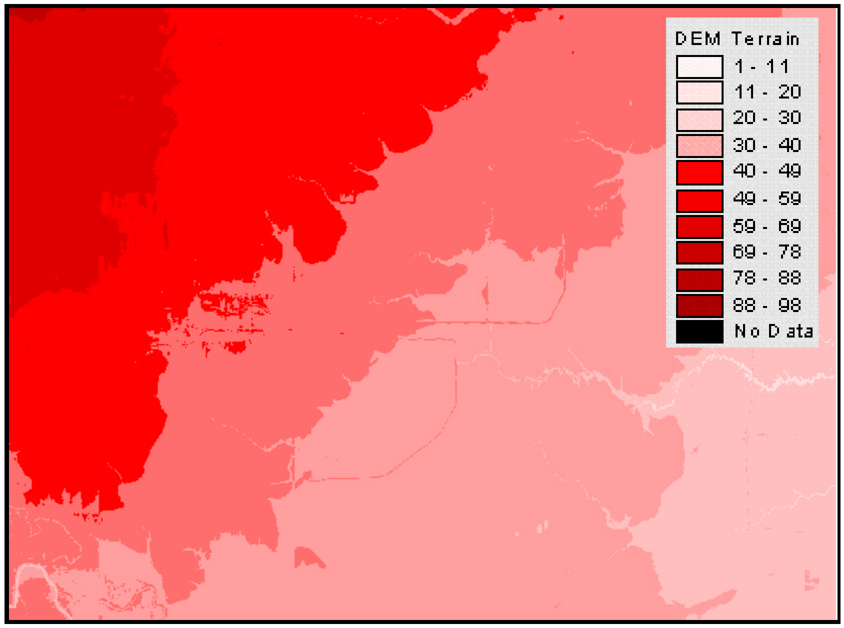


Figure 5–3. Continuous DEM.

“Hydrologically Corrected” and “Depressionless” Terrain Model

The preparation of “hydrologically corrected” terrain data often requires much iteration through drainage path computations. To represent the movement of water through the watershed, the “hydrologically corrected” DEM must have the proper accuracy and resolution to capture details of the stream alignments and watershed divides. Some of the problems arise when the watershed has low relief and the resolution is not fine enough to delineate the needed details.

Construction of a “hydrologically corrected” terrain model involves more complexity than combining tiled USGS’s DEMs into a unified DEM grid. The DEM assembled from the USGS represented by elevation averages at regular intervals may not accurately represent stream locations and watershed boundaries. For example, stream and watershed delineation sometimes does not coincide with published data sources like the EPA’s RF1 and the USGS’s watershed in the Hydrologic Unit Code (HUC). A “hydrologically corrected” terrain model must represent accurate stream patterns across the landscape, stream alignments, topographic ridges, stream confluence, internal drainage areas, and drainage facilities. Many factors, such as cell resolution, accuracy, topographic relief, and drainage facilities deserve careful considerations because they often affect the quality of the terrain model. In theory, combining GIS data sets of different resolutions is generally not recommended because of the difficulty in assessing the accuracy and the precision of the resulting data set. In practice, however, combining data sets of various resolutions is necessary due to lack of uniform data and data coverage.

In contrast to the effort required for the "hydrologically corrected" DEM, the "depressionless" DEM is simply constructed using automated algorithms to fill in the sinks or depressions in the assembled DEM. Because of the complexity and effort required for constructing a "hydrologically corrected" terrain model, a "depressionless" terrain model often serves as a simpler substitute in the analysis. For study regions with moderate to high topographic relief, the "depressionless" terrain model may be adequate for the analysis. For low-relief regions, however, the "depressionless" terrain model often needs additional work to adequately represent the terrain. For example, a watershed with flat terrain often requires editing to force proper drainage location.

Until better data quality and editing techniques are available, users may struggle with terrain data assembly. It is important to identify the issues with the data so that the user knows and fixes the problems. As an encouraging note, many governmental institutions, including the USGS and the EPA, are working to develop seamless terrain information and streams and watersheds information, which will ease the data assembly efforts.

Data Issues

A number of issues have been identified to increase awareness as a first step in formulating a solution. When assembling terrain data, the user should address the considerations shown in Table 5-1.

Table 5-1. Data Issues

Data Issues	Descriptions and Potential Solutions
1. Low-relief terrain	With low-relief terrain, it is often difficult to delineate reliable drainage paths from relative average elevations. Finer resolution terrain data should be considered for the flat region if it is available. However, finer resolution data has its tradeoffs with increased storage and longer computation times. Other possible approaches include imposing the published stream alignment onto the terrain.

2. Man-made structures	Man-made structures like dams often alter the flow direction because the water surface prevents the mapping of the reservoir bottom. In addition, when the terrain data get filled, the terrain is represented as a flat surface behind the dam. A potential way to deal with this situation would be to put an artificial notch at the dam and carve a stream on to the terrain.
3. Missing elevation data	Missing elevation data that often exist along the edges and can be filled with interpolated values from neighboring elevations. Bad elevation data due to re-sampling effects and other causes can be fixed with spot elevation editing on a cell by cell basis or by region.
4. Subsidence and other Environmental Impacts	The ground surface may subside due to overdraft of groundwater. Recognizing when the terrain data were developed, the terrain data should be checked for subsidence.

Hydrologic Coordinate System Specifications

Transforming spatial data into a common coordinate system ensures proper alignment of various data sets for spatial analysis. Coordinate system transformation often leads to map distortions of direction, distance, shape, and area. From a hydrologic perspective where the terrain and precipitation are important, a suitable coordinate system should preserve area. The two possible coordinate systems are the Standard Hydrologic Grid (SHG) and the Hydrologic Rainfall Analysis Project (HRAP). The SHG is based on the Albers Equal Area projection, which preserves area. The SHG coordinate system is defined in Table 5-2. More information on both coordinate systems is in Appendix D.

Table 5-2. Standard Hydrologic Grid Definition

Projection:	Albers Equal-Area
Spheroid:	Clarke 1866
Datum:	North American Datum, 1983 (NAD83)
Central Meridian:	96 degrees 0 minutes 0 seconds West
Latitude of Origin:	23 degrees 0 minutes 0 seconds North
1st Standard Parallel:	29 degrees 30 minutes 0 seconds North
2nd Standard Parallel:	45 degrees 30 minutes 0 seconds North
False Easting:	0.0
False Northing:	0.0
Units:	Meters

CHAPTER 6

Terrain Preprocessing

Refering to the overview in Chapter 3, the terrain preprocessing marks the first step to using HEC-GeoHMS. In this step, a terrain model is used as an input to derive eight additional data sets that collectively describe the drainage patterns of the watershed and allows for stream and subbasin delineation. The first five data sets in grid representation are the flow direction, flow accumulation, stream definition, stream segmentation, and watershed delineation. The next two data sets are the vectorized representation of the watersheds and streams, and they are the watershed polygons and the stream segments. The last data set, the aggregated watersheds, is used primarily to improve the performance in watershed delineation. The terrain preprocessing is performed in the ***MainView***.

The objectives of the terrain preprocessing are described below.

- The terrain is processed and analyzed using the 8-pour point approach to determine flow paths. The terrain analysis is computer intensive and some steps may require several hours depending on the sizes of the data and computer resources.
- After the terrain preprocessing is completed, the resulting data sets serve as a spatial database for the study. With the information centralized in the spatial database, pertinent data sets can be extracted for subsequent work on building the hydrologic models.
- Preliminary watershed and stream delineation provides results that can be verified with published information to detect possible errors in the terrain model. If errors are detected in the terrain model, the DEM should be edited outside of the program. When the DEM has been revised to better represent field conditions, it should be processed again to update the spatial database.

This chapter will discuss the terrain preprocessing features and functionality, HMS model setup, and related utilities.

<u>Contents</u>

- Features and Functionality
- Data Management
- Terrain Preprocessing

Features and Functionality

The HEC-GeoHMS extension adds features and functionality to standard ArcView menus (**Terrain Preprocessing**, **HMS Project Setup**, and **Utility**), buttons, and tools are added to the standard ArcView GUI as shown in Figure 6–1. A number of capabilities related to terrain processing are under the **Terrain Preprocessing** menu. Once the terrain processing is complete, the data can be extracted to support hydrologic model creation via the **HMS Model Setup** menu. The **Utility** menu allows users to perform some limited administrative tasks in assigning or changing a theme, which is to be identified and used by the program. Each theme will be assigned a unique name or "tag" by which it will be known to the program. The tags are names associated with themes that identify the role of the theme in the program. Buttons perform tasks after they are activated, tools execute the task after they are activated and the user applies an action.

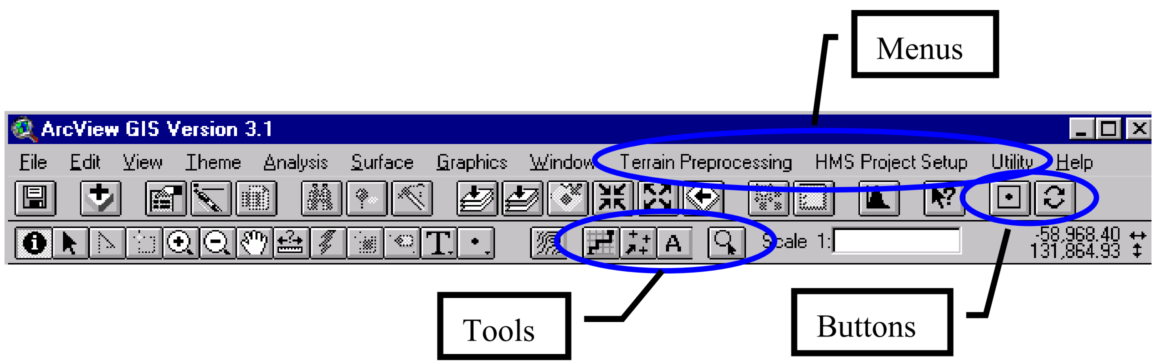


Figure 6–1. MainView GUI with GeoHMS extensions features.

Data Management

Data that are introduced or derived with the program are being managed through role association. For example, when a DEM is introduced into the program, GeoHMS will associate it with "RawDEM", which is the original DEM. When a Fill command is issued, the program will automatically offer the RawDEM as default for creating a depressionless DEM. Aside from associating data sets with their intended roles as they are created, the data management allows the user the ability to bring in other data sets and assign a role for it. For example, if the user has developed the flow direction and accumulation grid in another program, they can bring this data in as themes and assign their roles. This is a good way to keep track of data as they are generated. Another example is the flow tracing tool and area tool; the program knows which data layer should be operated on to provide the results. Figure 6–2 shows the data management of themes on the left-hand side and the assigned themes on the right-hand side. The "Null" entry for the assigned theme indicates that the appropriate theme has not been created and assigned. When the appropriate themes are created, their names replace the "Null" entry as shown in Figure 6–3.

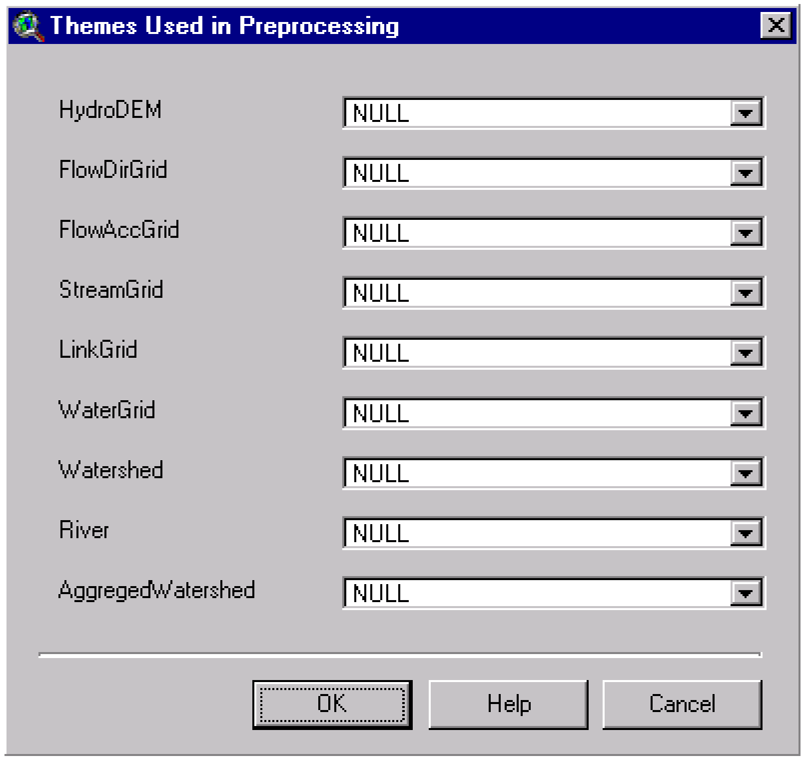


Figure 6–2. Data Management window.

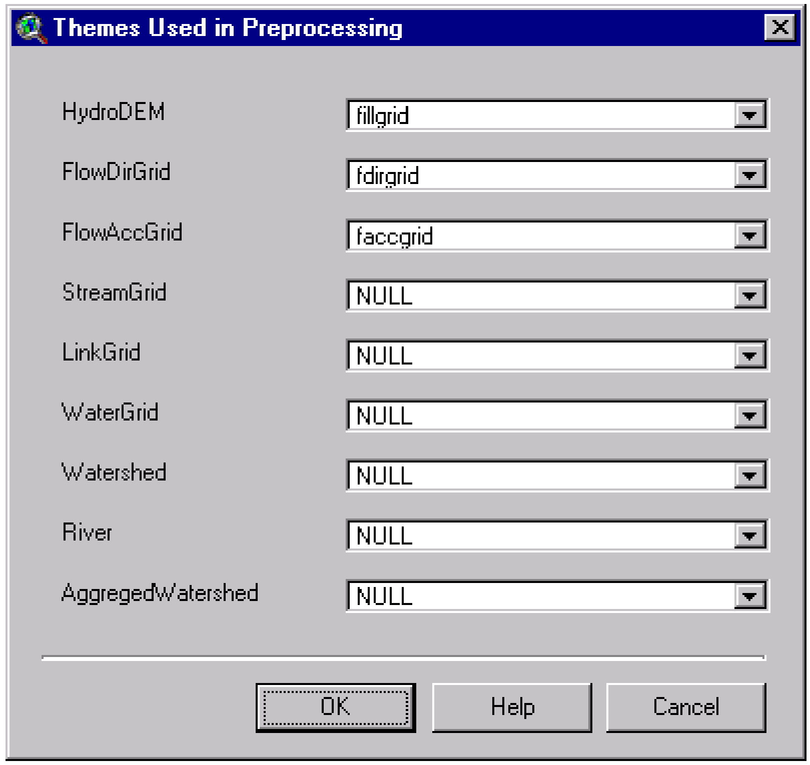


Figure 6–3. Data management with assigned themes.

Terrain Preprocessing

Applying the GIS algorithms discussed below, the terrain can be processed in two ways: step-by-step or batch processing. With the step-by-step approach as illustrated below, data sets are derived after each operation. Greater control over the results is obtained because the user verifies the results and makes decisions before proceeding. For example, prior to performing the stream definition, it is good practice to use the **Identify Area** tool and check the contributing area at several locations. This information on the area can help pick a threshold for adequate stream definition. With the batch mode, all of the inputs like the threshold and a few others are entered, and then the program generates all of the data sets. In a few instances, the batch mode may pause and prompt for more input to complete the terrain process. For example, if there are too many outlets, then the program will prompt for input whether stream segments serve as an outlet. When using the batch mode, there are some safeguards for changing the threshold to vary the detail of the stream definition. After the batch processing is complete, the user can use to the **Identify Area** tool to estimate a good threshold and then specify that threshold when setting up a hydrologic model.

GIS Approach

GIS approaches toward hydrologic analysis require a terrain model that is "hydrologically corrected". A "depressionless" terrain model is used in the analysis. The GIS analyzes the "depressionless" terrain model by applying the 8-point pour model, where water flows across the landscape from cell to cell based on the direction of the greatest elevation gradient. The process of analyzing the landscape characteristics and slopes for stream networks and subbasin boundaries is presented in Table 10. The steps in the analysis include filling depressions or pits, calculating flow direction and flow accumulation, delineating streams with an accumulation threshold, stream definitions, stream segmentation, watershed delineation, watershed polygon processing, stream processing, and watershed aggregation.

Depressionless DEM

The depressionless DEM is created by filling the depressions or pits by increasing the elevation of the pit cells to the level of the surrounding terrain in order to determine flow directions. The pits are often considered as errors in the DEM due to re-sampling and interpolating the grid. For example, in a group of three-by-three cells, if the center cell has the lowest elevation compared to its eight neighboring cells, then the center cell's elevation will be increased equaling the next lowest cell. Filling the depressions allows water to flow across the landscape. This assumption is generally valid when a large event storm fills up the small depressions and any incremental amount of water that flows into the depression will displace the same amount of water from the depression.

The steps to fill the depressions are shown below.

- Add the unfilled DEM into the ***MainView*** using the **Add Theme** button, see Figure 6–4.

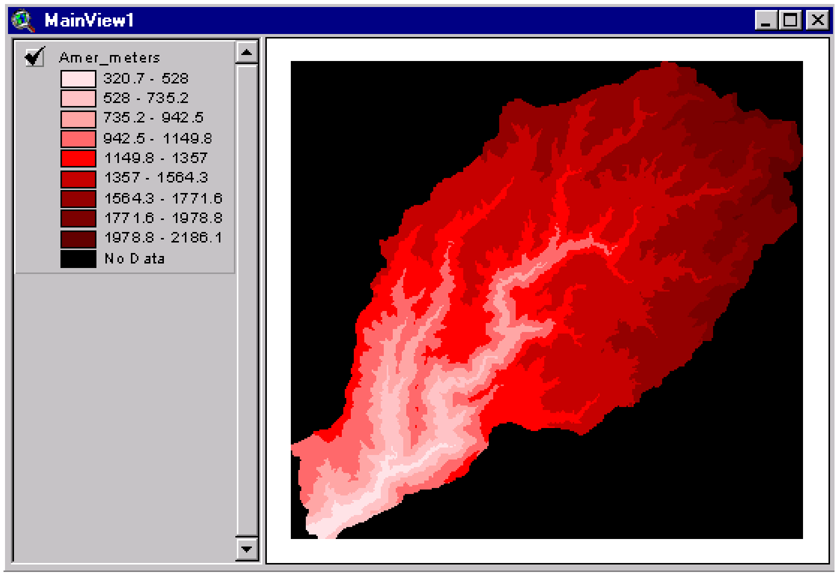


Figure 6–4. Depressionless DEM.

- Select **Terrain Preprocessing ⇒ Fill Sinks** when a "MainView" document is active.
- Confirm that the input of the RawDEM (also referred to as the unfilled DEM) is "Amer_meters". The output of the HydroDEM is "FillGrid", see Figure 6–5. "FillGrid" is a default name that can be overwritten by the user.
- Press OK

Figure 6–5. Fill Sinks operation

The result of the Fill Sinks operation is the "Fillgrid" theme as shown in Figure 6–6, where the lowest cell elevation is increased from 320.7 meters to 324.2 meters.

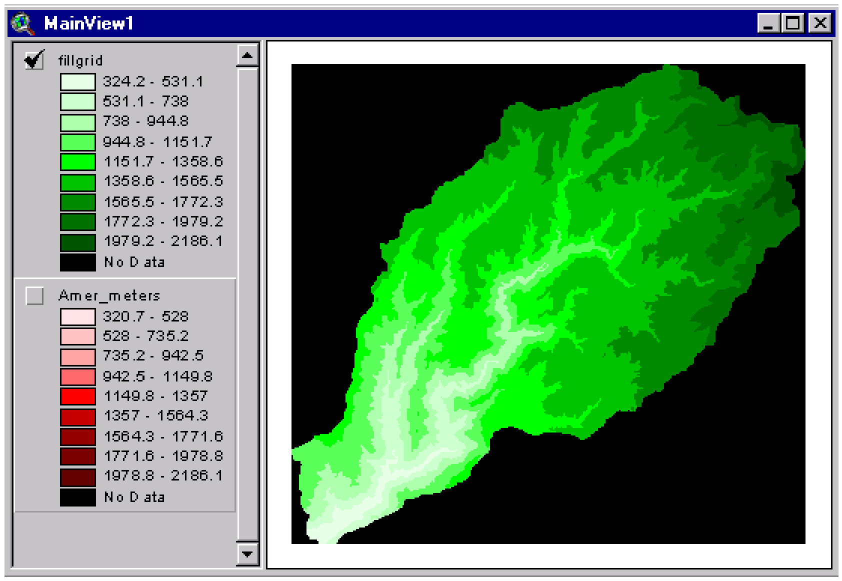


Figure 6–6. Fill Sinks operation result.

Step-by-Step Process

When performing this procedure, the user needs to bring in a "hydrologically corrected" or the "depresssionless" DEM from the previous step. With the step-by-step approach, each step starts with offering a list of inputs that will be used to produce the output grid. If the step-by-step procedure is performed in a sequential order, the program will be able to offer the correct data input for processing. In a few instances, when certain step are repeated or performed out of order, it would be important to verify that the appropriate data sets are used.

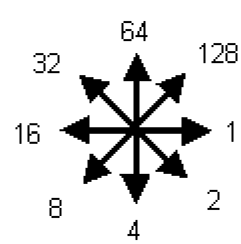
Flow Direction. This step defines the direction of the steepest descent for each terrain cell. Similar to a compass, the eight-point pour algorithm specifies the following eight possible directions:

1 = east, 2= southeast,

4 = south, 8 = southwest,

16= west, 32=northwest,

64 = north, 128=northeast.



The steps to compute flow directions are shown below.

- Select **Terrain Preprocessing ⇒ Flow Direction**.

- Confirm that the input of the HydroDEM is “Fillgrid”. The output of the FlowDirGrid is “FdirGrid”, see Figure 6–7. “FdirGrid” is a default name that can be overwritten by the user.
- Press **OK**

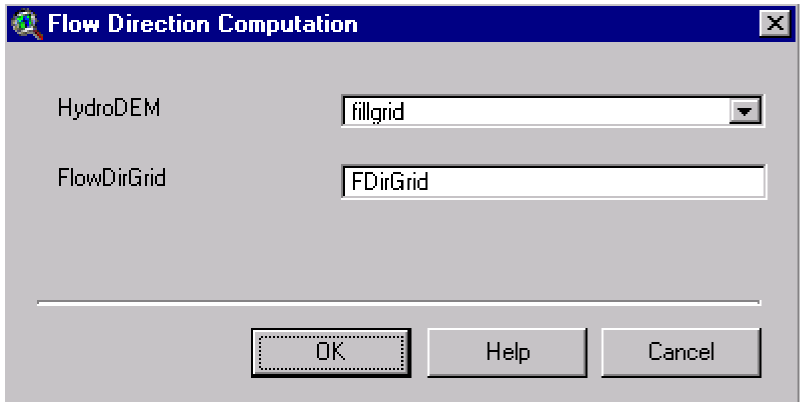


Figure 6–7. Flow Direction operation.

The result of the Flow Direction operation is the “FdirGrid” as shown in Figure 6–8.

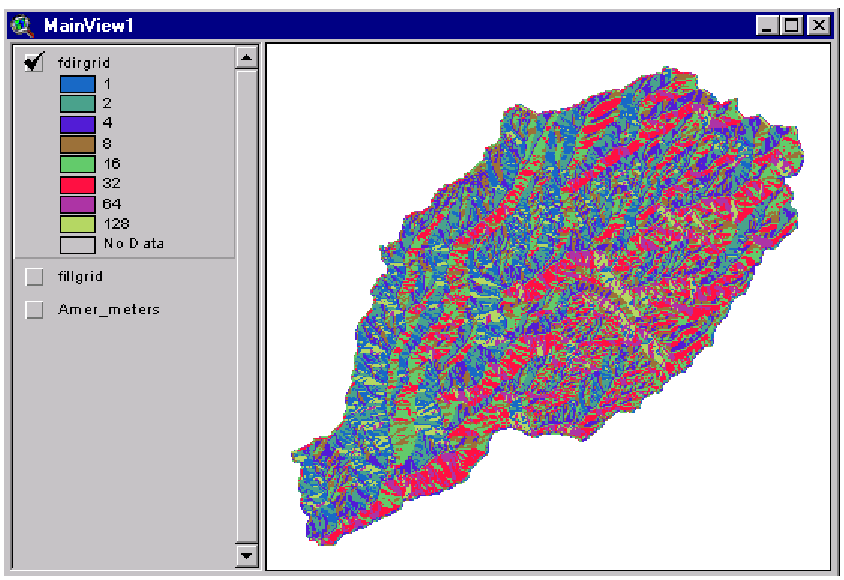


Figure 6–8. Flow Direction operation result.

Flow Accumulation. This step determines the number of upstream cells draining to a given cell. Upstream drainage area at a given cell can be calculated by multiplying the flow accumulation value with the cell area.

The steps to compute flow accumulation are shown below.

- Select **Terrain Preprocessing ⇒ Flow Accumulation**.

- Confirm that the input of the FlowDirGrid is “FdirGrid”. The output of the FlowAccGrid is “FaccGrid”, see Figure 6–9. “FaccGrid” is a default name that can be overwritten by the user.
- Press **OK**

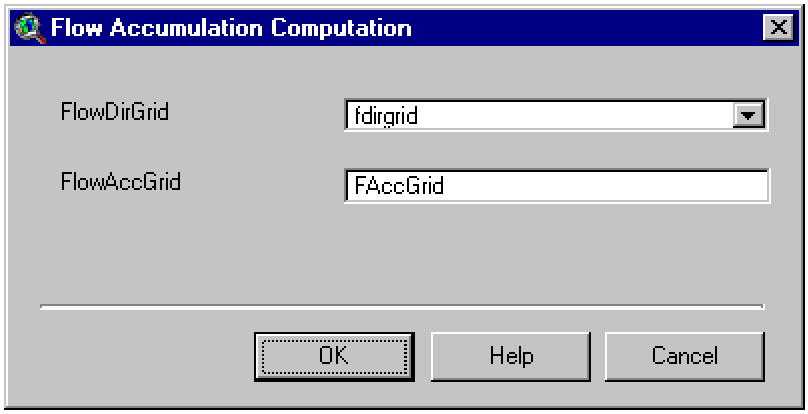


Figure 6–9. Flow accumulation operation.

The result of the Flow Accumulation operation is the “FaccGrid” as shown in Figure 6–10.

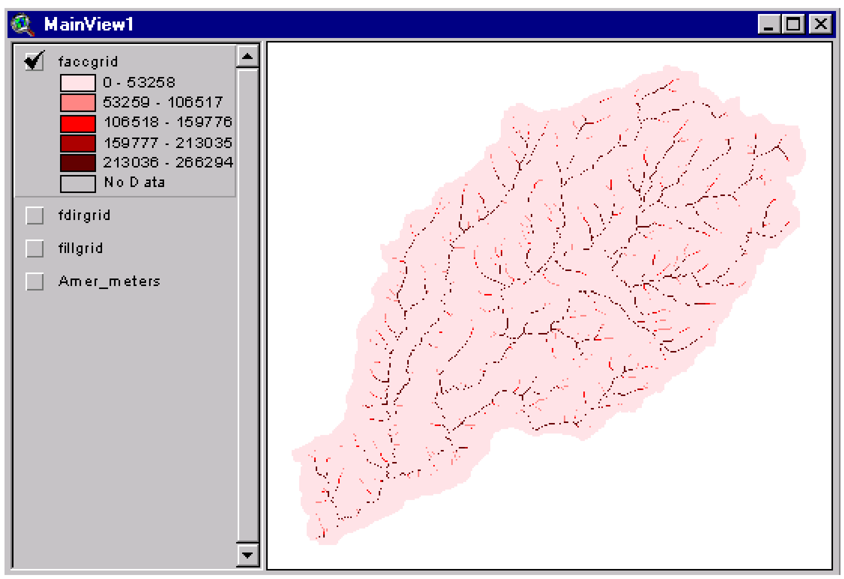


Figure 6–10. Flow accumulation operation result.

Stream Definition. This step classifies all cells with flow accumulation greater than the user-defined threshold as cells belonging to the stream network. Typically, cells with high flow accumulation, greater than a user-defined threshold value, are considered part of a stream network. The user-specified threshold may be specified as an area in distance units squared, e.g., square miles, or as a number of cells. The flow accumulation for a particular cell must exceed the user-defined threshold for a stream to be initiated. The default is one percent (1%) of the largest drainage area in the entire basin. The smaller the threshold chosen, the greater the number of subbasins delineated by Geo-HMS.

The steps to compute stream definition are shown below.

- Select **View ⇒ Properties**; this results in Figure 6–11.
- The Map Units are the X and Y coordinates units of the GIS themes units. In this example, the horizontal unit of the DEM data units is measured in meters. **Specify** the **Map Units** as **meters** from the dropdown menu.
- The Distance Units are the reporting units in ArcView. In this example, the Distance Units are chosen as miles so that the information generated from ArcView can be compared with the stream flow gage drainage area reported in square miles. **Specify** the **Distance Units** as **miles** from the dropdown menu.
- Press **OK** and then save the project.

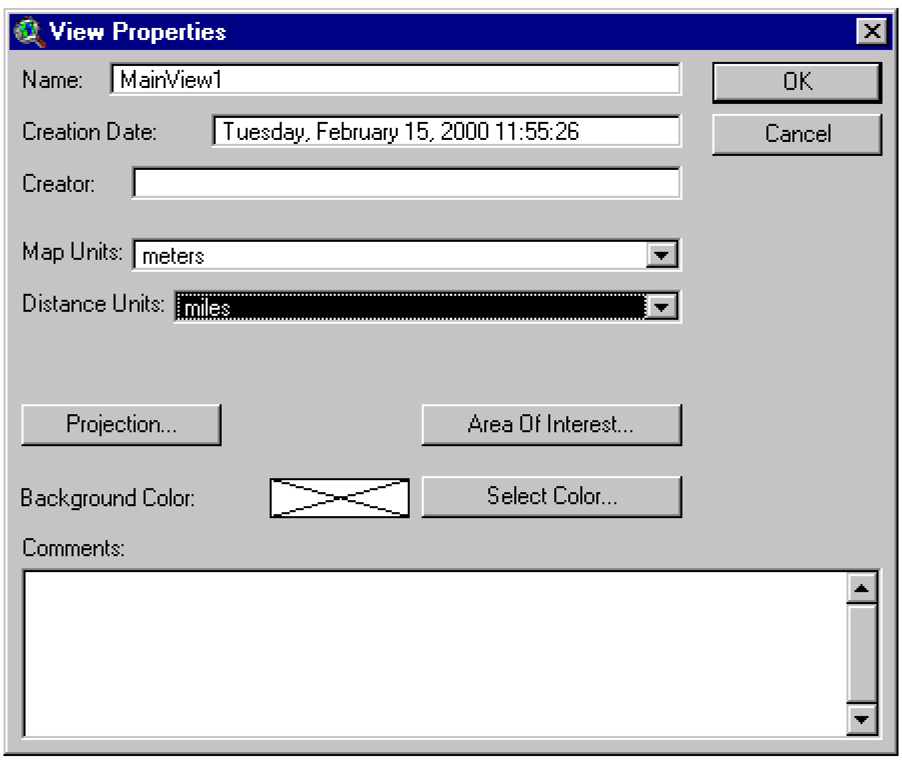


Figure 6–11. View Properties window.

- Select **Terrain Preprocessing ⇒ Stream Definition**.
- Confirm that the input of the FlowAccGrid is “FaccGrid”. The output of the StreamGrid is “StrGrid”, see Figure 6–12. “StrGrid” is a default name that can be overwritten by the user.
- Press OK

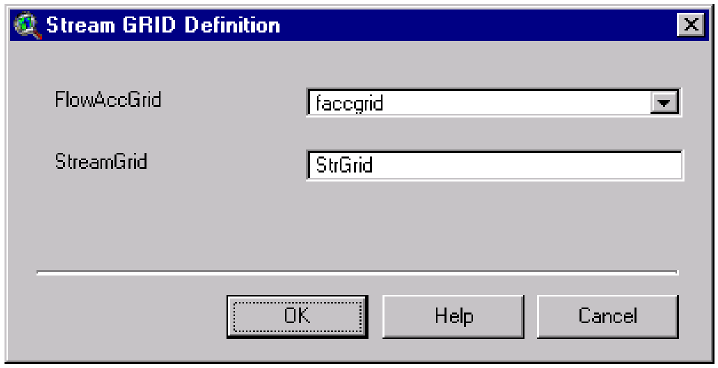


Figure 6–12. Stream definition operation.

- The threshold types are Area in Distance Units squared, which is in square miles, or Number of Cells available under the dropdown menu as shown in Figure 6–13.
- Select **Area in Distance Units squared**.

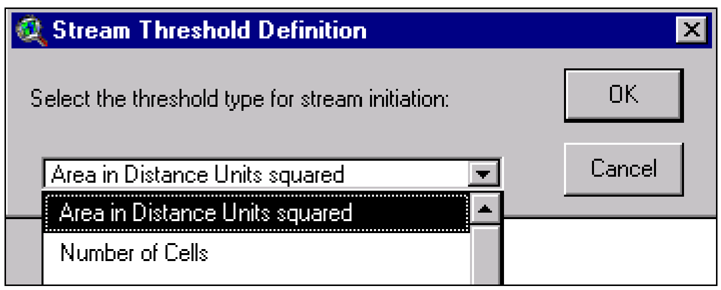


Figure 6–13. Stream threshold definition types.

- Enter the threshold as "5" square miles, as shown in Figure 6–14. Press **OK**.

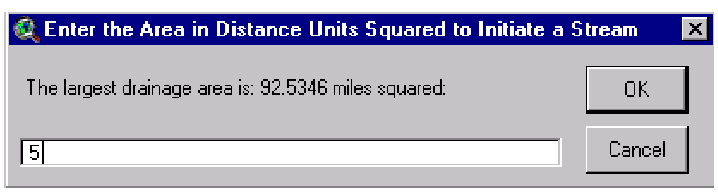


Figure 6–14. Stream threshold entry window.

The result of the Stream Definition operation is the "StrGrid"as shown in Figure 6–15.

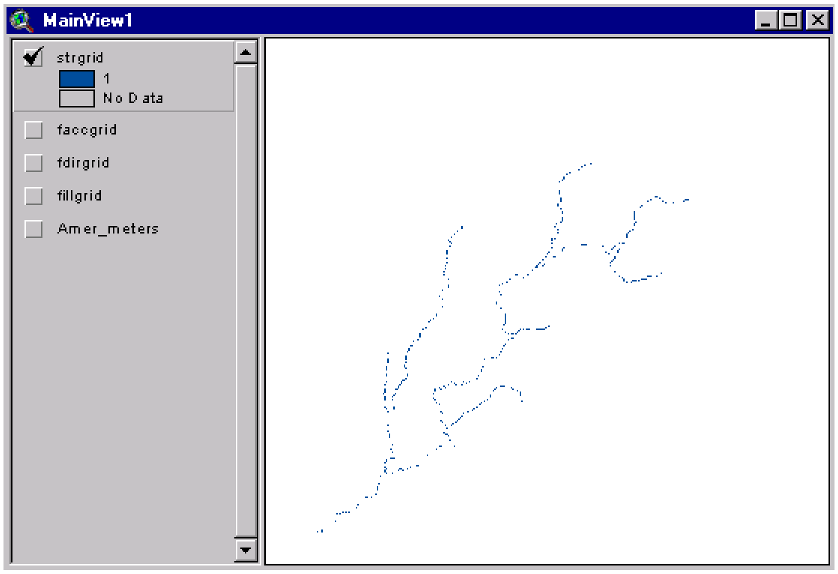


Figure 6–15. Stream definition operation result.

Stream Segmentation. This step divides the stream into segments. Stream segments or links are the sections of a stream that connect two successive junctions, a junction and an outlet, or a junction and the drainage divide.

The steps to compute flow accumulation are shown below.

- Select **Terrain Preprocessing ⇒ Stream Segmentation**.
- Confirm that the input of the FlowDirGrid is “FdirGrid” and StreamGrid is “StrGrid”. The output of the LinkGrid is “StrLnkGrid”, see Figure 6–16. “StrLnkGrid” is a default name that can be overwritten by the user.
- Press **OK**

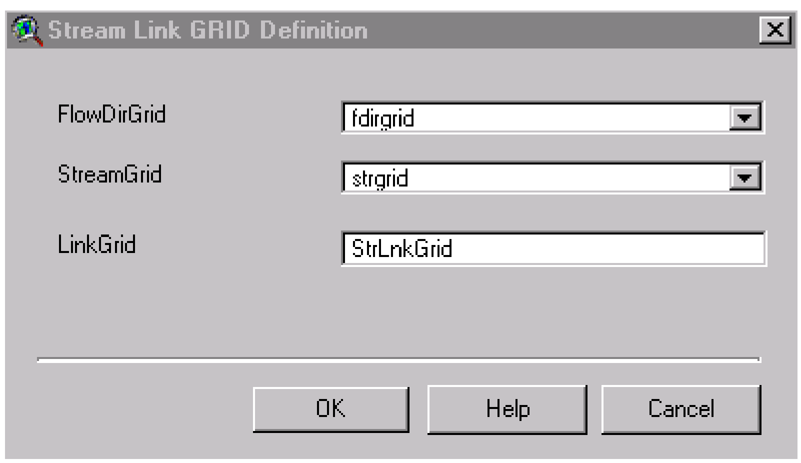


Figure 6–16. Stream segmentation operation.

The stream segmentation operation results in 13 stream segments as shown in the "StrLnkGrid" theme in Figure 6–17.

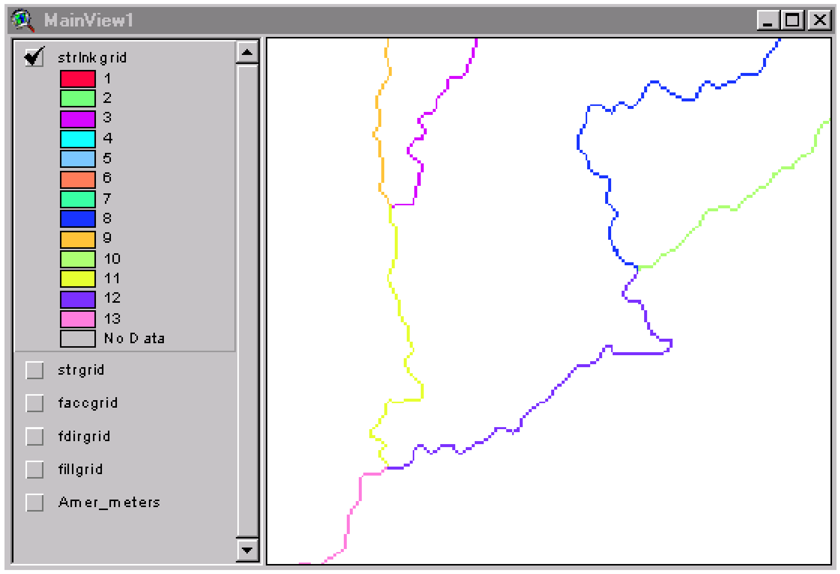


Figure 6–17. Stream segmentation operation result.

Watershed Delineation. This step delineates a subbasin or watershed for every stream segment.

The steps to delineate watersheds are shown below.

- Select **Terrain Preprocessing ⇒ Watershed Delineation**.
- Confirm that the input of the FlowDirGrid is "FdirGrid" and LinkGrid is "StrLnkGrid". The output of the WaterGrid is "WshedGrid", see Figure 6–18. "WshedGrid" is a default name that can be overwritten by the user.
- Press **OK**

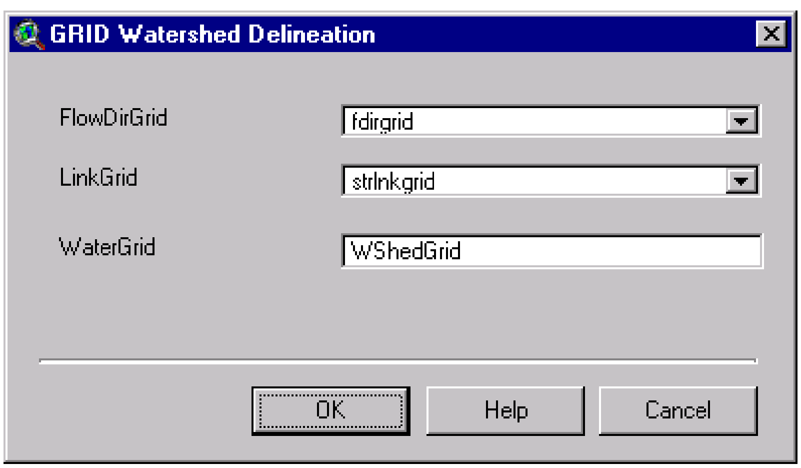


Figure 6–18. Watershed delineation operation.

The watershed delineation operation results in 13 subbasins as shown in the "WshedGrid" theme in Figure 6–19.

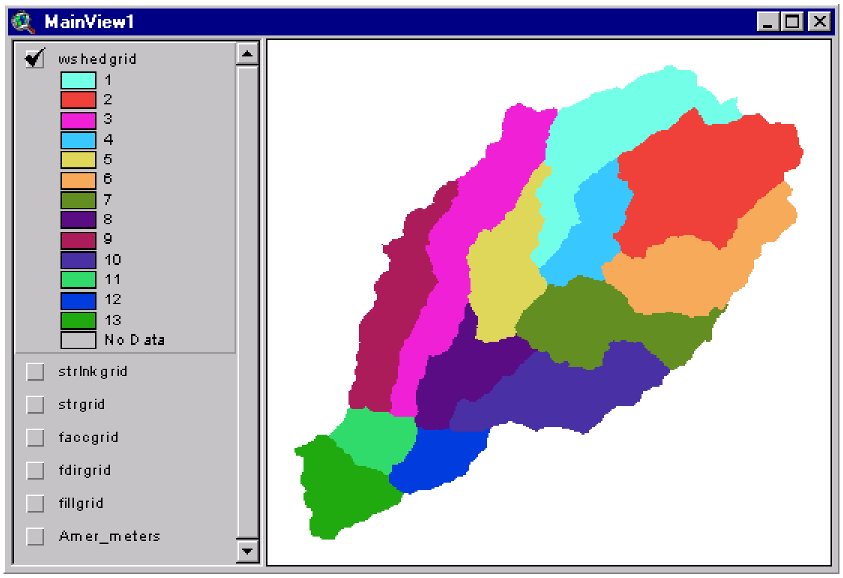


Figure 6–19. Watershed delineation operation result.

Watershed Polygon Processing. This step converts subbasins in the grid representation into a vector representation.

The steps to vectorize a grid-based watershed are shown below.

- Select **Terrain Preprocessing ⇒ Watershed Polygon Processing**.
- Confirm that the input of the WaterGrid is "WshedGrid" and the output of the Watershed is "WshedShp.shp", see Figure 6–20. "WshedShp.shp" is a default name that can be overwritten by the user.
- Press **OK**

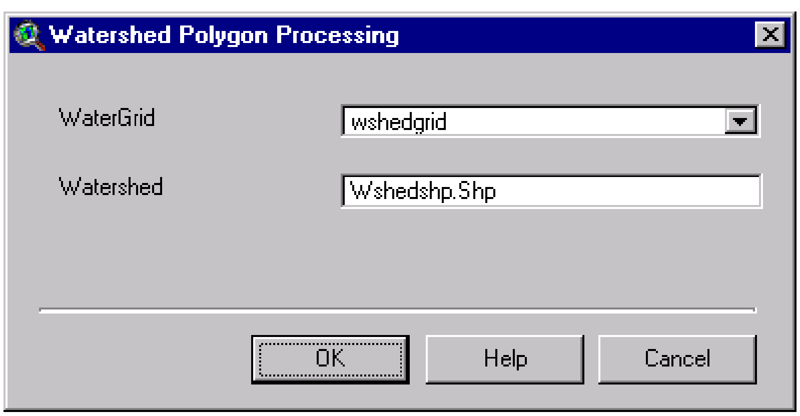


Figure 6–20. Watershed polygon processing operation.

The watershed polygon processing operation vectorized the grid-based subbasin into polygon vectors as shown in the "Wshedshp.Shp" theme in Figure 6–21.

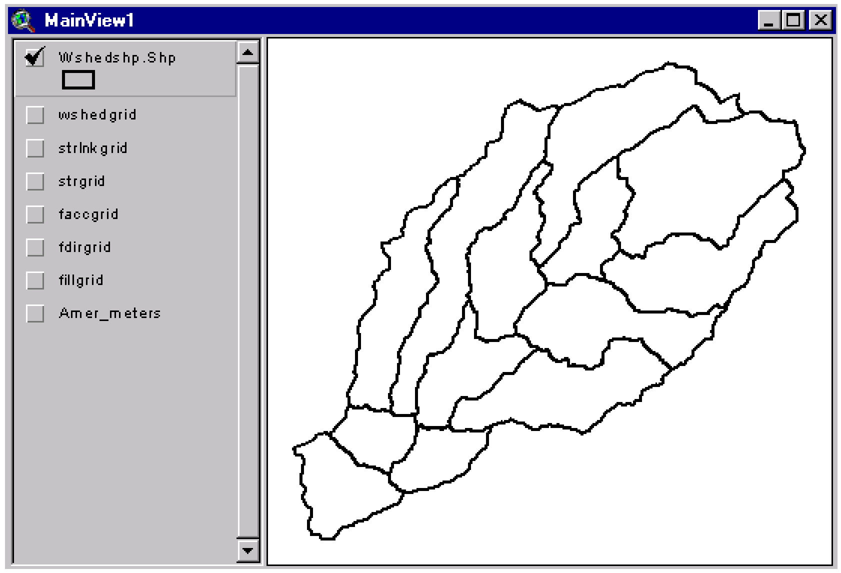


Figure 6–21. Watershed polygon processing operation result.

Stream Segment Processing. This step converts streams in the grid representation into a vector representation.

The steps to vectorize stream segments are shown below.

- Select **Terrain Preprocessing ⇒ Stream Segment Processing**.
- Confirm that the input of the LinkGrid is "StrLnkGrid" and FlowDirGrid is "FdirGrid". The output of the River is "River", see Figure 6–22. "River" is a default name that can be overwritten by the user.
- Press **OK**

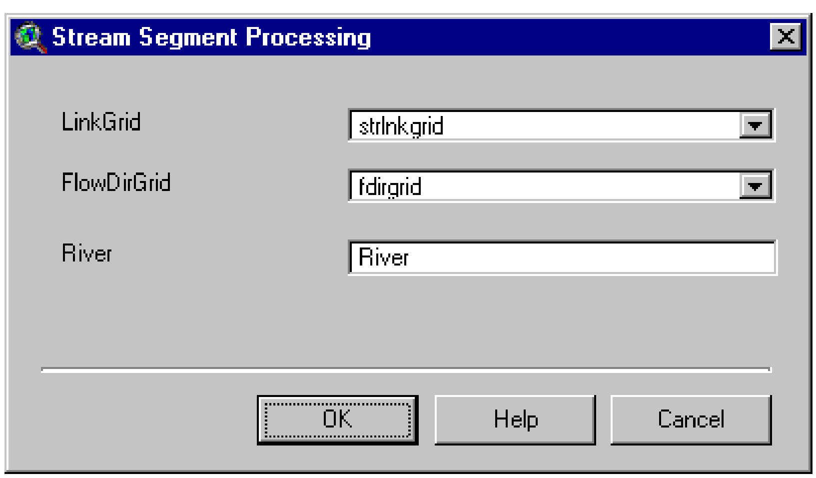


Figure 6–22. Stream segment processing operation.

The stream processing operation vectorized the grid-based streams into line vectors as shown in the "River.shp" theme in Figure 6–23.

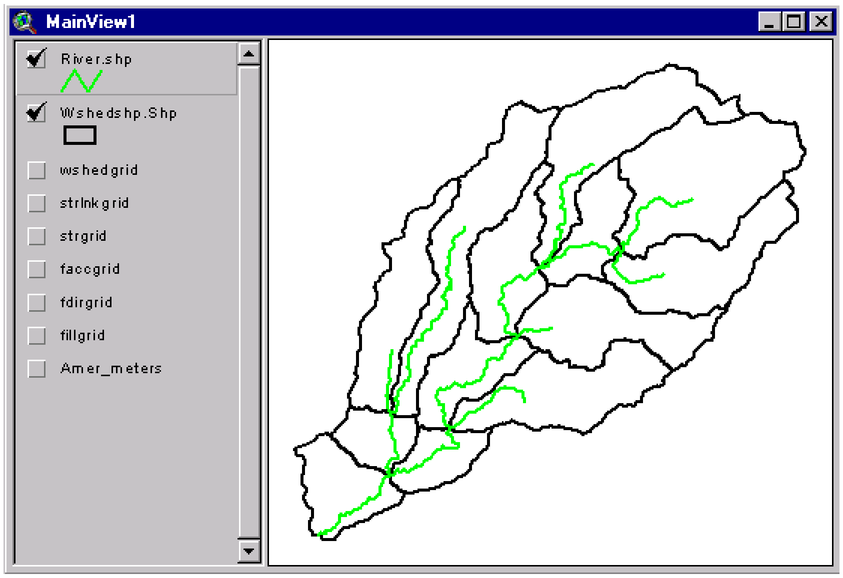


Figure 6–23. Stream segment processing operation result.

Watershed Aggregation. This step aggregates the upstream subbasins at every stream confluence. This is a required step and is performed to improve computational performance for interactively delineating subbasins and to enhance data extraction. This step does not have any hydrologic significance.

The steps to aggregate watersheds are shown below.

- Select **Terrain Preprocessing ⇒ Watershed Aggregation**.
- Confirm that the input of the River is "River.shp" and Watershed is "Wshedshp.shp". The output of the AggregatedWatershed is "WshedMg.shp", a default name that can be overwritten by the user, see Figure 6–24.
- Press **OK**

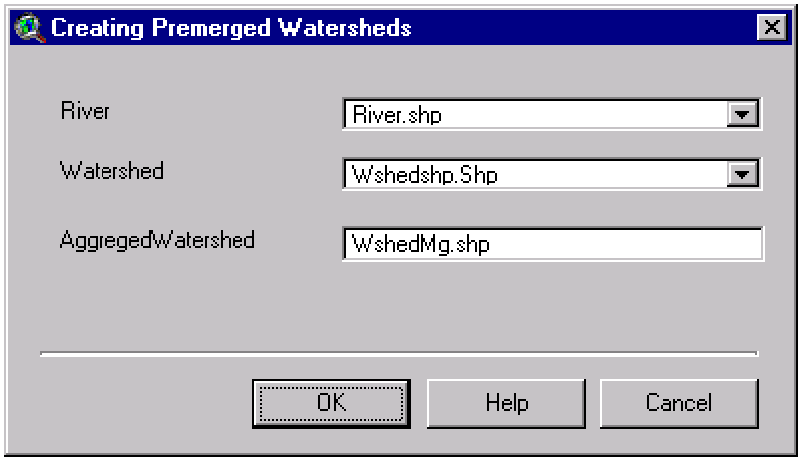


Figure 6–24. Watershed aggregation operation.

The watershed aggregation operation results are shown in the "WshedMg.shp" theme in Figure 6–25.

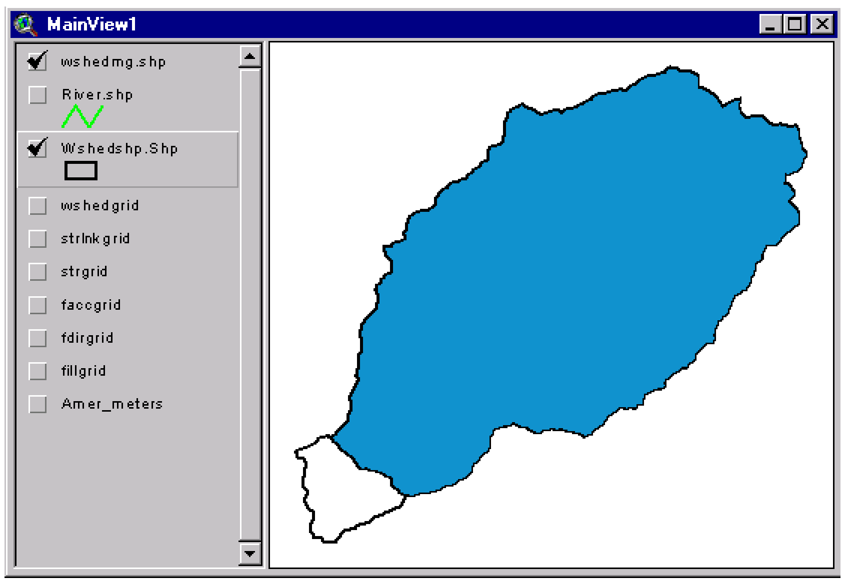


Figure 6–25. Watershed Aggregation Operation Result

Full Processing Setup

When terrain processing is performed in batch mode, **Full Processing Setup** is used. The inputs are specified prior to processing, and a list of default names is presented. The full delineation accepts the depressionless DEM and derived drainage data set from it. Therefore, the DEM must be filled first to prepare for full delineation setup. The inputs to the batch processing include the stream threshold for stream initiation.

The steps to perform full preprocessing are shown below.

- To preserve the content of ***MainView1***, create another view called ***MainView2***.
- Select **MainView** on the project window, and press **New**
- Add the "Amer_meters" DEM.
- Perform **Fill Sinks** and name the filled DEM as "Fillgrid2".
- Select the **Terrain Preprocessing ⇒ Full Preprocessing Setup**.

The default names are shown in Figure 6–26. These default names need to be changed to avoid naming conflicts with the MainView1.

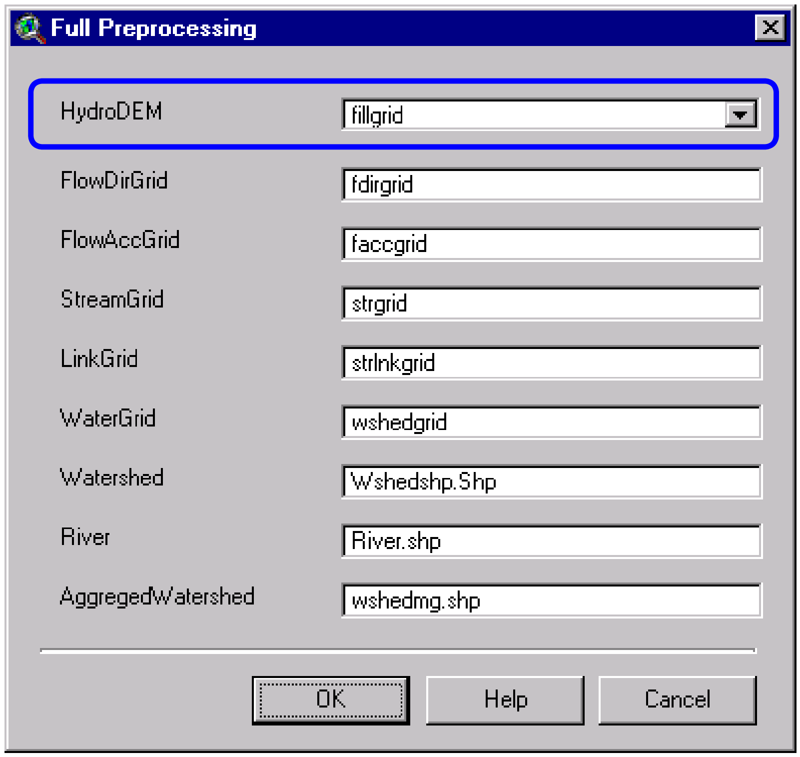


Figure 6–26. Full preprocessing setup with default theme names.

- From the **HydroDEM** dropdown menu, select the **Fillgrid2**.
- Rename the default names by adding a "2" behind the default names as shown in Figure 6–27.
- Press **OK**

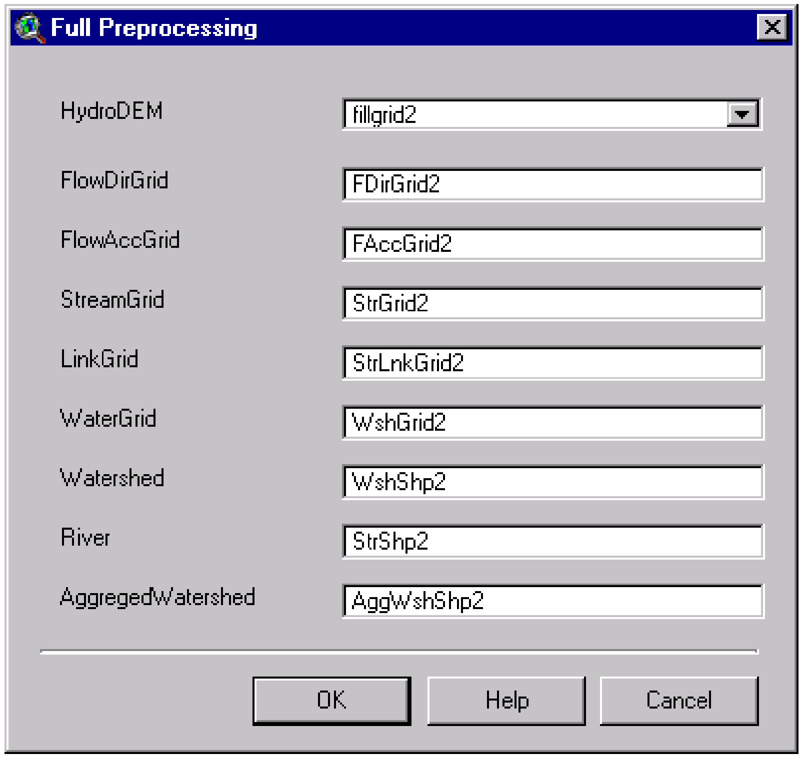
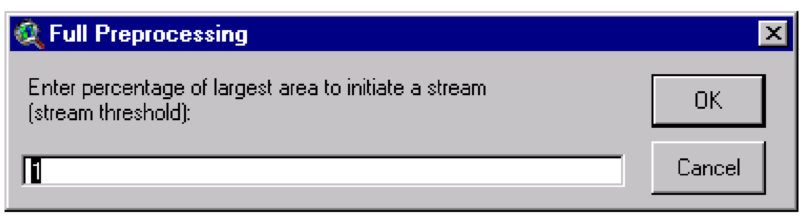


Figure 6–27. Full preprocessing setup with revised theme names.

- Enter the threshold to initiate a stream in terms of a percentage of the largest drainage area. In batch processing, the threshold must be defined as a percentage of the largest drainage area.
- Enter "`1`" to initiate the stream at 1%.



The full preprocessing operation creates the eight themes shown in Figure 6–28.

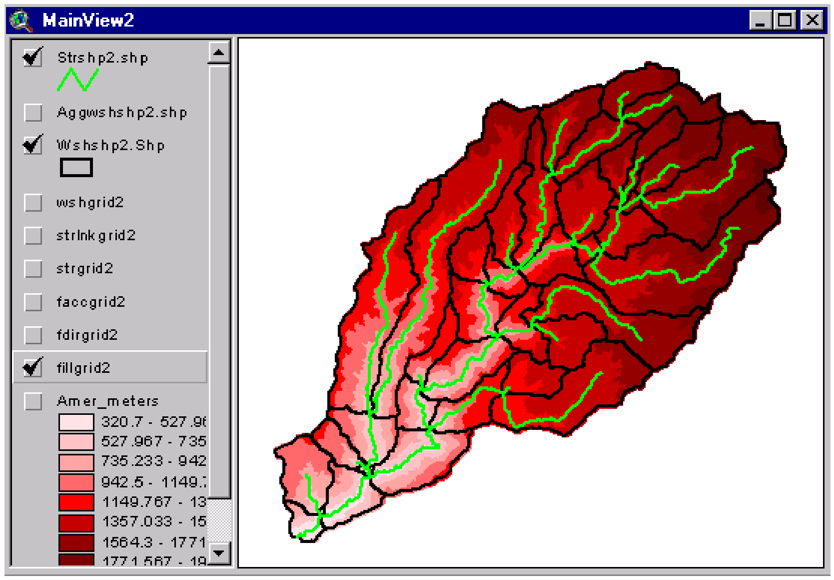


Figure 6–28. Full preprocessing setup results.

Data Exploration with Buttons and Tools

This section discusses the buttons and tools that the user may need to explore and derive data. The buttons and tools allow the user to find the drainage area at a point or find the point that has a specified drainage area. The tools also allow the user to draw a flow path from a specified point and delineate the area tributary to a point. This functionality allows the user to compare the GIS results with published results. In the following example, a streamflow gage with specified drainage area will serve as the published data source.

- Add the theme "gage.shp" with the  (Add Theme) button. There are four gages in this data set as displayed in Figure 6–29.

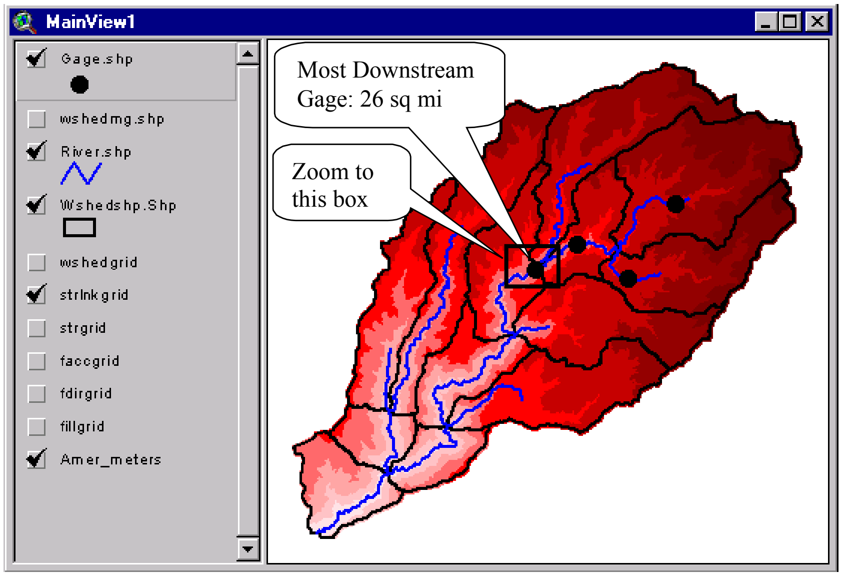
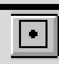
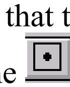


Figure 6–29. Gage Locations

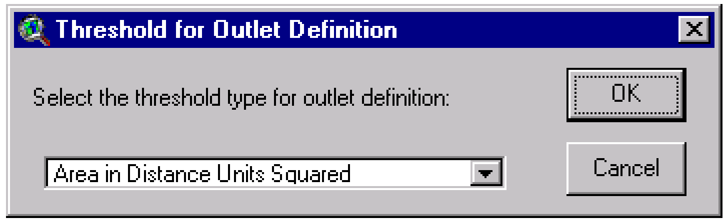
- Zoom in to the region of the most downstream gage whose reported drainage area is 26 square miles (sq mi).

The descriptions and procedures for useful buttons are explained in Table 6-1.

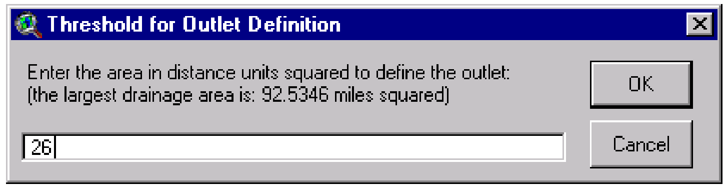
Table 6-1. MainView Button Descriptions and Procedures

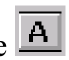
Button	Descriptions and Procedures
 Find Area	<u>Description</u> Find possible locations on each stream that have the closest, but not exceeding, drainage area to the user-specified area. This tool provides many candidate points, with some points containing much smaller areas than the target area. In order to narrow the number of candidate points, the tool should be used when the user zooms to the area of interest. <u>Procedure</u> In this case, the downstream gage is close to three streams. The user knows that the downstream gage drains 26 sq mi. Using the  (Area Find) button, the user searches within the zoomed-in region for the locations along the streams whose area does not exceed the specified 26 sq mi. With this information, the user can define the watershed of interest.

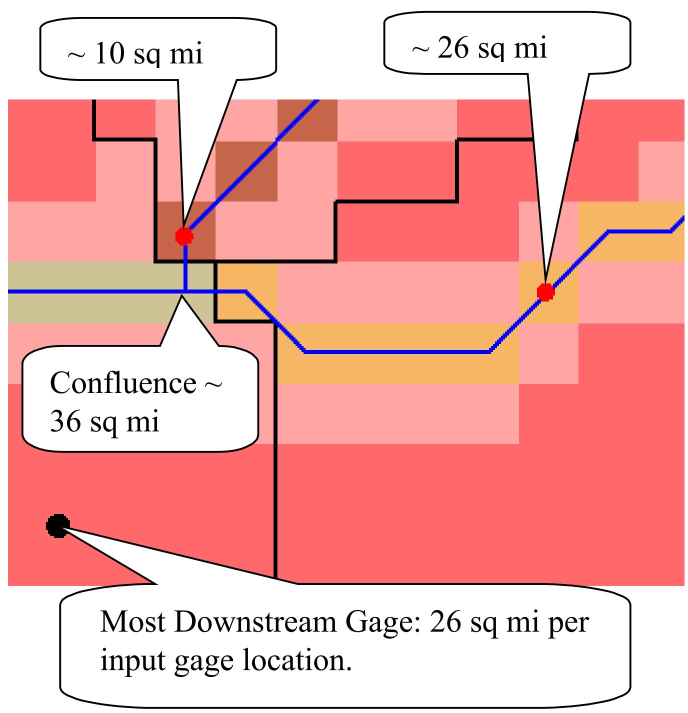
Select the threshold type and press **OK**.



Enter the Area as “26”.

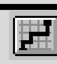
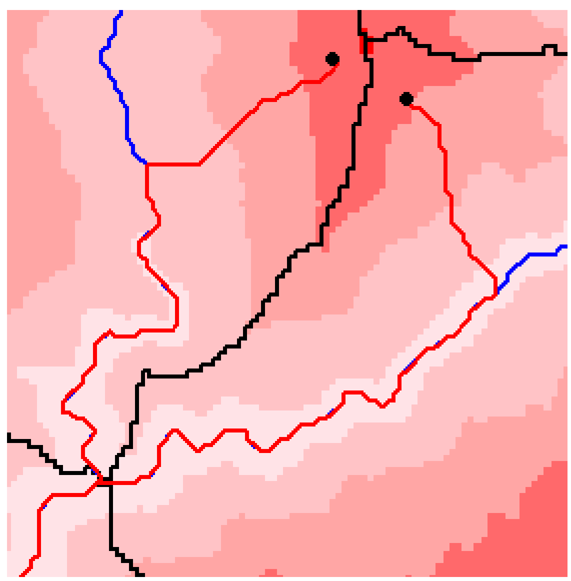
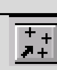


The results of the search provide two possible points that do not exceed the specified area. Using the  (Identify Area) tool, the user finds that one possible point drains about 10 sq. miles while the other point drains about 26 sq mi. From this analysis, the user understands that the downstream stream gage does not belong on the stream with 10 sq mi drainage area or stream from the confluence. The applicable location of the downstream gage is on the stream with the 26 sq mi drainage area.



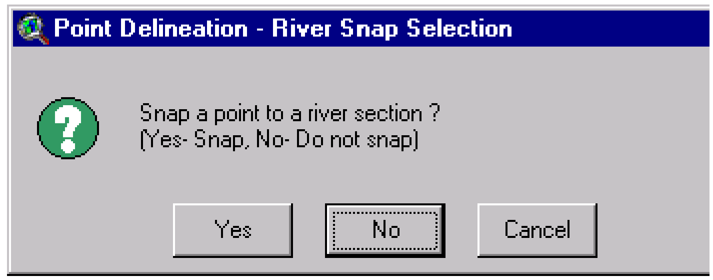
The descriptions and procedures for useful tools are explained in Table 6-2.

Table 6-2. MainView Tools Descriptions and Procedures

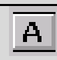
Tools	Descriptions and Procedures
 Flow Trace	Description This tool traces the flow path downstream of a user-specified point. Procedure To verify the drainage paths and watershed boundaries, the user can apply the flow-tracing tool and click on the display. A flow path is drawn downstream as a graphic from the specified point. The graphics can be selected and deleted when the user is done examining them. To delete the graphics, select the graphic with a standard ArcView  (Pointer) tool or Select **Edit ⇒ Select All Graphics**, and select **Edit ⇒ Delete Graphics.** 
 Point Delineate	Description Delineate the watershed tributary to a user-specified point.

Procedure

Zoom in to the stream. Select the **Point Delineate** tool. Click **Yes** to enable snapping to a river or **No** to disable snapping.



The result of this operation is saved in a point and polygon shapefiles.



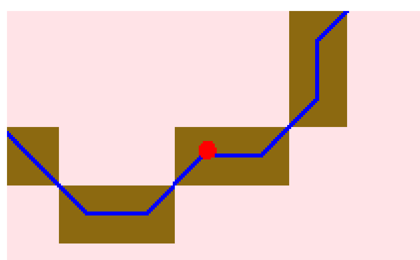
Identify Tool

Description

Identify contributing area for any cell in distance units as specified in the View's properties.

Procedure

Select the Identify Tool. Click on the cell in question.



The drainage area in distance units at the cell is displayed in the lower left-hand corner of the status bar as shown below.

The area is : 89.3464 miles squared.

Hydrologic Model Setup

The **HMS Project Setup** menu on the ***MainView*** GUI is responsible for extracting necessary information from the spatial database and creating an HMS project. The approach for extraction involves specifying control points at the downstream outlet, which defines the tributary of the HMS basin. As multiple HMS Basin models can be produced from the same spatial database, these models are managed through two shapefiles themes: project points "ProjPnts.shp" and project area "ProjArea.shp". The management of these models shows the regions that already have a project. In addition, management of these models allows re-creation of a study area with different thresholds or delete the project and related files easily and conveniently.

Start New Project

To define a new project name and create a directory to contain extracted data and related files, go to the **HMS Project Setup** menu.

- Select **HMS Project Setup ⇒ Start New Project**.
- Enter the project name as "AmerRiv1" as shown in Figure 6–30.

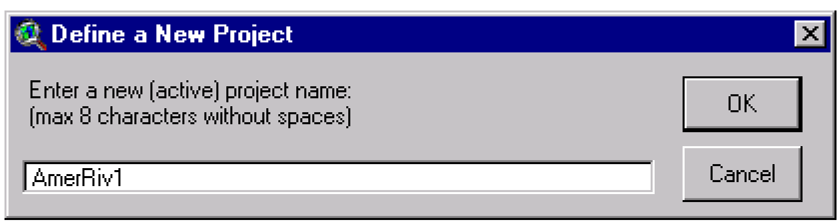
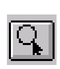


Figure 6–30. New project definition.

- Select the  (Specify Outlet Point) tool.
- Specify the outlet point for a tributary basin model as shown in Figure 6–31.

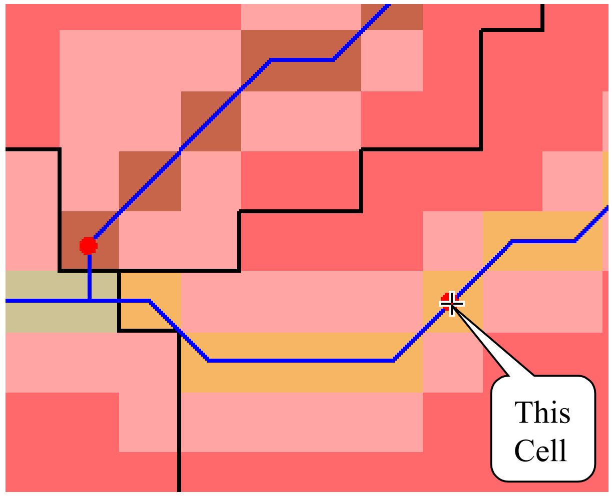


Figure 6–31. Specify outlet location.

- Select **HMS Project Setup ⇒ Generate Project.**
- Select the method of generating the project. Select **Original stream definition** from the dropdown menu as shown in Figure 6–32. The other two options are "A new threshold" and "Head basin area". The option "A new threshold" allows the user to specify a new threshold for the project. The option "Head basin area" allows the user to specify a threshold such that the head subbasins are approximately equals to the threshold.
- Press **OK**

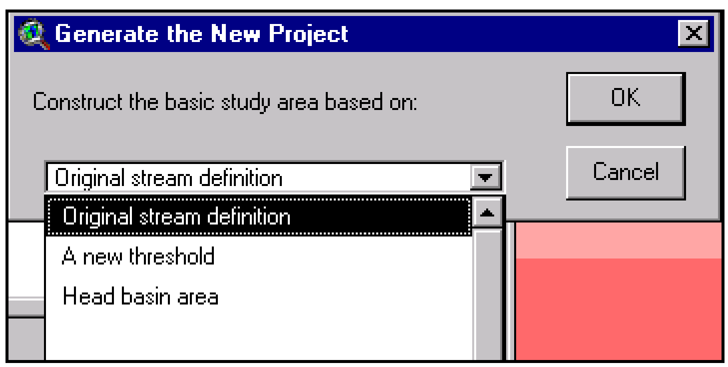


Figure 6–32. Generate project with options.

- Use the default name "ProjArea.SHP"as shown in Figure 6–23.

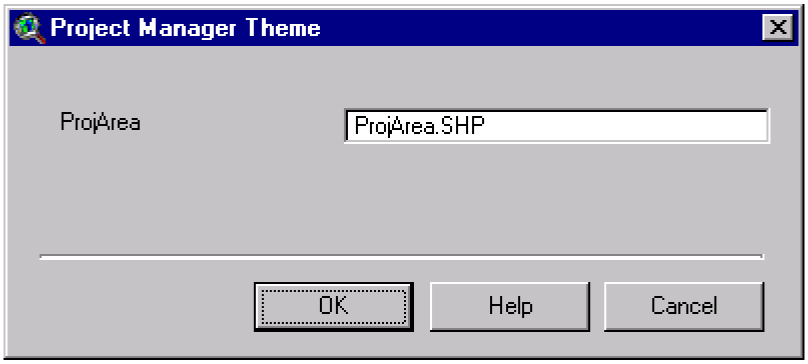


Figure 6–33. Project manager theme window.

- Press **OK** to generate a new project in the ***ProjView*** document type named "AmerRiv1" as shown in Figure 6–34.

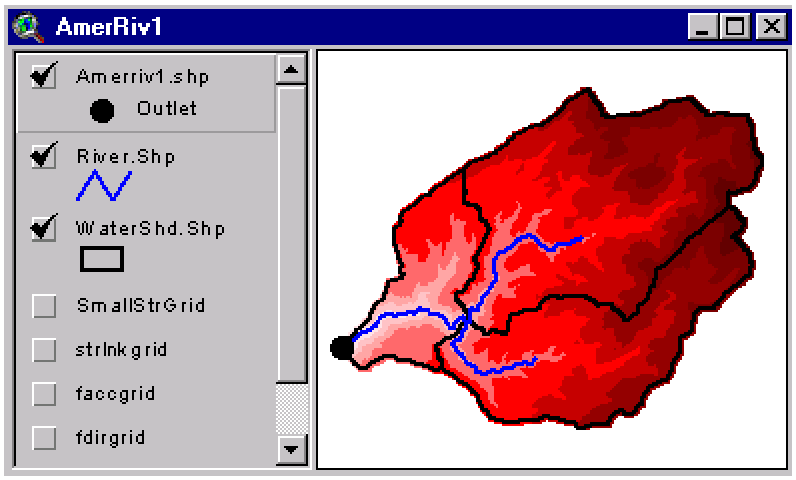


Figure 6–34. New project for hydrologic model.

In the ***ProjView*** named "AmerRiv1", the following data sets are extracted and created for the specified study area. The extracted area includes the buffer zone in order to deal with the boundary conditions. The data sets ending with "Grid" are raster data sets and the data sets with the "shp" extension are vector data sets in industry standard shapefiles format.

- "FillGrid" represents the extracted terrain for the study area.
- "FdirGrid" represents the extracted flow direction for the study area.
- "StrLnkGrid" represents extracted stream segments for the study area.
- "SmallRivGrid" is an additional grid theme created using 10% of the specified threshold. It contains denser stream representation for visualization purposes.
- "WaterShp.Shp" represents the extracted subbasins for the study area.

- "River.Shp" represents the extracted stream segments for the study area.
- "AmerRiv1.Shp" contains project outlet and source point that defines the study area.

Additional HMS projects or Basin Models can be generated from the original set of preprocessed data sets. As illustrated in Figure 6–35 and Figure 6–36, the user can extract the pertinent data sets from the ***MainView*** to create another project. The benefit of this setup is that it allows the user to preserve the original data sets and work on multiple projects.

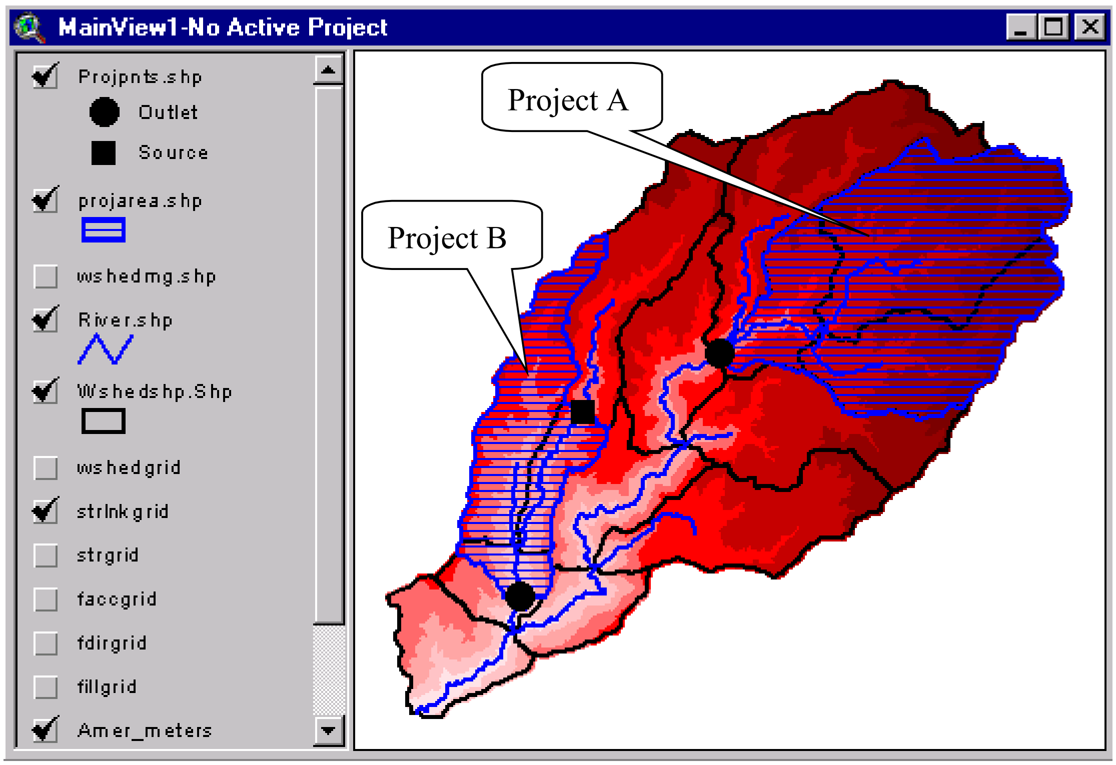


Figure 6–35. MainView with two projects.

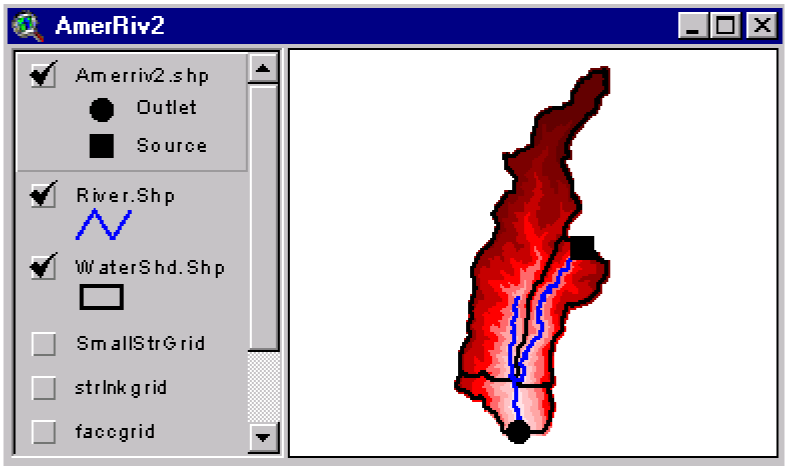


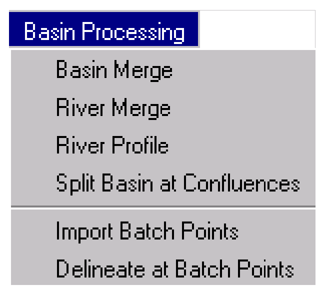
Figure 6–36. Generation of a separate project B from Figure 6–35.

CHAPTER 7

Basin Processing

After the terrain preprocessing is performed in the ***MainView***, the extracted data for the HMS model is generated and placed in the ***ProjView***, which allows the user to revise the subbasins delineation. Subbasin and routing reach delineations include points where information is needed, i.e., streamflow gage locations, flood damage centers, environmental concerns, and hydrologic and hydraulic controls. The tools described in this chapter will allow the user to interactively combine or subdivide subbasins as well as to delineate subbasins to a set of points in a batch manner.

This chapter will discuss the tools for subbasin delineation that are available in the ***ProjView*** GUI under the **Basin Processing** menu.



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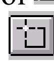
Basin Merge

Under the **Basin Processing** menu, the **Basin Merge** menu item merges multiple subbasins according to the following rules. This tool works interactively by presenting the result of the operation, allowing the user to examine the result, and giving the user options to accept or cancel the operation.

Rules!

- The subbasins must share a common confluence or
- The subbasins must be adjacent in an upstream and downstream manner.
- More than two subbasins are permitted.

Steps

- Make the "WaterShp.Shp" theme active by pressing on the theme with the pointer tool . The active theme appears raised.
- Use the select tool  and select the two subbasins as shown in Figure 7–1.

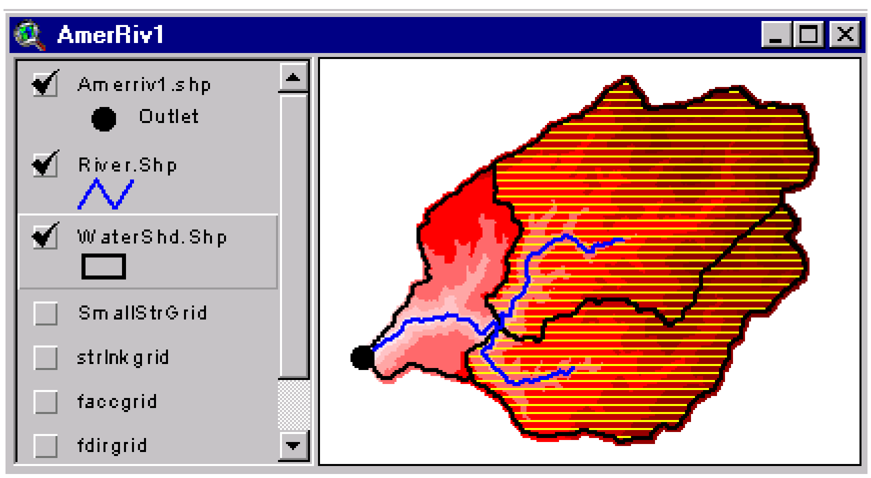


Figure 7–1. Basin merge.

- Select the **Basin Processing ⇒ Basin Merge**, as shown in Figure 7–2.

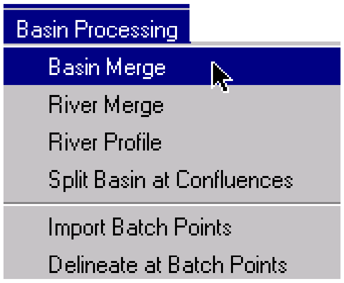


Figure 7–2. Basin merge menu item.

- The result of the merged subbasin is shown with a red outline. Press **Yes** to accept the resulting merged subbasin or No to cancel the merge operation.
- In this case, press **Yes** as shown in Figure 7–3.

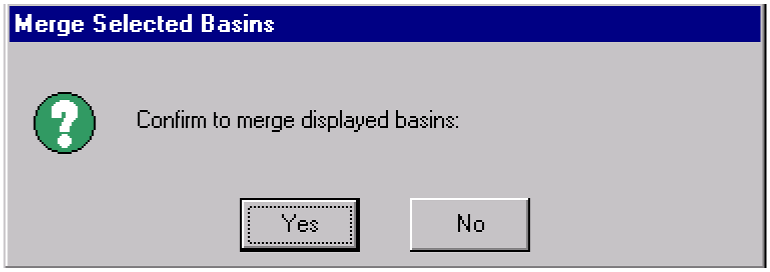


Figure 7–3. Basin merge confirmation.

The result of the merged basin is shown in Figure 7–4.

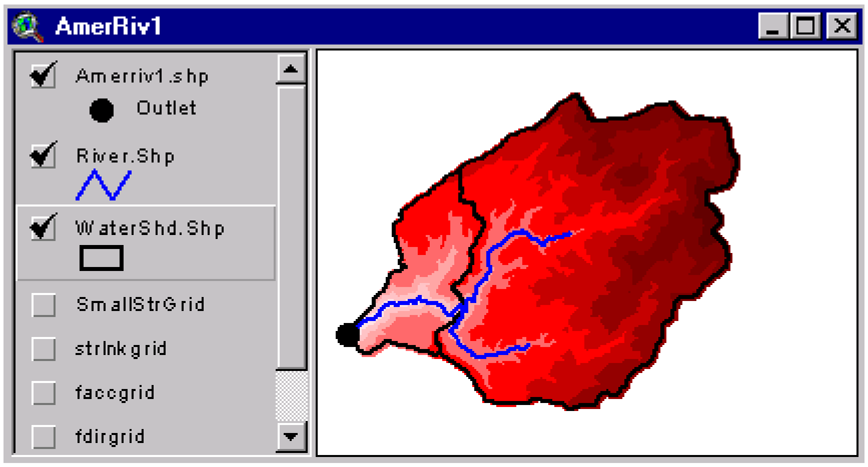


Figure 7–4. Basin merge result.

Basin Subdivision

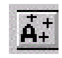
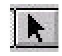
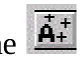
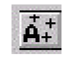
A basin can be subdivided with the  (Basin Subdivide) tool. The tool tip can be viewed by placing the pointer tool  over the  tool as shown in Figure 7–5. The tool tip indicates that the users can 1) Click on the stream to subdivide a basin or 2) Control key plus Click to remove unnecessary point. The unnecessary point is often a residual from multiple basin subdivision and merge. The basin subdivision  tool can be applied in three methods.

Figure 7–5. Basin subdivision.

Method 1: Basin Subdivision on Existing Stream

An existing basin can be subdivided into two basins on an existing stream.

- Zoom in to the area of interest as shown in Figure 7–6 and make the “SmallStrGrid” theme visible by checking the box next to it; this results in Figure 7–7. The “SmallStrGrid” theme represents the grid cells that compose the stream network. The existing streams are shown as blue lines according the “River.Shp” theme.

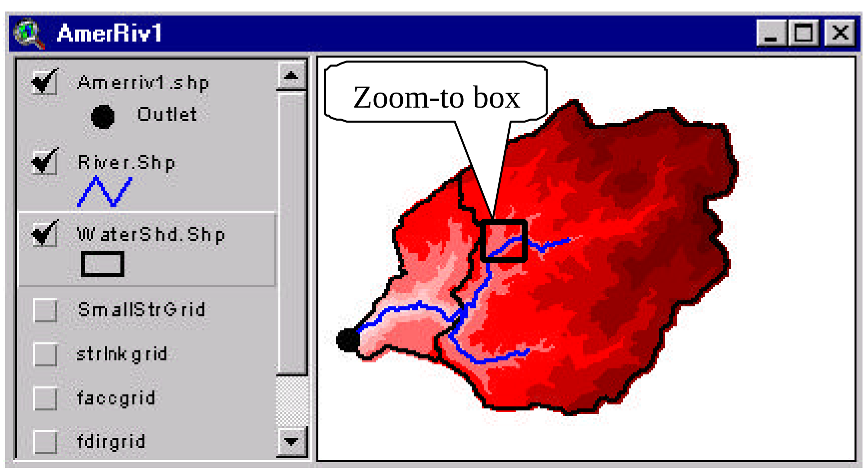
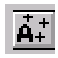


Figure 7–6. Zoom in prior to basin subdivision.

- Select the  tool.
- Click on the cell of interest as shown in Figure 7–7.

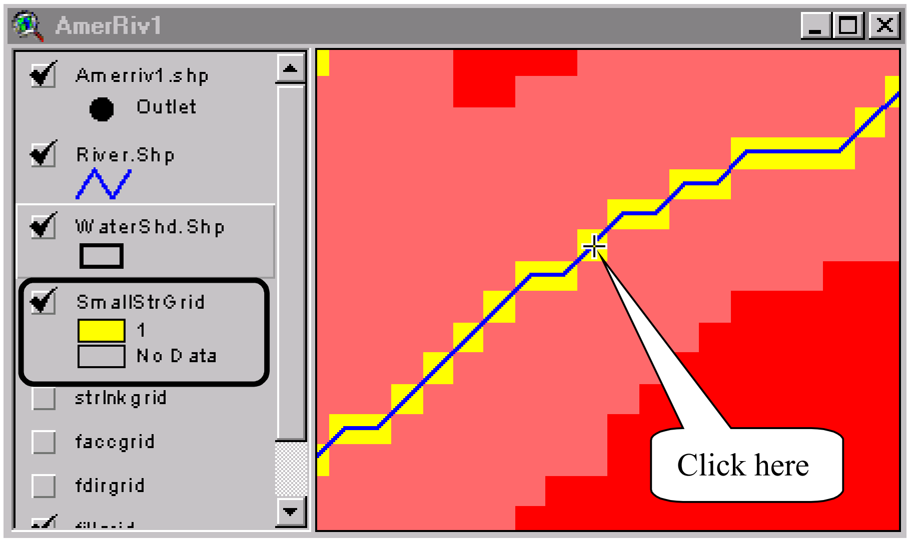


Figure 7–7. Click on the cell to subdivide basin.

- The user can accept the default name for the new basin outlet or overwrite it in the text box as shown in Figure 7–8.
- In this example, accept the default name. Press OK.

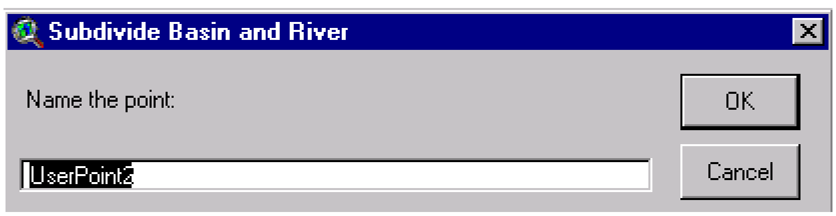


Figure 7–8. Default outlet name.

- A few seconds later, the result shown by the red outline is displayed and the user can examine it. In this case, accept the result by pressing **Yes**.

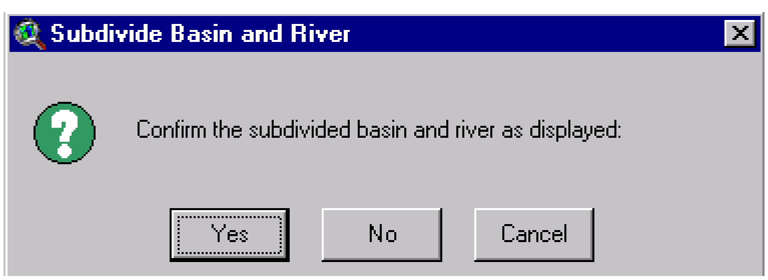


Figure 7–9. Basin subdivision confirmation.

The result of the operation is shown in Figure 7–10.

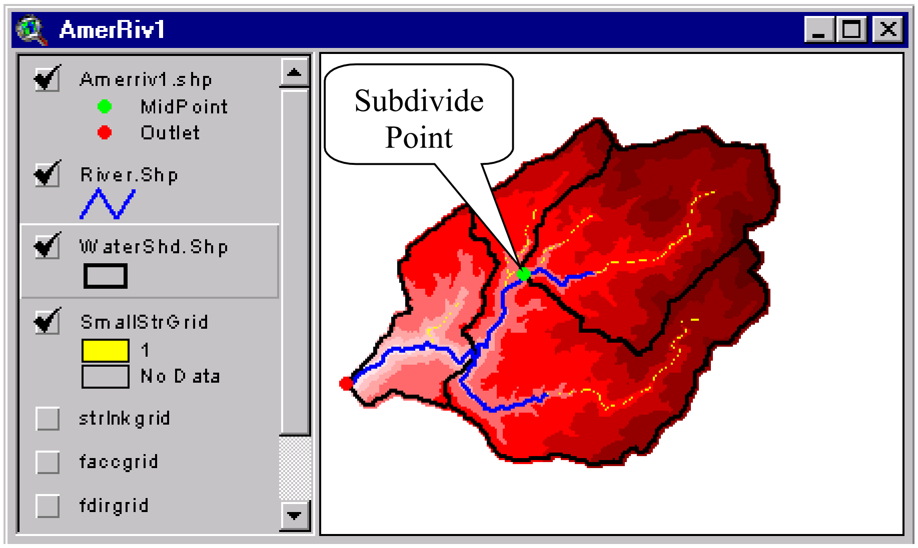


Figure 7–10. Basin subdivision result.

Method 2: Basin Subdivision without Existing Stream

When an existing stream does not extend upstream far enough, the user can use the same Basin Subdivide tool to delineate a new subbasin. For example in Figure 7–11, the blue (if document is in color) or dark (if document is in black and white) stream does not extend up to the area of interest indicated by the box. The tool delineates a subbasin at the specified point that is not on the existing stream and traces a new stream segment downstream from the specified point to the existing stream.

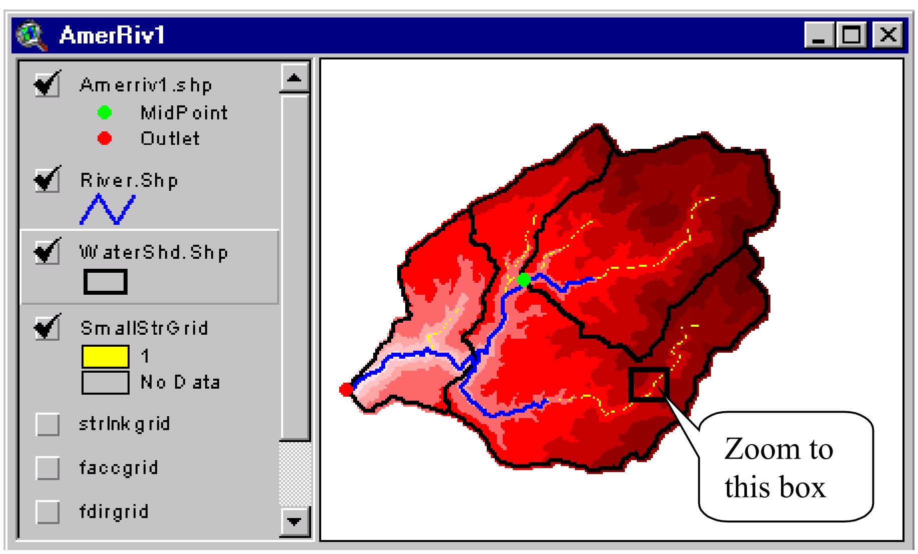


Figure 7–11. New subbasin delineation.

- Zoom in to the area of interest and make the “SmallStrGrid” theme visible.
- With the Basin Subdivide tool selected, click on the point shown below. Notice that the existing blue or dark stream does not exist in Figure 7–12.

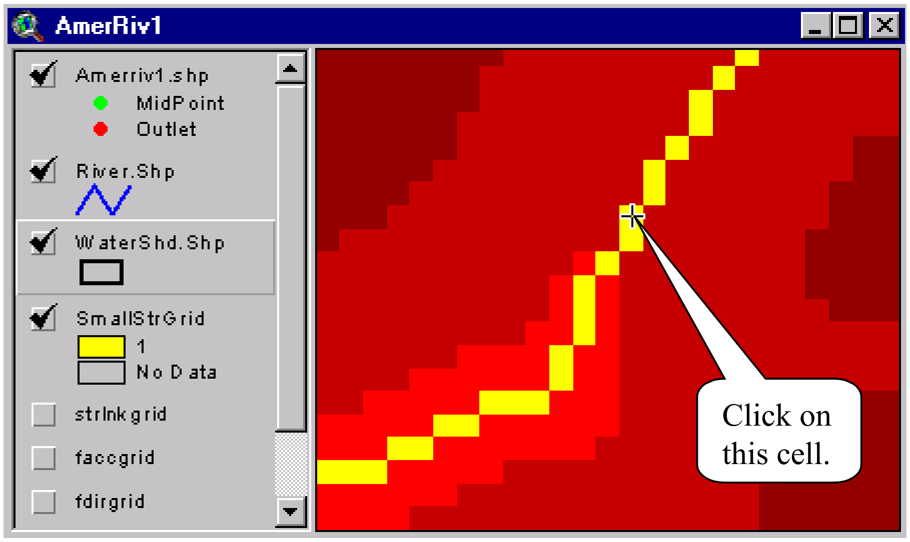


Figure 7–12. Zoom in prior to basin delineation.

- Accept the default name for the outlet and press **OK** as shown in Figure 7–13.

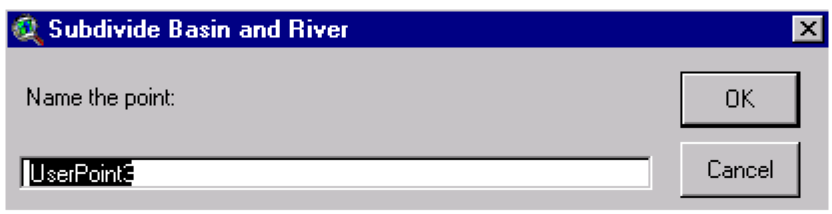


Figure 7–13. Default name of new outlet.

The result of the operation is shown in Figure 7–14. A new subbasin is created and a new blue or dark stream segment is also created from the specified point to the existing stream. Where the two streams meet, a point is created for reference information. The existing and new stream segments are not joined together.

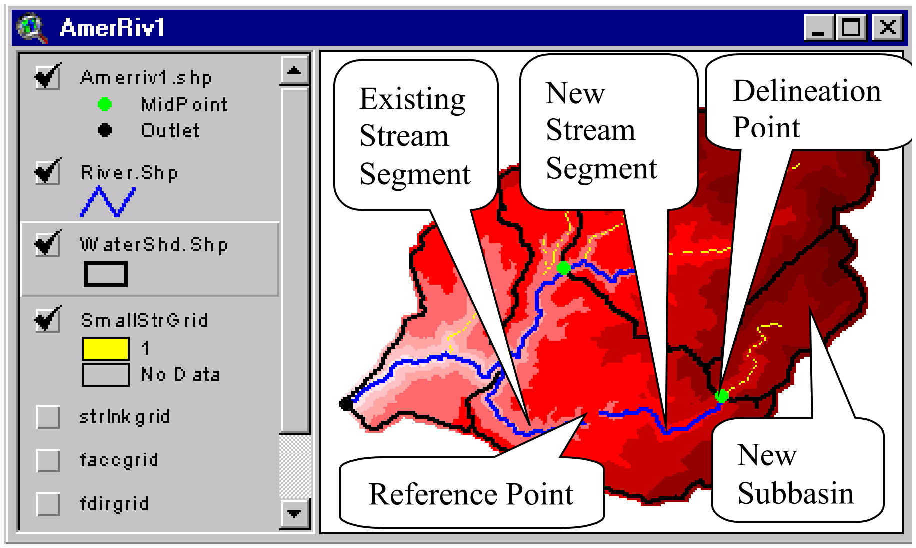


Figure 7–14. New subbasin delineation result.

Method 3: Basin Subdivision on Tributary

Similar to Method 2, the situation in Method 3 involves subbasin delineation on a tributary branch where the stream does not exist. For example in Figure 7–15, the blue or dark stream does not have a tributary stream extending up to the area of interest indicated by the delineation point. Clicking on the delineation point with the **Point Delineation** tool delineates a subbasin at the specified point not on the existing stream, traces a new stream segment downstream from the specified point to the existing stream, and splits the existing stream at the confluence.

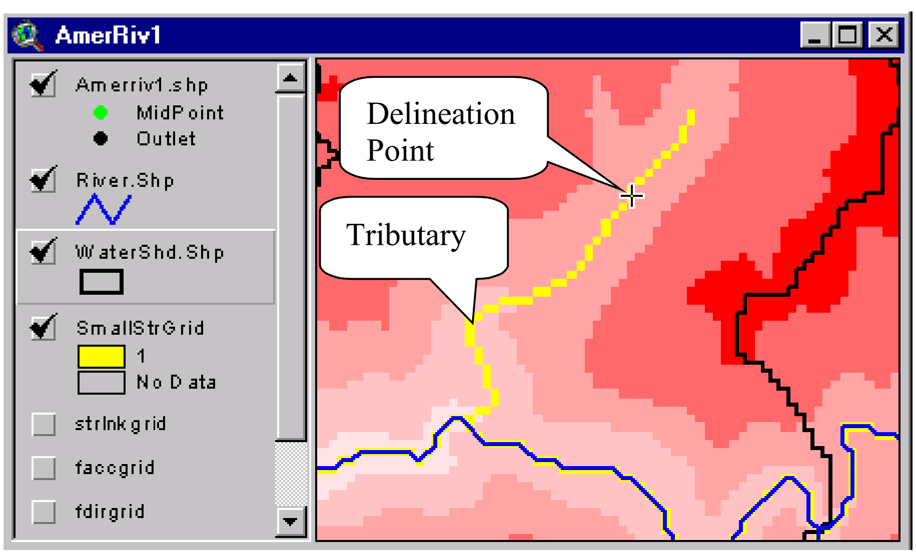


Figure 7–15. Subbasin delineation on a tributary.

- Accept the default name for the outlet and press **OK** as shown in Figure 7–16.

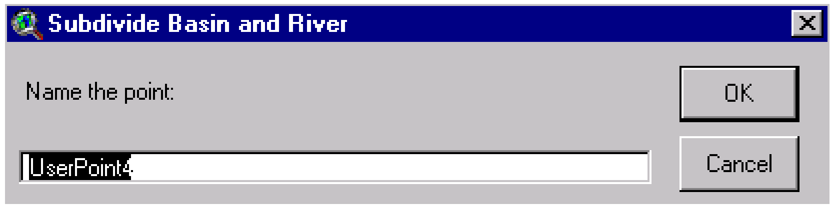


Figure 7–16. Default name for outlet.

The result of the operation is shown in Figure 7–17. A new subbasin is created with the outlet at the user-specified point; and a new stream segment is created from the user-specified point to the existing stream. Where the new stream segment met the existing stream, a confluence is established by splitting the existing stream into two segments. At the confluence, there are two stream segments flowing in and one segment is flowing out. The existing and new stream segments are not joined.

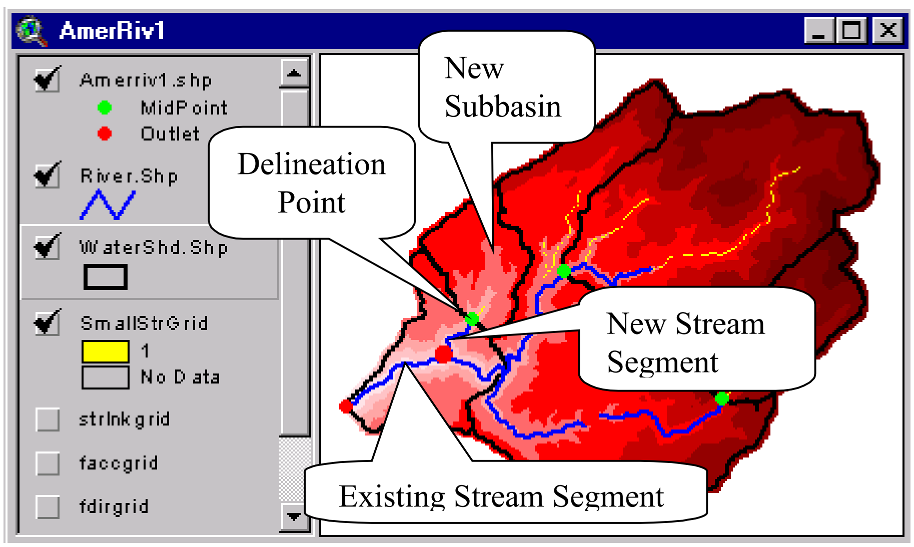


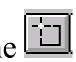
Figure 7–17. Subbasin delineation on a tributary result.

River Merge

When basin merges and subdivisions are performed, stream segments are often created. As an example, the basin subdivision with method 2 created a stream segment that extends from the existing stream to the user-specified basin outlet as shown in Figure 7–18. The point shown in the figure shows that the two segments are not joined together. From a hydrologic perspective, the two segments are considered as routing reaches.

If the user intends to model the routing with multiple reaches, the user will need to develop routing parameters for both reaches. However, if the user intends to model the routing with a single reach, then the user will need to merge both stream segments. The capability to route the hydrograph through multiple reaches is supported in HMS. The issue here is to raise awareness on modeling techniques options.

Steps

- Activate the "River.Shp".
- Select the two stream segments with the  (Select) tool.
- Select **Basin Processing ⇒ River Merge**.
- The selected stream segments become one segment. The reference point is not deleted.

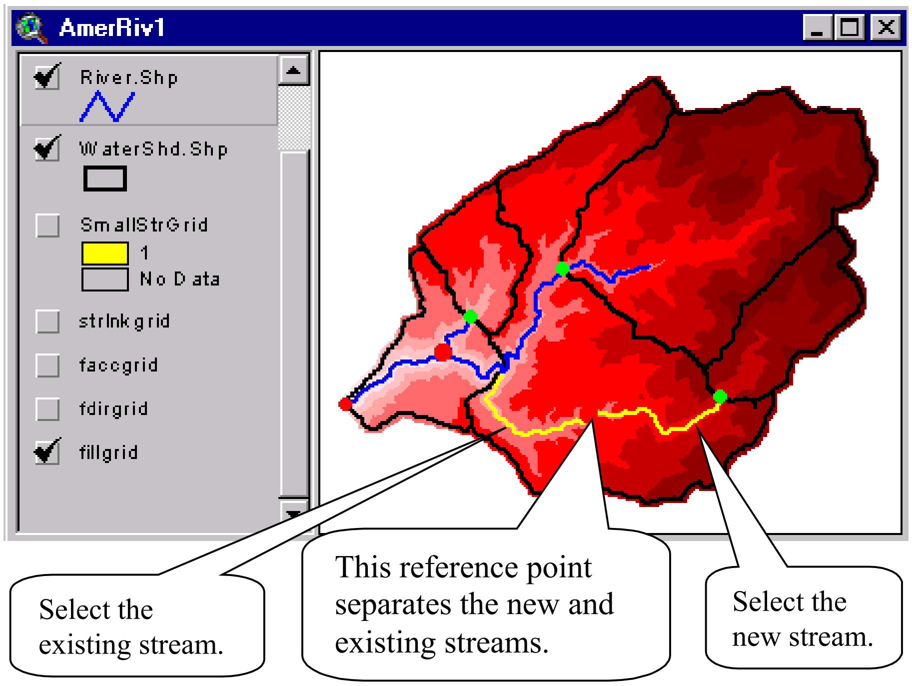
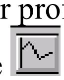


Figure 7–18. River merge.

River Profile

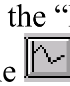
The river profile tool provides information on slopes and grade breaks that can be used to delineate subbasins. The river profile is created by extracting elevation values from the terrain model along the stream. Creating the river profile can be performed in two ways: **River Profile** menu item or the  (Profile) tool.

Method 1: River Profile menu item

Steps

- While in the ProjView document, activate the “River.Shp” theme.
- Select one or several contiguous stream segments shown in Figure 7–18 with the  (Select) tool.
- Select **Basin Processing** ⇒ **River Profile**.

Method 2: Profile Tool

- Activate the “River.Shp” theme.
- Select the  (Profile) tool and view the tool tip for directions as shown in Figure 7–19.

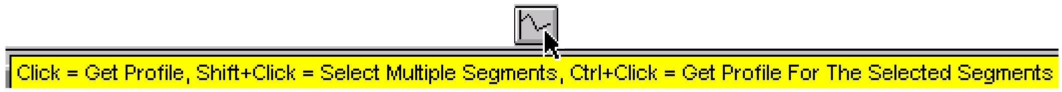


Figure 7–19. Profile tool.

- Click on the stream segment on the map to get the profile as shown in Figure 7–20.

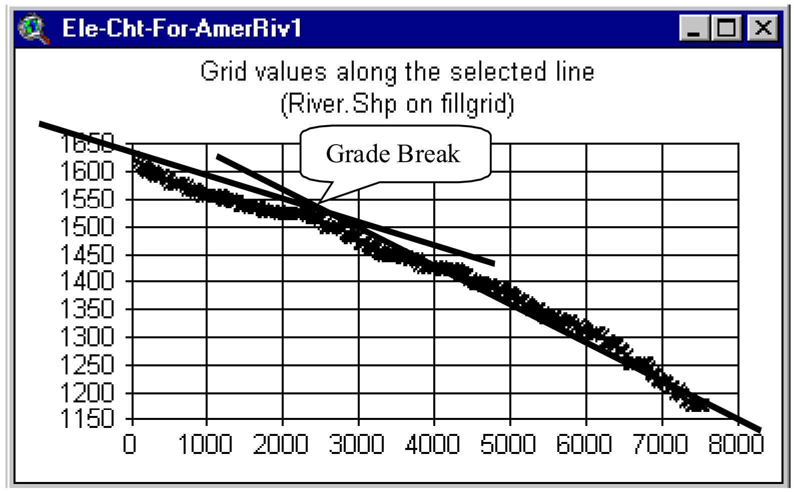


Figure 7–20. Stream profile.

The user has the capability to subdivide a basin based on grade break shown in Figure 7–20.

Steps

- Select the  (Profile Subdivide) tool when the stream profile chart is active and view the tool tip for directions as shown in Figure 7–21.

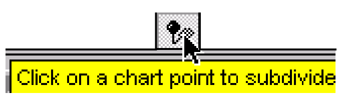


Figure 7–21. Profile subdivide tool.

- Click on the chart approximately at the grade break as shown in Figure 7–22.

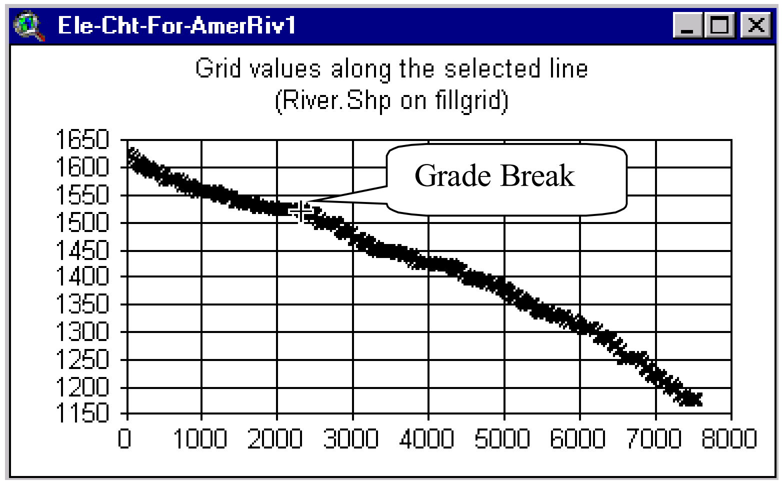
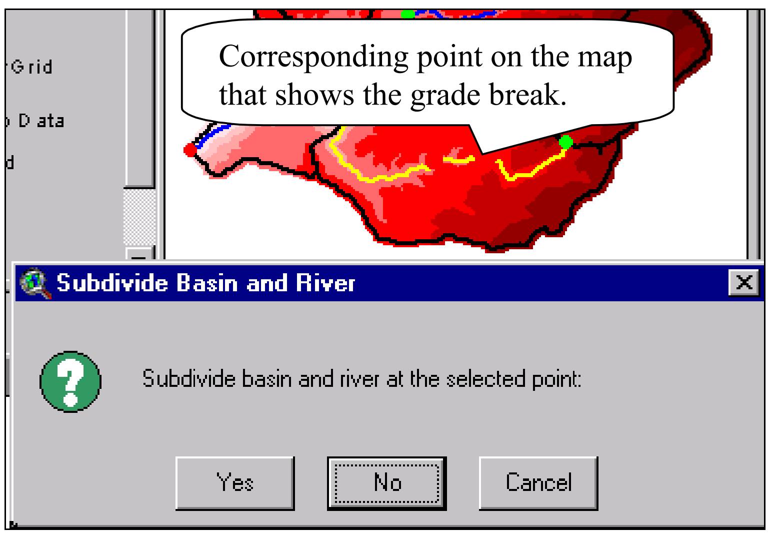


Figure 7–22. Stream profile with grade break.

- Watch the corresponding point that the user clicked as it blinks on the map display.
- Inspect the result and accept it. Press **Yes**.



- Accept the default name for the outlet. Press **OK** as shown in Figure 7–23.

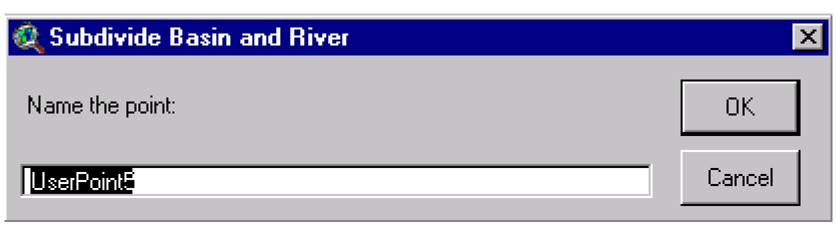


Figure 7–23. Default name for outlet.

The result of the basin subdivision is shown in Figure 7–24.

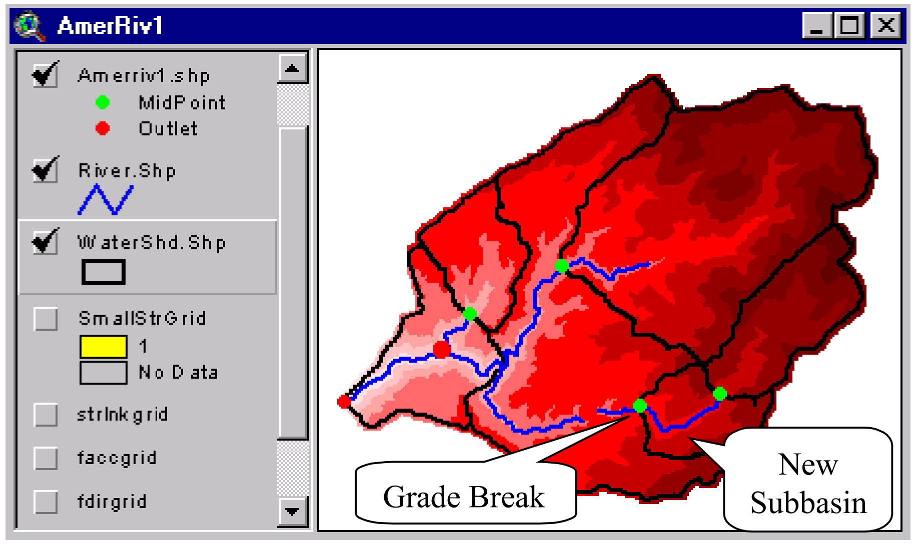


Figure 7–24. Basin subdivision from a profile.

Split Basins at Confluences

The **Split Basins at Confluences** menu item allows the user to subdivide a basin at a confluence. For the situation shown in Figure 7–25, the menu item should be used instead of the interactive  (Basin Subdivide) tool.

Rules!

- Only one basin can be selected for each operation.
- This menu item can be used with a basin having multiple confluences.

Steps

- Activate the “WaterShp.shp” theme on the ***ProjView*** document.
- Select the basin containing the confluence as shown in Figure 7–25.

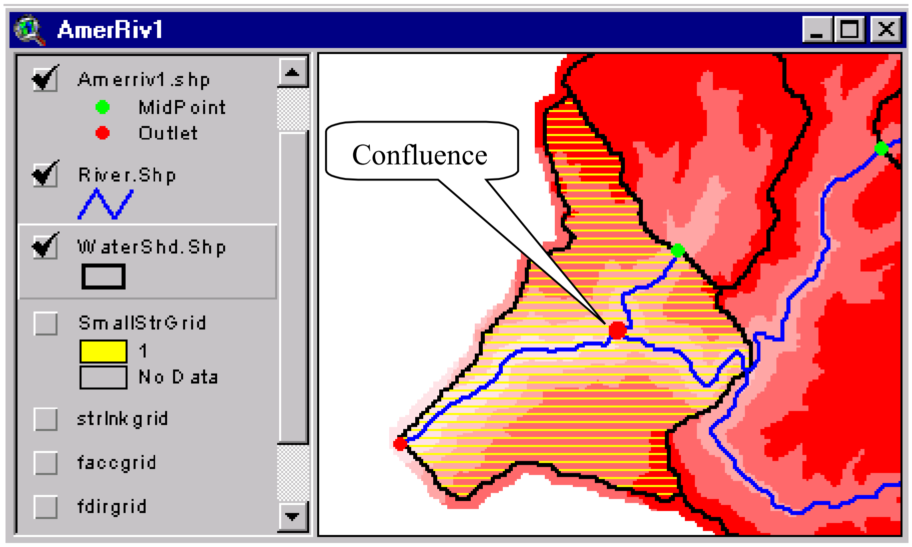


Figure 7–25. Subdivide basin at confluences.

- Select **Basin Processing ⇒ Split Basin at Confluences** as shown in Figure 7–26.

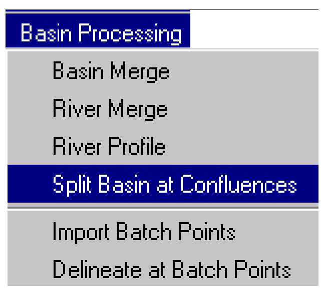


Figure 7–26. Split basin at confluences menu item.

The operation resulted in creating three subbasins as shown in Figure 7–27. One basin for each stream segments.

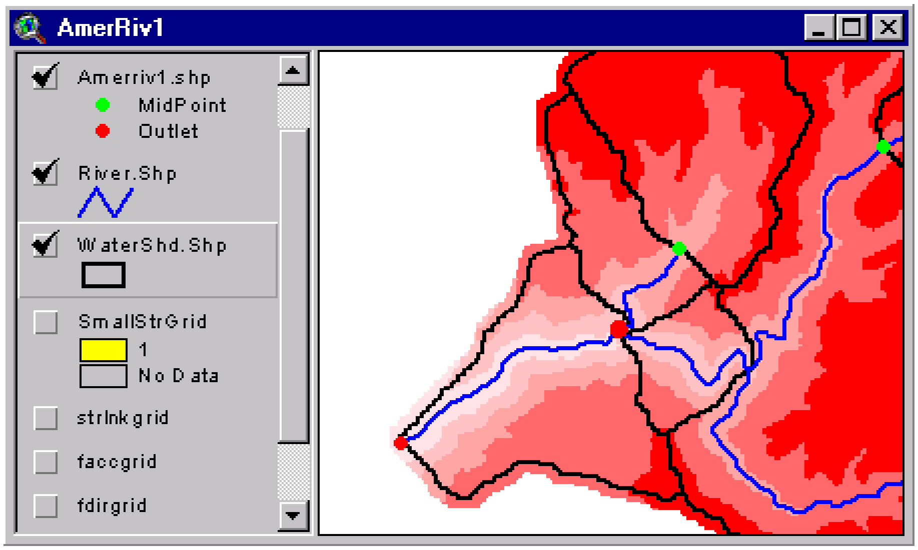


Figure 7–27. Basin subdivided at confluence.

Batch Subbasin Delineation

Subbasin delineation may also be accomplished through batch processing; this requires that a point shapefile be created which contains the desired outlet locations. It is important to recognize that the batch subbasin delineation operates on the existing delineations by further delineating with the new outlet points in the shapefile. If the user wants to abandon the existing delineation, then the user can batch process the outlet locations and follow with subbasin revisions to remove existing delineations. There are two ways to create a point shapefile for batch subbasin delineation.

Method 1: Batch Point Tool

The user applies the  (Batch Point) tool to place points on the map display and a point shapefile named "Batchpnt.Shp" is created. To use this tool effectively, the user should turn on the StrLnkGrid or SmallStrGrid, zoom in until the grid cell is visible, and place the point within the grid cell.

Rules!

- The point should be located within the grid cell that has an existing stream.

Steps

- Place four batch points in the order shown in Figure 7–28.
- Zoom in to the batch points to specify the batch points on the cells.

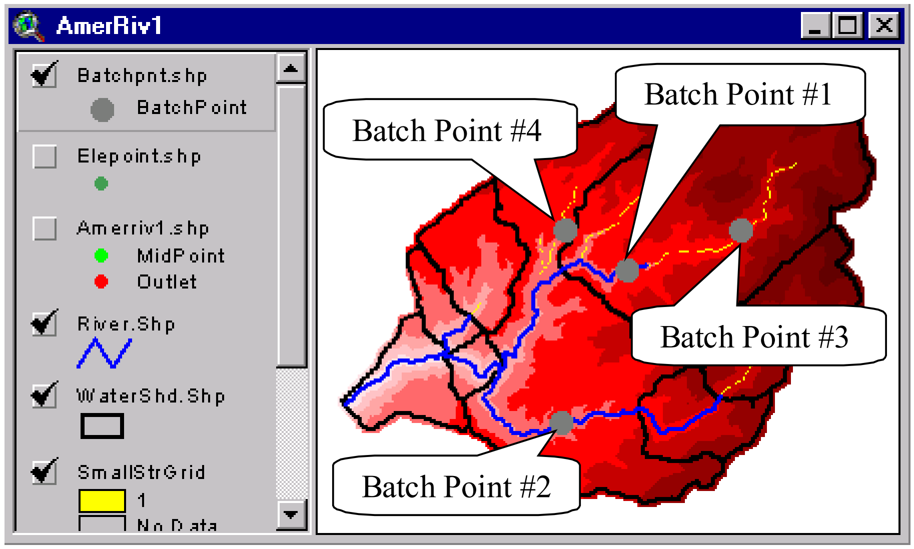


Figure 7–28. Subbasin delineation at batch points.

- Click on the grid cell to specify batch point #1 as shown in Figure 7–29. Notice that batch point #1 follows the rule concerning the presence of the existing stream.

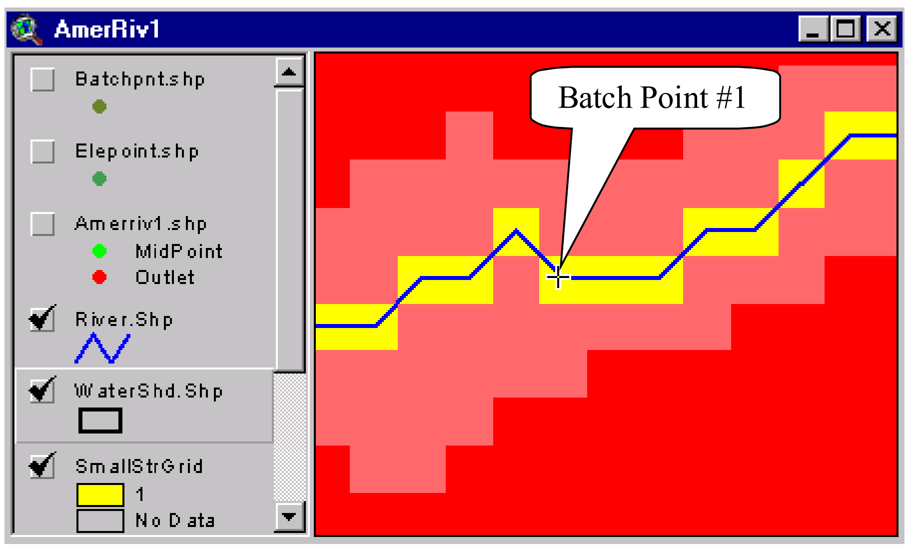


Figure 7–29. Batch Point #1 specification.

- Accept the default name as "BatchPoint1" as shown Figure 7–30. Press **OK**.

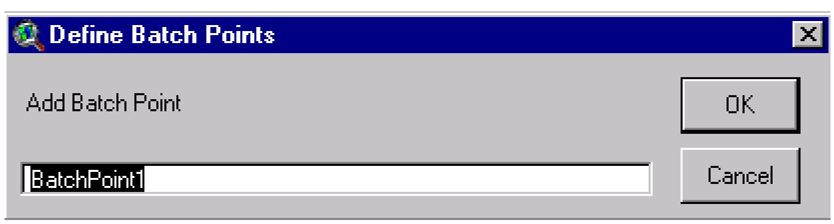


Figure 7–30. Default name for Batch Point #1 outlet.

- Locate Batch Point #2 as shown in Figure 7–32 with same procedure as before.

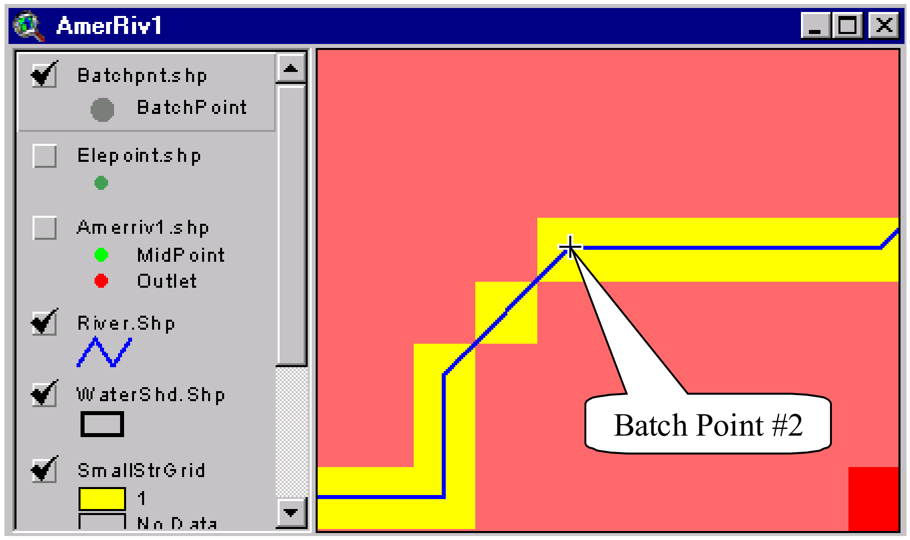


Figure 7–31. Batch Point #2 Specification

- Accept the default name as BatchPoint2 as shown in Figure 7–32. Press OK.

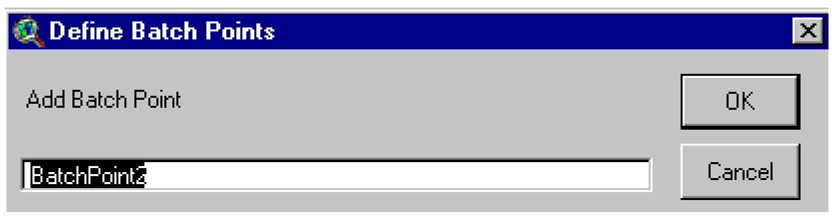


Figure 7–32. Default Name for Batch Point #2 Outlet

- Locate Batch Point #3 and #4. *Notice that Batch Point #3 and #4 violate the rule concerning the presence of the existing stream.*

The batch-point shapefile contains the essential fields that serve as instructions and information for the programs to perform batch subbasin delineation as shown in Figure 7–33. The field heading and values are discussed in Table 7-1.

Attributes of Batchpnt.shp

Shape	SnapDist	Name	ID	BatchDone	SnapOn	PntDesc	PntTYPE
Point	0.0000	BatchPoint1	1	0	1	BatchPoint	15
Point	0.0000	BatchPoint2	2	0	1	BatchPoint	15
Point	0.0000	BatchPoint3	3	0	1	BatchPoint	15
Point	0.0000	BatchPoint4	4	0	1	BatchPoint	15

Figure 7–33. Batch-Point attribute table.

Table 7-1. Batch Point Fields, Descriptions, and Values

Field Headings	Descriptions	Possible Values
Shape	Standard ArcView requirement for noting the types (point, line, polygon) of shapefiles.	Point
SnapDist	The distance between the user-specified point to the final outlet point for subbasin delineation.	Real values in map units.
Name	The name of the outlet location (can be overwritten by the user).	Text
ID	An identifier for tracking the number of points generated.	Integer values
BatchDone	An indicator if batch processing has been performed for the points.	“0” indicates that batch processing has not been performed yet. “1” indicates that batch processing has been performed. “-1” indicates that batch processing has been performed unsuccessfully.
SnapOn	A flag that can be set to enable snapping of the user-specified point to the stream.	“1” enables snapping as a default. “0” can be entered by the user to disable snapping.
PntDesc	A textual description for the user-specified point.	“Batchpoint”
PntTYPE	A numerical value that corresponds to the PntDesc.	“15” corresponds to the batch point type.

- To process the batch points in the “Batchpnt.shp”, select **Basin Process ⇒ Delineate at Batch Points** as shown in Figure 7–34.

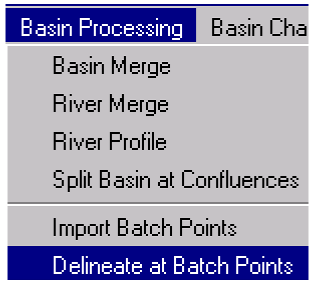


Figure 7–34. Delineate at Batch Points menu item.

The result of the batch delineation is shown in Figure 7–35. Notice that BatchPoint #1 and #2 have been successfully delineated. However, BatchPoint #3 and #4 did not result in subbasin delineation because their placements do not comply with the rules.

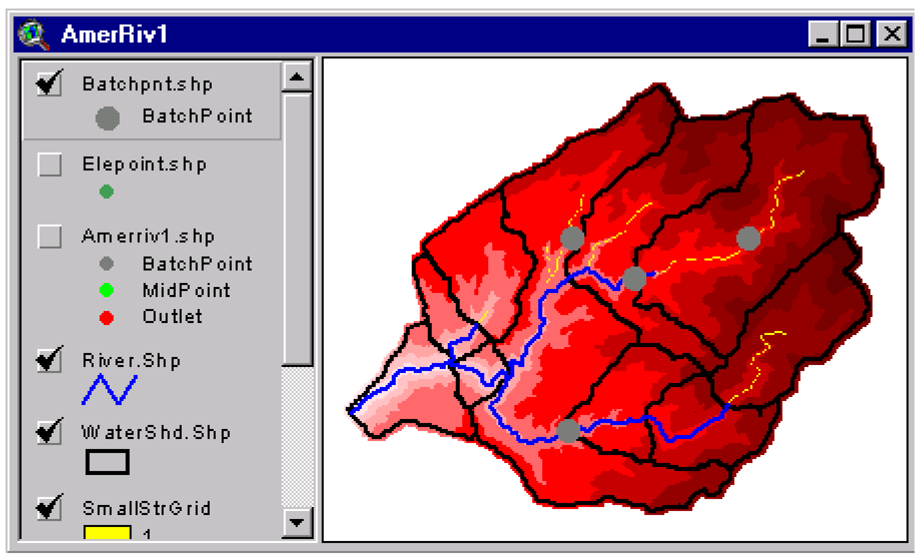
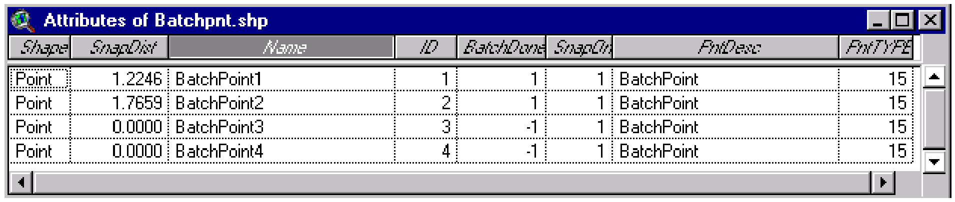


Figure 7–35. Batch points delineation results.

The attribute table of the “Batchpnt.shp” also shows a negative confirmation for subbasin delineation at Batch Points #3 and #4. Notice the “-1” under the BatchDone field heading as shown in Figure 7–36.



Shape	SnapDist	Name	ID	BatchDone	SnapOn	PntDesc	PntTYPE
Point	1.2246	BatchPoint1	1	1	1	BatchPoint	15
Point	1.7659	BatchPoint2	2	1	1	BatchPoint	15
Point	0.0000	BatchPoint3	3	-1	1	BatchPoint	15
Point	0.0000	BatchPoint4	4	-1	1	BatchPoint	15

Figure 7–36. Batch point attribute table after subbasin delineation.

Method 2: Import Batch Points

This method is useful when the user has existing point shapefiles containing points of interest, stream flow gage locations, and/or previous hydrologic model outlet specifications. The user can import the existing point shapefile to prepare a batch point shapefile.

As an example, the streamflow gage locations in the "Gage.shp" as shown in Figure 7–37 can be imported into "Batchpnt.Shp".

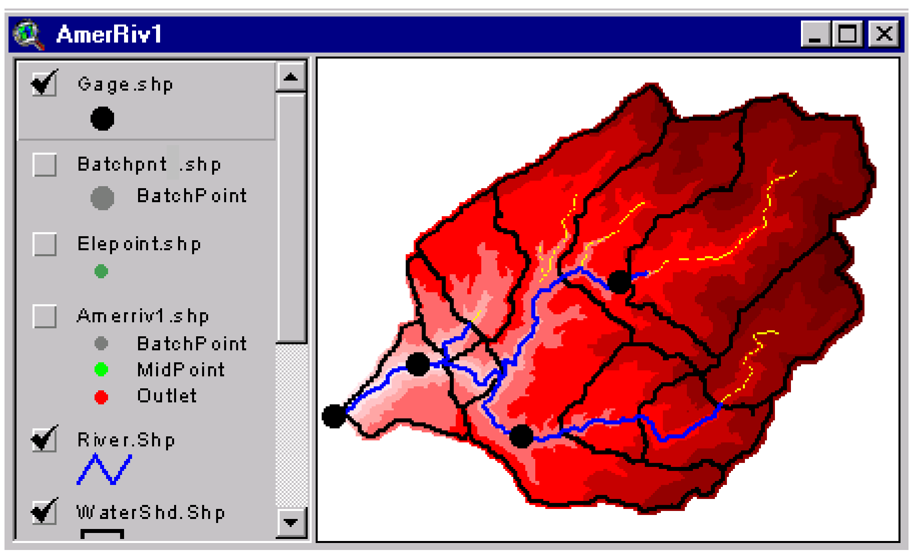


Figure 7–37. Import batch points.

Steps

- Select the **Basin Processing ⇒ Import Batch Points** as shown in Figure 7–38.

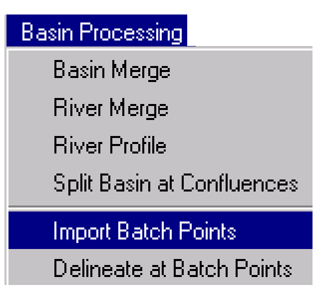


Figure 7–38. Import batch points menu item.

- Select the "Gage.shp" theme as the input from the drop down menu as shown in Figure 7–39. Press **OK**.

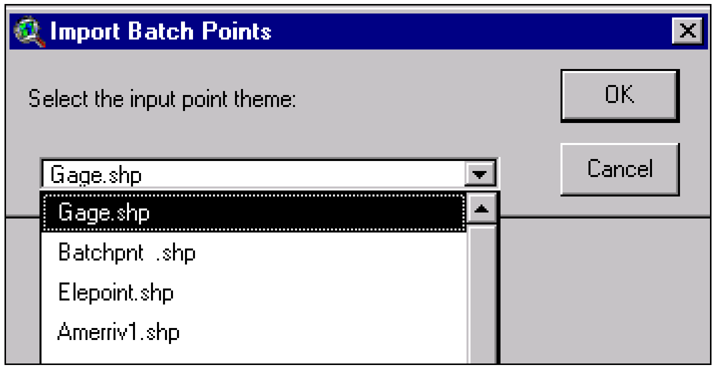


Figure 7–39. Input point theme selection.

- With the field names available in the "Gage.shp", select the gage number, "Gage_No", field to be imported in for the Name field in the "Batchpnt.shp" as shown in Figure 7–40. The "Gage_No" field is a suitable choice because it has unique values. Press **OK**.

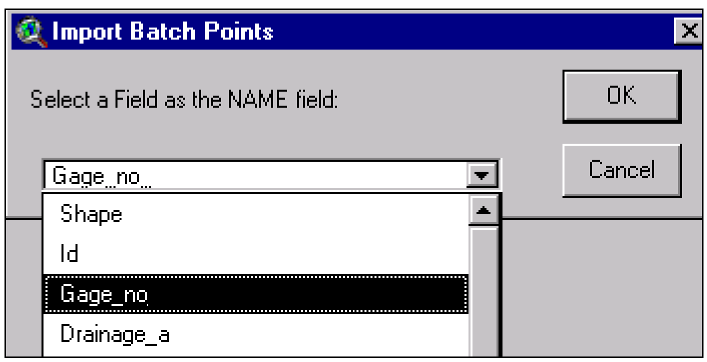


Figure 7–40. Field selection as name field.

- Press **Yes** on Figure 7–41 to enable snapping.

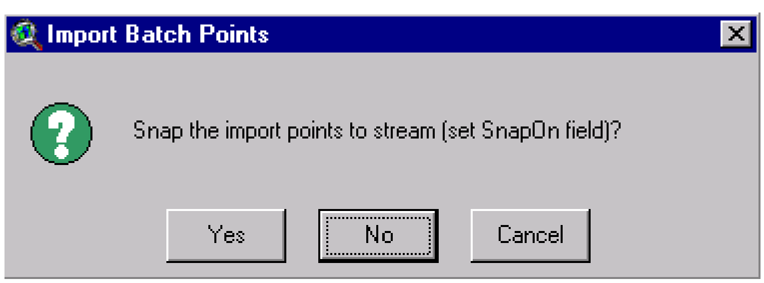


Figure 7–41. Snap options.

The result indicates that the four gages in the "Gage.shp" have been imported into the "Batchpnt.shp" as shown in Figure 7–42. Press **OK**.

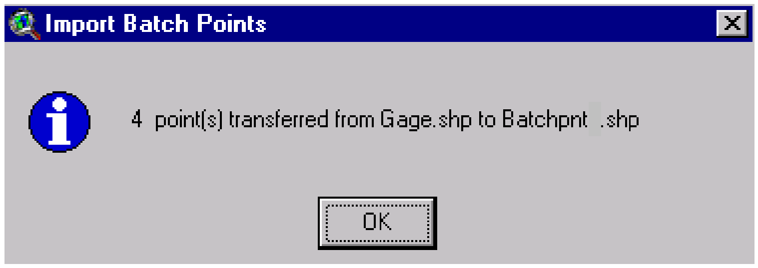


Figure 7–42. Import batch points confirmation.

The "Batchpnt.shp" now contains 8 batch points as shown in Figure 7–43. The four recently added batch points are shown in yellow (if the document is in color) or white (if this document is in black and white) in Figure 7–44.

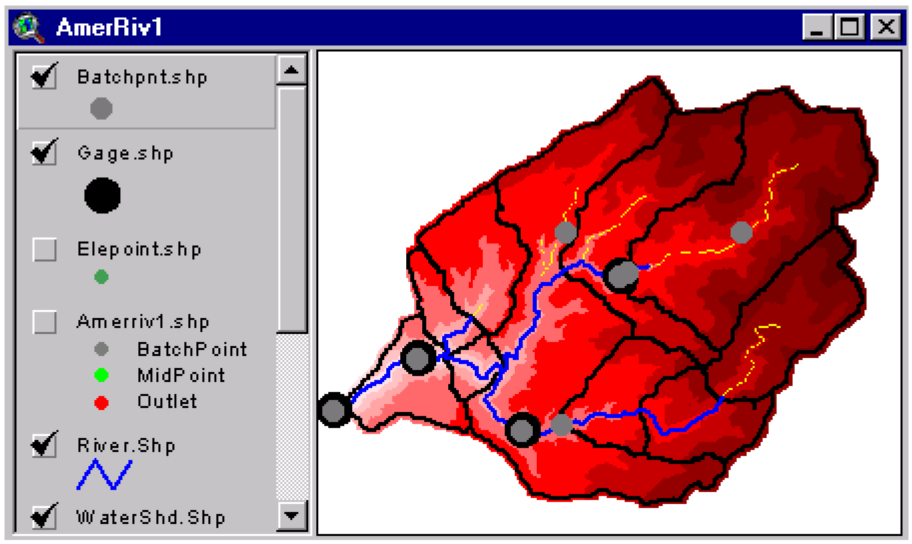


Figure 7–43. Import batch points result.

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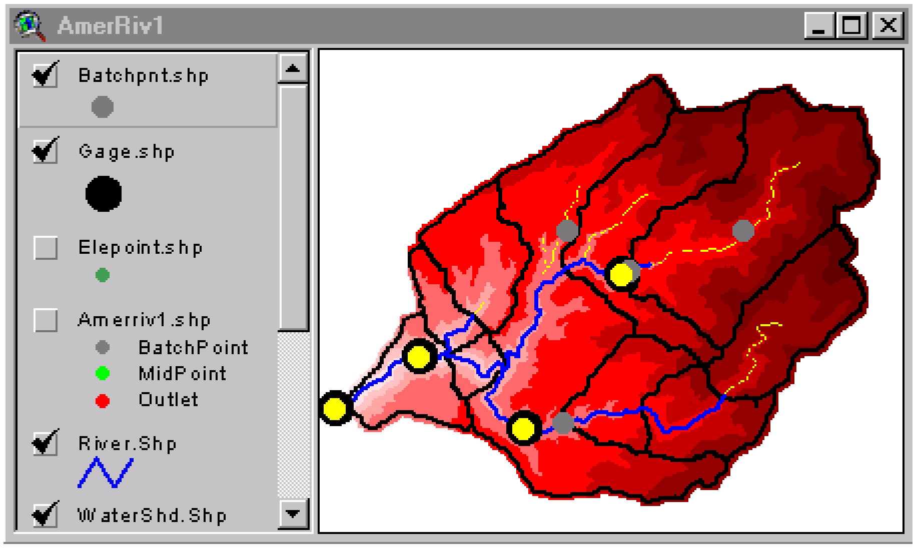
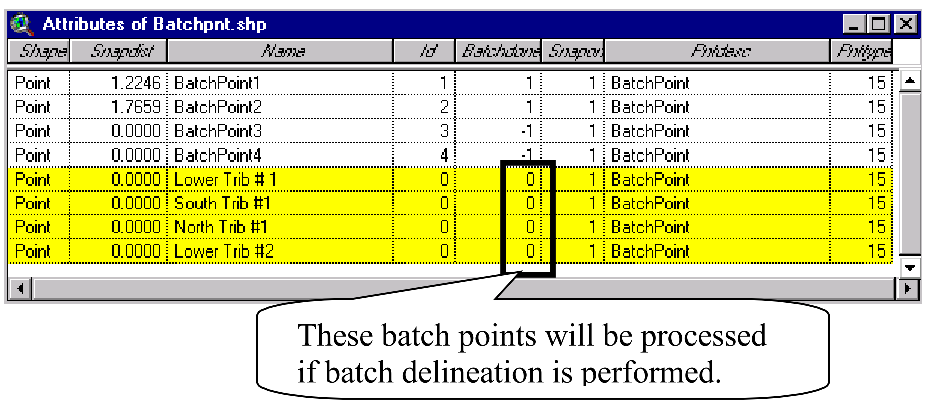


Figure 7–44. Imported batch points in yellow or white.

As shown in Figure 7–45, the “BatchDone” flags are set to “0” to indicate that the user can re-run the **Delineate at Batch Points** menu item to delineate subbasin at the four newly added batch points.



Attributes of Batchpnt.shp

Shape	Snapdist	Name	Id	Batchdone	Snapon	Pntdesc	Pnttype
Point	1.2246	BatchPoint1	1	1	1	BatchPoint	15
Point	1.7659	BatchPoint2	2	1	1	BatchPoint	15
Point	0.0000	BatchPoint3	3	-1	1	BatchPoint	15
Point	0.0000	BatchPoint4	4	-1	1	BatchPoint	15
Point	0.0000	Lower Trib # 1	0	0	1	BatchPoint	15
Point	0.0000	South Trib #1	0	0	1	BatchPoint	15
Point	0.0000	North Trib #1	0	0	1	BatchPoint	15
Point	0.0000	Lower Trib #2	0	0	1	BatchPoint	15

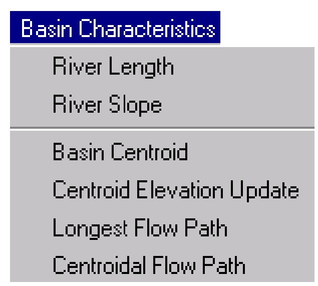
Figure 7–45. Batch-Points attribute table.

CHAPTER 8

Stream and Watershed Characteristics

HEC-GeoHMS computes several topographic characteristics of streams and watersheds. These characteristics are useful for comparison of basins and for estimating hydrologic parameters. The user should compare and verify the physical characteristics with published information prior to estimating the hydrologic parameters. The stream and watershed physical characteristics are stored in attribute tables, which can be exported for use with a spreadsheet and other programs. When more experience is gained from working with GIS data, initial estimates of hydrologic parameters will be provided in addition to the physical characteristics.

This chapter will discuss the tools for extracting topographic characteristics of the watershed and river that are available in the ***ProjView*** GUI under the **Basin Characteristics** menu.



The physical characteristics extracted for the streams and subbasins are summarized in Table 8-1.

Contents

- River Length
- River Slope
- Basin Centroid
- Longest Flow Path
- Centroidal Flow Path

Table 8-1. Physical Characteristics of streams and subbasins

	Physical Characteristics	Attribute Table Heading
Stream (River.Shp)	Length	Riv_Length
	Upstream elevation	US_Elv
	Downstream elevation	DS_Elv
	Slope	Slp_Endpt
	Stream Profile	N/A (See Chart)
Watershed (WaterShd.shp)	Area	Area
	Centroid Location	N/A (See WshCentroid.shp)
	Centroid Elevation	Elevation
	Longest Flow Path	N/A (See LongestFP.shp)
	Longest Flow Length	Longest_FL
	Upstream elevation	USElv
	Downstream elevation	DSElv
	Slope between endpoints	Slp_Endpt
	Slope between 10% - 85%	Slp_1085
	Centroidal Path	N/A (See CentoidalFP.shp)
	Centroidal Length	CentroidalFL

The following sections illustrate the process outlined under the **Basin Characteristics** menu on the ***ProjView*** GUI to extract the stream and subbasin characteristics.

River Length

This step computes the river length for all subbains and routing reaches in the "River.shp" file as shown in Figure 8–1. The initial attribute table prior to any computations for "River.shp" theme is shown in Figure 8–2. The computed river length is added as an attribute to the existing "River.shp" file as shown in Figure 8–2. The length column in the attribute table is computed roughly from the raster representation of the stream. This step will compute the river length more accurately with the vector representation of the stream.

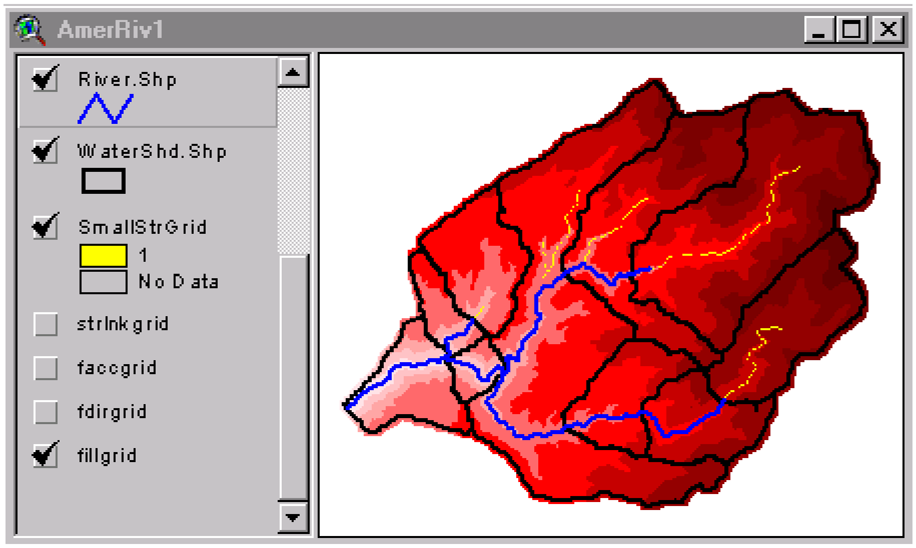


Figure 8–1. River shapefile.

Attributes of River.Shp

Shape	Arcid	Grid_code	From_node	To_node	Wshld	Rivld	Length
PolyLine	1	2	1	2	2	2	3190
PolyLine	2	4	2	3	9	4	2749
PolyLine	3	2	4	2	2	6	3089
PolyLine	0	2	0	0	5	7	1913
PolyLine	0	0	0	0	6	8	64
PolyLine	0	0	0	0	11	12	1853
PolyLine	0	0	0	0	7	11	45
PolyLine	0	0	0	0	10	13	1261
PolyLine	0	2	0	0	8	14	2480
PolyLine	0	2	0	0	12	15	455
PolyLine	0	2	0	0	13	16	1953

Figure 8–2. Initial attribute table for the river shapefile.

Steps

- Select **Basin Charateristics ⇒ River Length** as shown in Figure 8–3.

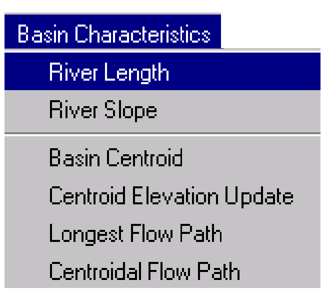
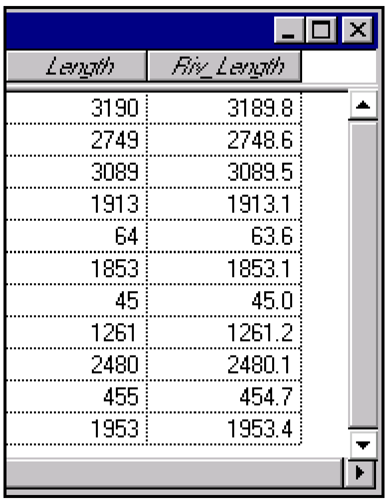


Figure 8–3. River length menu item.

- Press **OK** at the message box as shown in Figure 8–4.

Figure 8–4. River length confirmation.

The result of the river length computation is the "Riv_Length" column added to the initial attribute table as shown in Figure 8–5. "Riv_Length" is in the map units, which are meters in this example.



Length	Riv_Length
3190	3189.8
2749	2748.6
3089	3089.5
1913	1913.1
64	63.6
1853	1853.1
45	45.0
1261	1261.2
2480	2480.1
455	454.7
1953	1953.4

Figure 8–5. Populated attribute table with river length.

River Slope

This step extracts the upstream and downstream elevation of a river reach and computes the slope. The upstream and downstream elevation and slope are added as columns to the "River.shp" attribute table with the column headings: "us_Elv", "ds_Elv", and "Slp_Endpt".

Steps

- Select **Basin Characteristics** ⇒ **River Slope** as shown in Figure 8–6.

Figure 8–6. River Slope menu item

- Select the **DEM Vertical Units** as **meters** as shown Figure 8–7 because this terrain data has both the vertical and horizontal units in meters. Sometimes, the terrain data has the horizontal units of meters and the vertical units in feet or decimeters. Press **OK**.

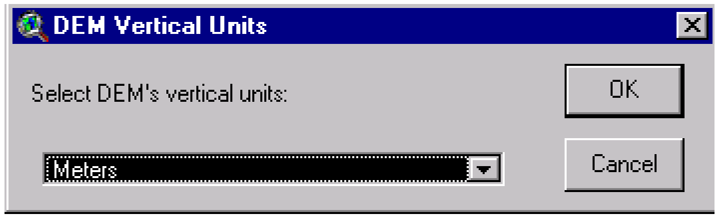


Figure 8–7. DEM vertical units.

- Press **OK** at the confirmation as shown in Figure 8–8.

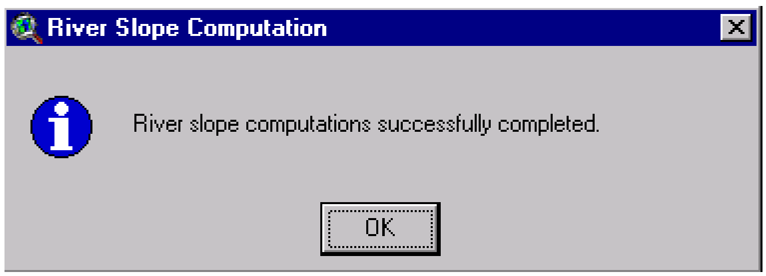
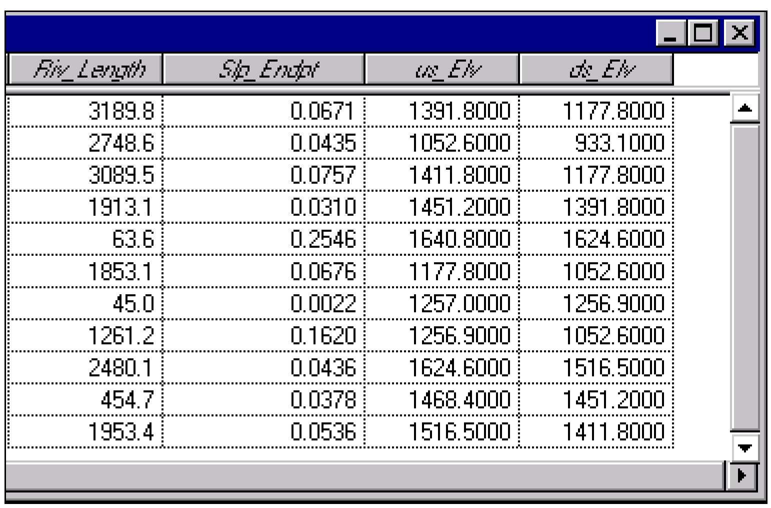


Figure 8–8. River slope confirmation.

The river slope computation results in adding the upstream and downstream elevations and slope to the existing attribute table as shown in Figure 8–9.



Riv_Length	Slp_Endpt	us_Elv	ds_Elv
3189.8	0.0671	1391.8000	1177.8000
2748.6	0.0435	1052.6000	933.1000
3089.5	0.0757	1411.8000	1177.8000
1913.1	0.0310	1451.2000	1391.8000
63.6	0.2546	1640.8000	1624.6000
1853.1	0.0676	1177.8000	1052.6000
45.0	0.0022	1257.0000	1256.9000
1261.2	0.1620	1256.9000	1052.6000
2480.1	0.0436	1624.6000	1516.5000
454.7	0.0378	1468.4000	1451.2000
1953.4	0.0536	1516.5000	1411.8000

Figure 8–9. Populated attribute table with river slope.

Basin Centroid

The basin centroid location is estimated in four ways. The engineering approach to locating the centroid with momentum calculations around the X- and Y-axis is not implemented here because the centroid may be outside of U-shaped and other odd-shaped subbasins. The four methods of estimating the centroid are the bounding box, ellipse, flow path, and user-specified. The basin centroid menu item can operate on all of the subbasins or on selected subbasin.

Steps

- Select **Basin Charateristics ⇒ Basin Centroid,** as shown in Figure 8–10.

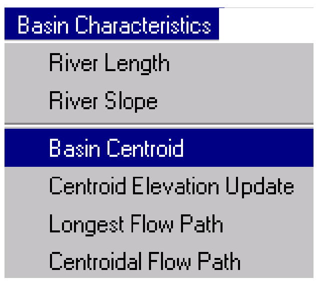


Figure 8–10. Basin Centroid menu item

- Confirm the three inputs and one output in the operation as shown in Figure 8–11. Press **OK**.

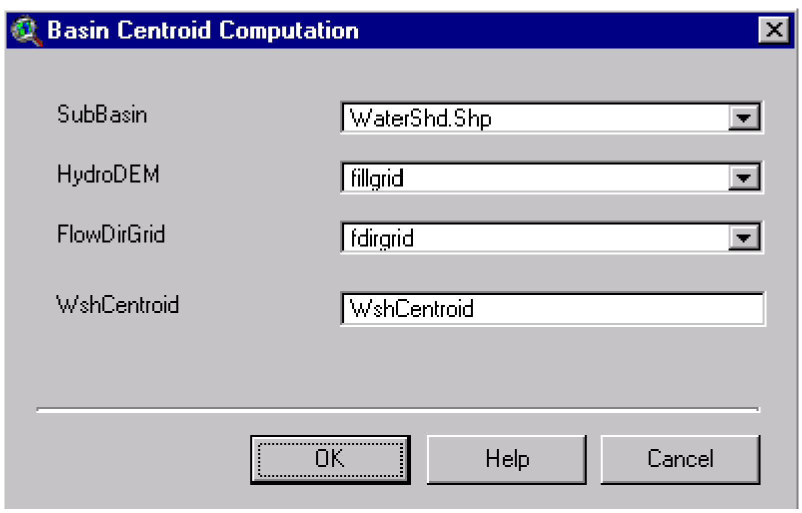


Figure 8–11. Basin centroid input and output files.

Method 1: Bounding Box

The Bounding Box method encompasses a subbasin with a rectangular box and approximates the centroid as the box center. This method works really fast but may not be applicable with many basin shapes.

- Select **Bounding Box Method** from the dropdown menu. Press **OK**.

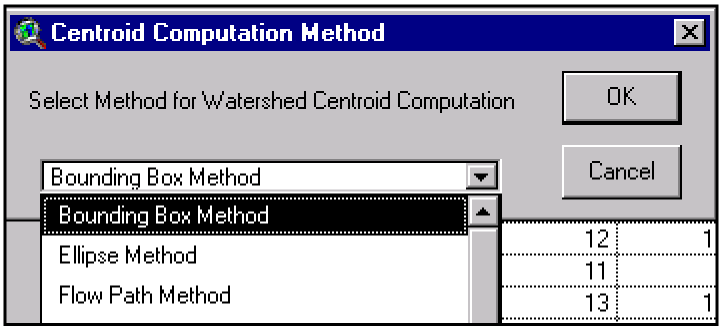


Figure 8–12. Centroid computation methods.

- Press OK at the confirmation as shown in Figure 8–13.

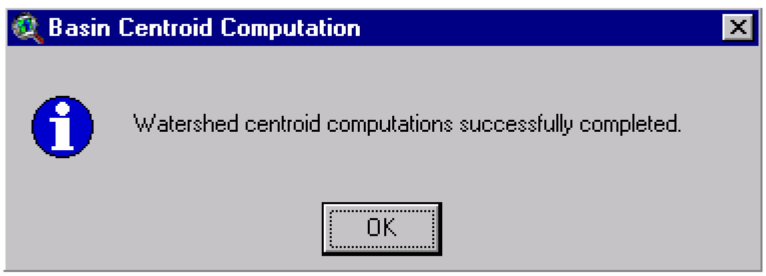


Figure 8–13. Centroid confirmation.

The result of the operation is a point shapefile, "WshCentroid.Shp", showing the basin centroids as shown in Figure 8–14.

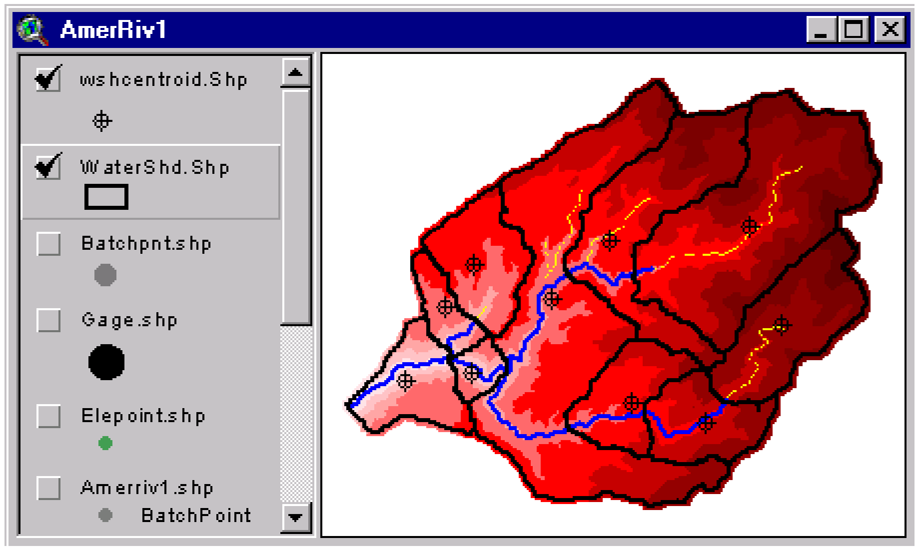


Figure 8–14. Basin centroid results.

The basin centroid elevation is computed and stored in the attribute table as shown in Figure 8–15. In addition, the basin centroid elevation is also stored in the "WaterShd.shp" attribute table as shown in Figure 8–16.

Attributes of wshcentroid.Shp

Shape	Wshld	Elevation
Point	2	1501.1000
Point	5	1545.2000
Point	6	1821.1000
Point	7	1509.5000
Point	8	1597.2000
Point	10	1456.5000
Point	11	1092.1000
Point	9	1223.2000
Point	12	1633.7000
Point	13	1605.4000

Figure 8–15. Basin centroid attribute table.

Attributes of WaterShd.Shp

Shape	Id	Gridcode	Area	Wshld	TopoDone	Perimeter	Elevation
Polygon	1	2	18795600.00	2	0	41940.00000	1501.1000
Polygon	0	2	8898300.000	5	0	25320.00000	1545.2000
Polygon	0	0	6289200.000	6	0	15660.00000	1821.1000
Polygon	0	0	4391100.000	7	0	12000.00000	1509.5000
Polygon	0	2	3858300.000	8	0	11520.00000	1597.2000
Polygon	0	4	1674900.000	10	0	8580.000000	1456.5000
Polygon	0	4	1104300.000	11	0	5760.000000	1092.1000
Polygon	0	4	3690000.000	9	0	11520.00000	1223.2000
Polygon	0	2	14752800.00	12	0	23220.00000	1633.7000
Polygon	0	2	3779100.000	13	0	12060.00000	1605.4000

Figure 8–16. Watershed attribute table with centroidal elevation.

Method 2: Ellipse Method

The Ellipse method encompasses a subbasin with an ellipse and approximates the centroid as the ellipse center. This method is slower than the bounding box, but it generally produces more desirable estimates of the basin centroids.

Rules!

- This method works only on subbasins of 2,000,000 cells or less.

Steps

- Activate the “WaterShd.Shp” theme.
- Select the subbasin as shown in Figure 8–17.

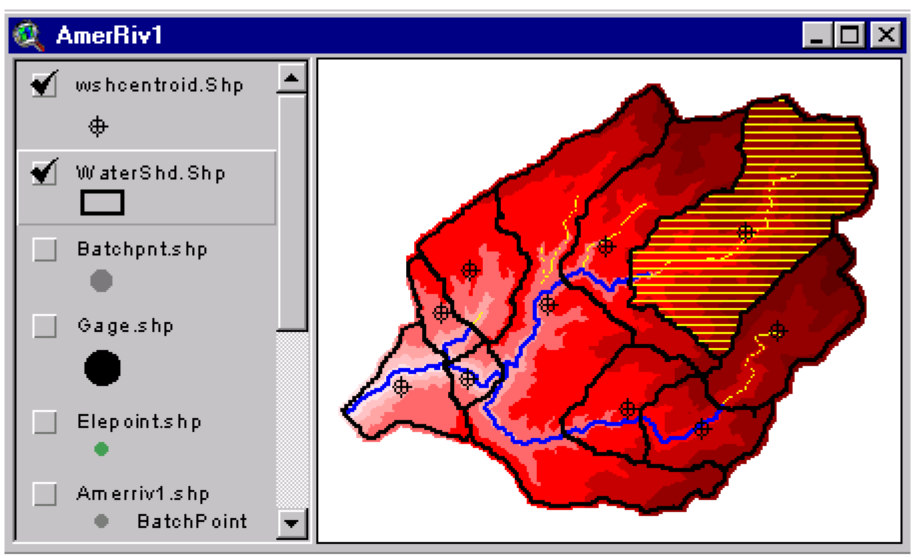
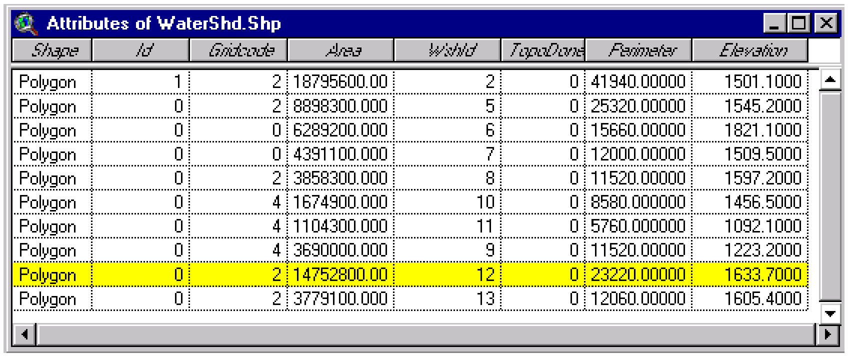


Figure 8–17. Basin centroid with ellipse method.

- Open the “WaterShd.Shp” attribute table. The highlighted row belongs to the selected subbasin. Notice that the centroid elevation is 1633.7.



Attributes of WaterShd.Shp

Shape	Id	Gridcode	Area	Wshld	TopoDone	Perimeter	Elevation
Polygon	1	2	18795600.00	2	0	41940.00000	1501.1000
Polygon	0	2	8898300.000	5	0	25320.00000	1545.2000
Polygon	0	0	6289200.000	6	0	15660.00000	1821.1000
Polygon	0	0	4391100.000	7	0	12000.00000	1509.5000
Polygon	0	2	3858300.000	8	0	11520.00000	1597.2000
Polygon	0	4	1674900.000	10	0	8580.000000	1456.5000
Polygon	0	4	1104300.000	11	0	5760.000000	1092.1000
Polygon	0	4	3690000.000	9	0	11520.00000	1223.2000
Polygon	0	2	14752800.00	12	0	23220.00000	1633.7000
Polygon	0	2	3779100.000	13	0	12060.00000	1605.4000

Figure 8–18. Watershed attribute table with one subbasin selected.

- Select the **Basin Charateristics ⇒ Basin Centroid**
- Select the **Ellipse Method** from the dropdown menu as shown in Figure 8–19. Press OK.

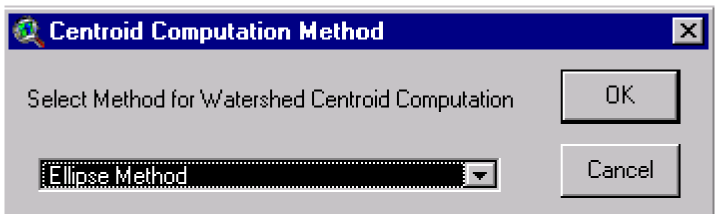


Figure 8–19. Basin centroid with ellipse method selected.

A new centroid is re-computed for the selected subbasin as shown in figure. The ellipse method produces a centroid that is adjusted slightly compared to the bounding box method. The elevation of the centroid is automatically updated in the "Wshcentroid.shp." The "Watershd.shp" and the attribute table are shown in Figure 8–20 and Figure 8–21.

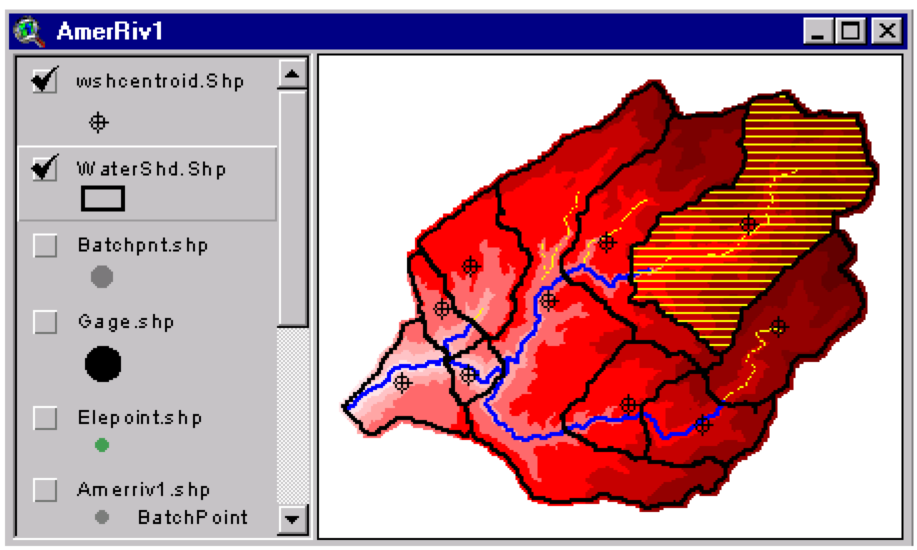
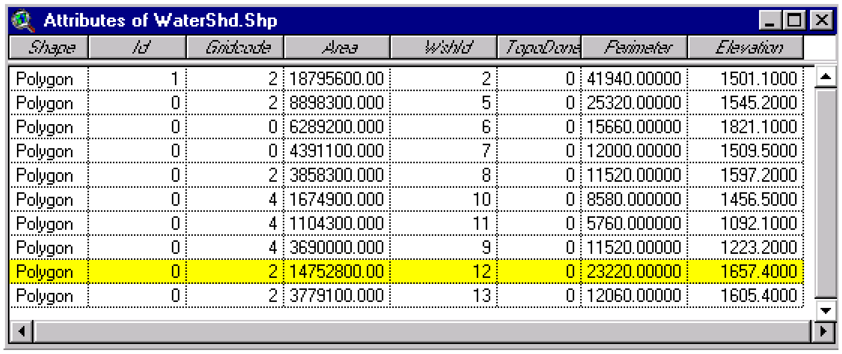


Figure 8–20. Ellipse method basin centroid result.



Attributes of WaterShd.Shp

Shape	Id	Gridcode	Area	Wshid	TopoDone	Perimeter	Elevation
Polygon	1	2	18795600.00	2	0	41940.00000	1501.1000
Polygon	0	2	8898300.000	5	0	25320.00000	1545.2000
Polygon	0	0	6289200.000	6	0	15660.00000	1821.1000
Polygon	0	0	4391100.000	7	0	12000.00000	1509.5000
Polygon	0	2	3858300.000	8	0	11520.00000	1597.2000
Polygon	0	4	1674900.000	10	0	8580.000000	1456.5000
Polygon	0	4	1104300.000	11	0	5760.000000	1092.1000
Polygon	0	4	3690000.000	9	0	11520.00000	1223.2000
Polygon	0	2	14752800.00	12	0	23220.00000	1657.4000
Polygon	0	2	3779100.000	13	0	12060.00000	1605.4000

Figure 8–21. Centroidal elevation updated in watershed attribute table.

Method 3: Flow Path

The Flow Path method draws the longest flow length for the subbasin and approximates the centroid as the midpoint on the longest flow length.

Steps

- Activate the “WaterShd.Shp” theme.
- Select the subbasin as shown in Figure 8–22.

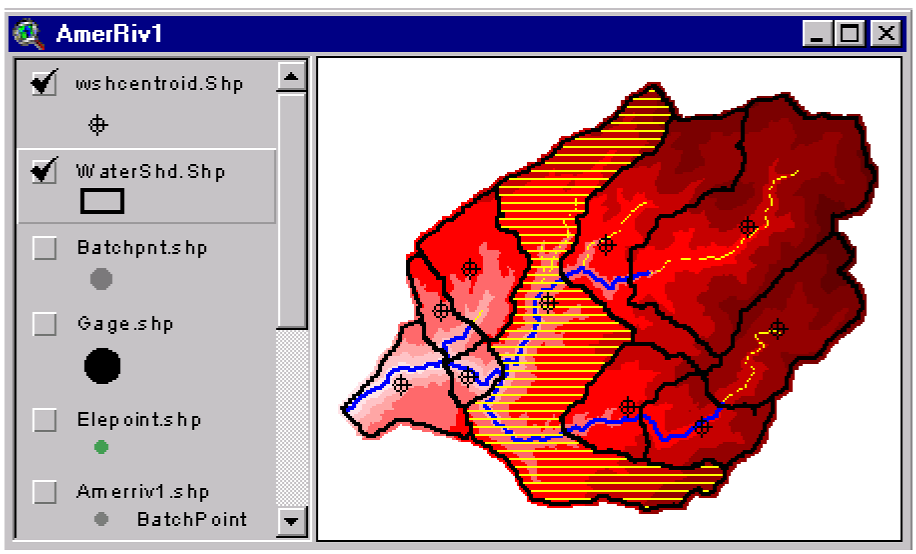


Figure 8–22. Basin centroid with flow path method.

- Select the **Basin Characteristics ⇒ Basin Centroid**
- Select the **Flow Path Method** from the dropdown menu as shown in Figure 8–23. Press OK.

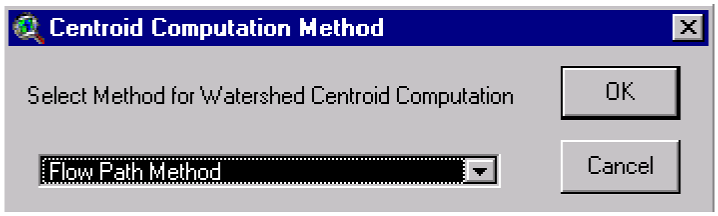


Figure 8–23. Basin centroid with flow path method selected.

Confirm the three inputs and one output in the operation as shown in Figure 8–24. The longest flow path, stored in “Longestfp.shp” theme, is computed for the selected subbasin. Press OK.

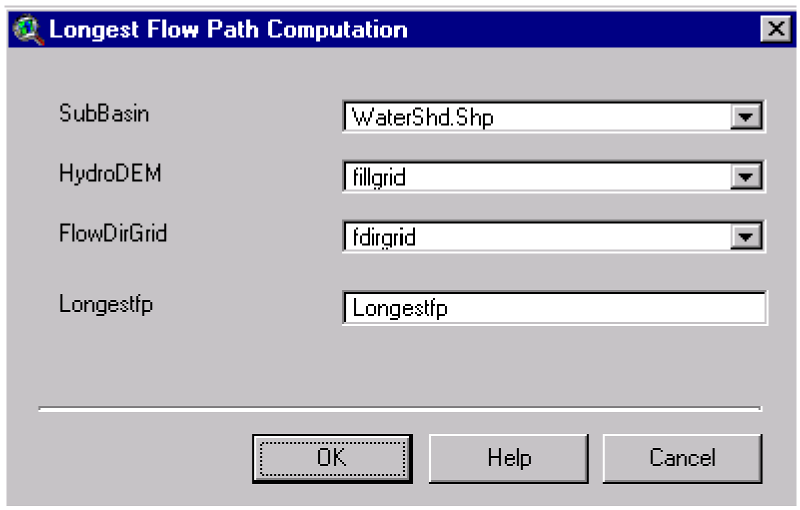


Figure 8–24. Flow path method input and output files.

The results are shown in Figure 8–25. A new centroid is re-computed for the selected subbasin. The elevation of the centroid is automatically updated in the “Wshcentroid.shp” and “Watershd.shp” attribute tables as shown in Figure 8–26.

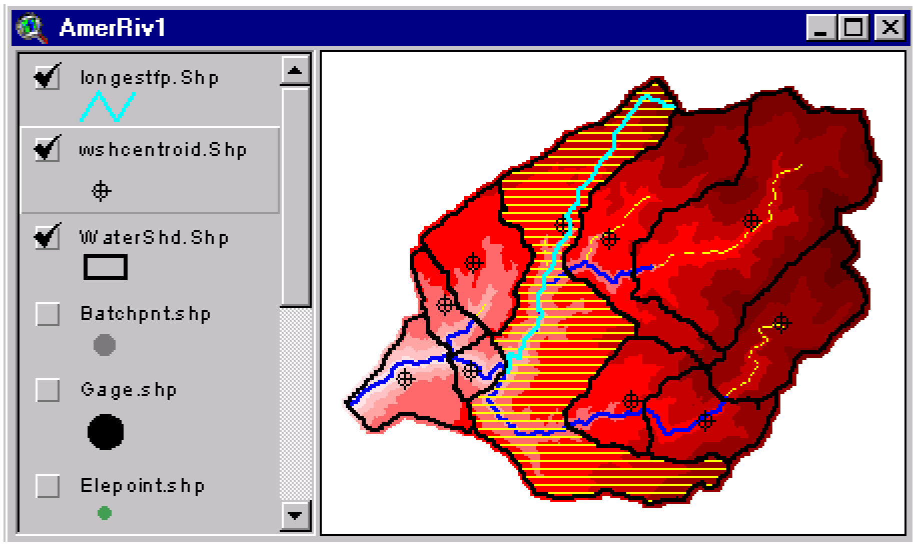


Figure 8–25. Flow Path method basin centroid result.

Attributes of WaterShd.Shp

Shape	Id	Gridcode	Area	Wshld	TopoDone	Perimeter	Elevation
Polygon	1	2	18795600.00	2	0	41940.00000	1487.0000
Polygon	0	2	8898300.000	5	0	25320.00000	1545.2000
Polygon	0	0	6289200.000	6	0	15660.00000	1821.1000
Polygon	0	0	4391100.000	7	0	12000.00000	1509.5000
Polygon	0	2	3858300.000	8	0	11520.00000	1597.2000
Polygon	0	4	1674900.000	10	0	8580.000000	1456.5000
Polygon	0	4	1104300.000	11	0	5760.000000	1092.1000
Polygon	0	4	3690000.000	9	0	11520.00000	1223.2000
Polygon	0	2	14752800.00	12	0	23220.00000	1657.4000
Polygon	0	2	3779100.000	13	0	12060.00000	1605.4000

Figure 8–26. Centroidal elevation updated with the Flow Path method.

Method 4: User-Specified Centroid Location

When the three previous methods do not produce satisfactory estimates of the centroid, this method allows to user to move the centroid to any location within the subbasin.

Steps

- Select the subbasin as shown in Figure 8–27.

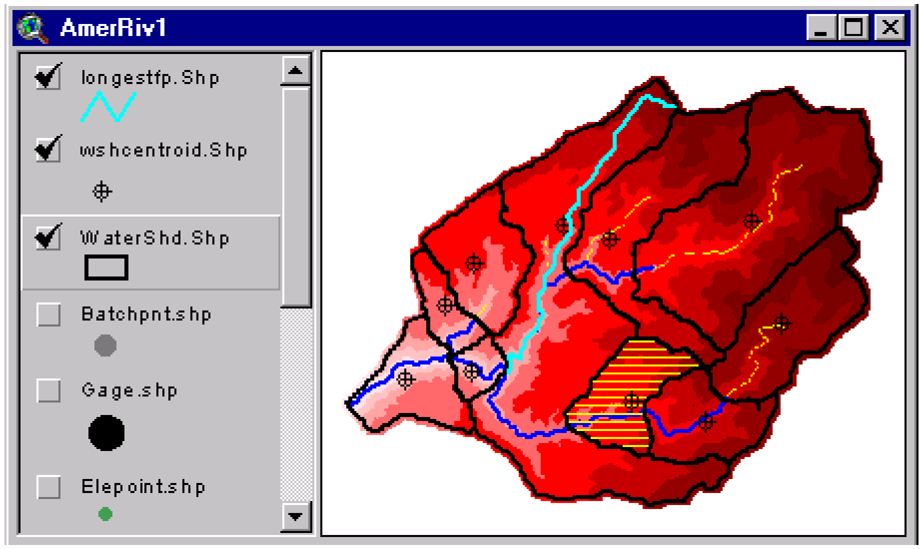


Figure 8–27. Selected subbasin for User-Specified method.

- Zoom in to the selected subbasin as shown in Figure 8–28.
- Open the "WaterShd.Shp" attribute table as shown in Figure 8–29.

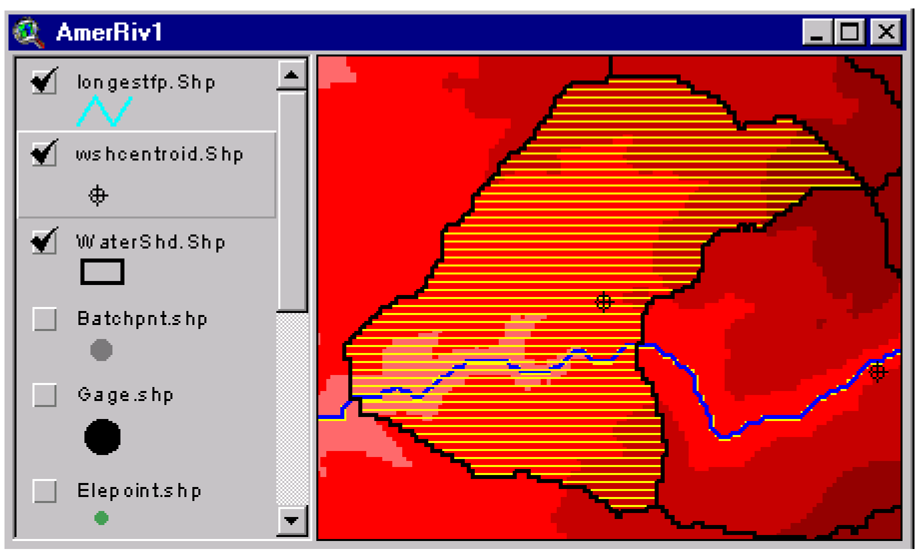


Figure 8–28. Zoom in to the selected subbasin.

Attributes of WaterShd.Shp

Shape	Id	Gridcode	Area	Wshld	TopoDone	Perimeter	Elevation
Polygon	1	2	18795600.00	2	0	41940.00000	1487.0000
Polygon	0	2	8898300.000	5	0	25320.00000	1545.2000
Polygon	0	0	6289200.000	6	0	15660.00000	1821.1000
Polygon	0	0	4391100.000	7	0	12000.00000	1509.5000
Polygon	0	2	3858300.000	8	0	11520.00000	1597.2000
Polygon	0	4	1674900.000	10	0	8580.000000	1456.5000
Polygon	0	4	1104300.000	11	0	5760.000000	1092.1000
Polygon	0	4	3690000.000	9	0	11520.00000	1223.2000
Polygon	0	2	14752800.00	12	0	23220.00000	1657.4000
Polygon	0	2	3779100.000	13	0	12060.00000	1605.4000

Figure 8–29. Watershed attribute table with the selected subbasin.

- Activate the “WshCentroid.Shp” theme.
- Select **Theme ⇒ Starting Editing** from the standard ArcView GUI as shown in Figure 8–30.

Figure 8–30. Start Editing menu item.

- When the “WshCentroid.Shp” is under editing mode, a dashed box is visible around the check box as shown in Figure 8–31.
- Use the pointer tool and click on the existing centroid.
- The pointer turns into a double arrow.
- Click and drag the centroid to another location as shown in Figure 8–31.

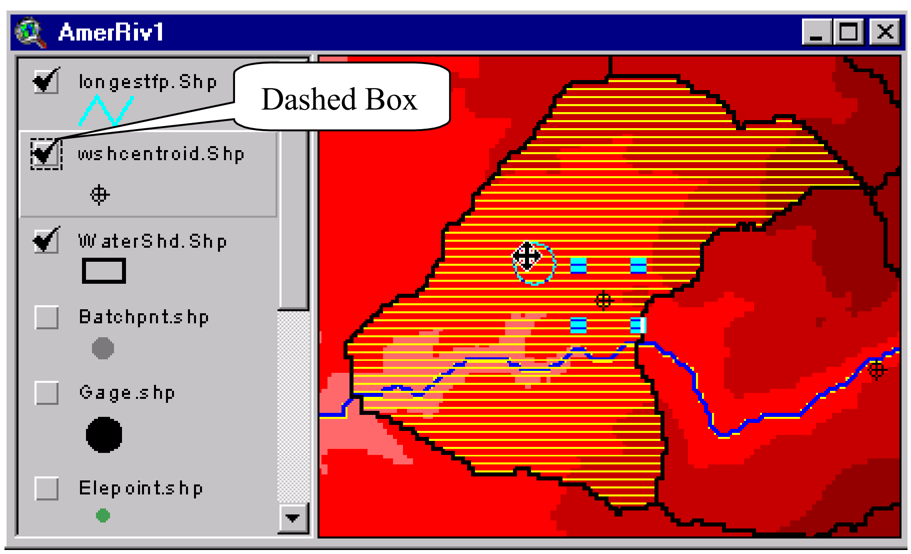


Figure 8–31. User-Specified new basin centroid location.

- To stop editing and save the changes, select **Theme ⇒ Stop Editing** as shown in Figure 8–32.

Figure 8–32. Stop Editing menu item.

After a centroid is moved, the centroid elevation in the “WshCentroid.Shp” and “WaterShd.shp” must be updated as shown in Figure 8–33.

- Select **Basin Characteristics ⇒ Centroid Elevation Update**

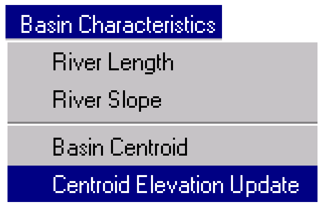


Figure 8–33. Centroid elevation update menu item.

The result of the user-specified centroid is shown in Figure 8–34 and elevation updates to the attribute tables of the “WshCentroid.Shp” and “WaterShd.shp” are shown in Figure 8–35 and Figure 8–36.

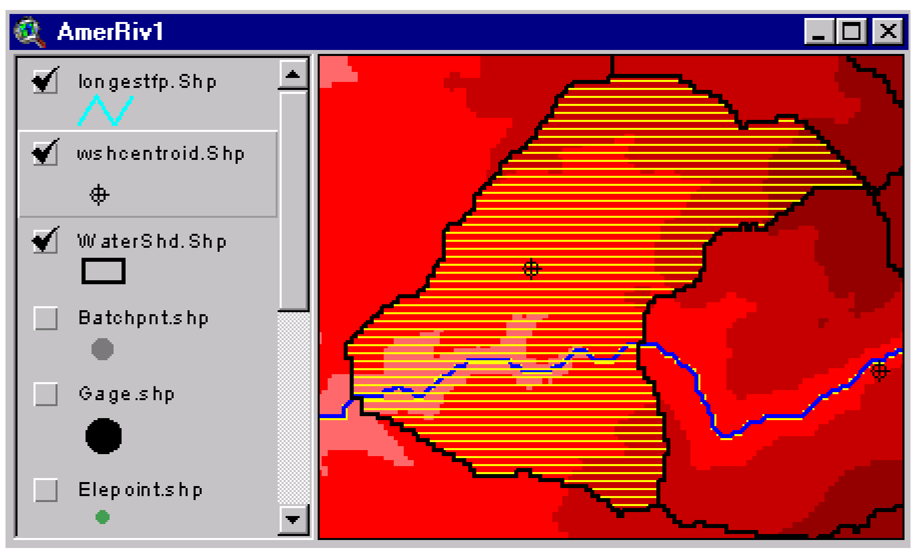


Figure 8–34. Moved basin centroid result.

Attributes of wshcentroid.Shp

Shape	Wshld	Elevation
Point	5	1545.2000
Point	6	1821.1000
Point	7	1509.5000
Point	8	1597.2000
Point	10	1456.5000
Point	11	1092.1000
Point	9	1223.2000
Point	13	1534.9000
Point	12	1657.4000
Point	2	1487.0000

Figure 8–35. Centroid elevation updated in the centroid attribute table.

Attributes of WaterShd.Shp

Shape	Id	Gridcode	Area	Wshld	TopoDone	Perimeter	Elevation
Polygon	1	2	18795600.00	2	0	41940.00000	1487.0000
Polygon	0	2	8898300.000	5	0	25320.00000	1545.2000
Polygon	0	0	6289200.000	6	0	15660.00000	1821.1000
Polygon	0	0	4391100.000	7	0	12000.00000	1509.5000
Polygon	0	2	3858300.000	8	0	11520.00000	1597.2000
Polygon	0	4	1674900.000	10	0	8580.000000	1456.5000
Polygon	0	4	1104300.000	11	0	5760.000000	1092.1000
Polygon	0	4	3690000.000	9	0	11520.00000	1223.2000
Polygon	0	2	14752800.00	12	0	23220.00000	1657.4000
Polygon	0	2	3779100.000	13	0	12060.00000	1534.9000

Figure 8–36. Centroid elevation updated in the watershed attribute table.

Longest Flow Path

The **Longest Flow Path** operation computes a number of basin physical characteristics: the longest flow length, upstream elevation, downstream elevation, slope between the endpoints, and slope between 10% and 85% of the length. These characteristics are stored in"WaterShd.shp" theme.

Steps

- Select **Basin Characteristics ⇒ Longest Flow Path** as shown in Figure 8–37. The program will not prompt the user to verify the data input and output because that confirmation was already made before in Figure 8–24.

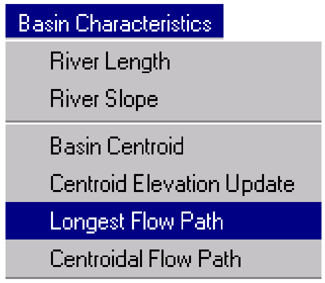


Figure 8–37. Longest flow path menu item.

- Press OK to confirmation message box as shown in Figure 8–38.

Figure 8–38. Longest flow path confirmation.

The result of the longest flow path operation is shown in Figure 8–39.

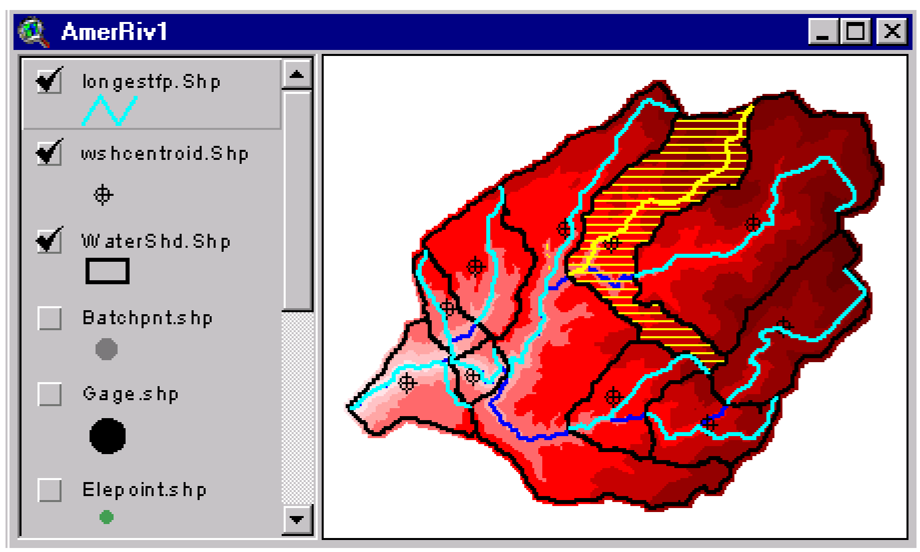


Figure 8–39. Longest flow path result.

The flow path attributes are written to both attribute tables for “Longestfp.shp” and “WaterShd.shp” as shown in Figure 8–40 and Figure 8–41, respectively.

Attributes of longestfp.Shp

Shape	Wshld	DSElv	Slp_EndPt	Slp_1085	LongestFL	USElv
PolyLine	2	1186.5000	0.093	0.081	8449.037	1971.0000
PolyLine	5	1391.8000	0.099	0.092	6563.818	2044.0000
PolyLine	6	1624.6000	0.094	0.067	5890.509	2181.0000
PolyLine	7	1256.9000	0.118	0.117	3434.924	1661.0000
PolyLine	8	1516.5000	0.087	0.096	4108.600	1873.0000
PolyLine	10	1056.2000	0.181	0.187	2792.498	1563.0000
PolyLine	11	1059.8000	0.214	0.189	2020.660	1493.0000
PolyLine	9	925.9000	0.147	0.186	3839.483	1491.0000
PolyLine	12	1451.2000	0.089	0.078	7618.082	2130.0000
PolyLine	13	1411.8000	0.121	0.125	3998.011	1896.0000

Figure 8–40. Longest flow path attribute table.

Attributes of WaterShd.Shp

Perimeter	Elevation	DSElv	Slp_EndPt	Slp_1085	LongestFL	USElv
41940.00000	1487.0000	1186.5000	0.093	0.081	8449.037	1971.0000
25320.00000	1545.2000	1391.8000	0.099	0.092	6563.818	2044.0000
15660.00000	1821.1000	1624.6000	0.094	0.067	5890.509	2181.0000
12000.00000	1509.5000	1256.9000	0.118	0.117	3434.924	1661.0000
11520.00000	1597.2000	1516.5000	0.087	0.096	4108.600	1873.0000
8580.000000	1456.5000	1056.2000	0.181	0.187	2792.498	1563.0000
5760.000000	1092.1000	1059.8000	0.214	0.189	2020.660	1493.0000
11520.00000	1223.2000	925.9000	0.147	0.186	3839.483	1491.0000
23220.00000	1657.4000	1451.2000	0.089	0.078	7618.082	2130.0000
12060.00000	1534.9000	1411.8000	0.121	0.125	3998.011	1896.0000

Figure 8–41. Longest flow path results populated in watershed attribute table.

Centroidal Flow Path

This operation computes the centroidal flow path length by projecting the centroid onto the longest flow path. The centroidal flow path is measured from the projected point on the longest flow path to the subbasin outlet as shown in Figure 8–42.

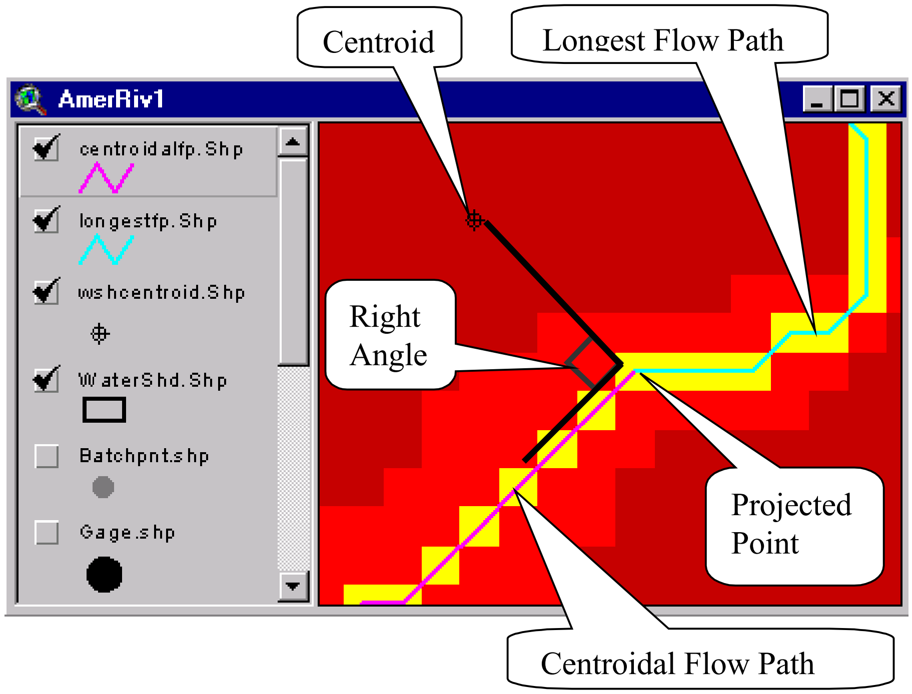


Figure 8–42. Centroidal flow path.

Steps

- Select **Basin Characteristics ⇒ Centroidal Flow Path** as shown in Figure 8–43.

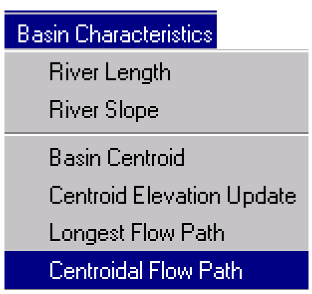


Figure 8–43. Centroidal flow path menu item.

- The program prompts the user to verify the five data inputs and one output, see Figure 8–44. Press OK.

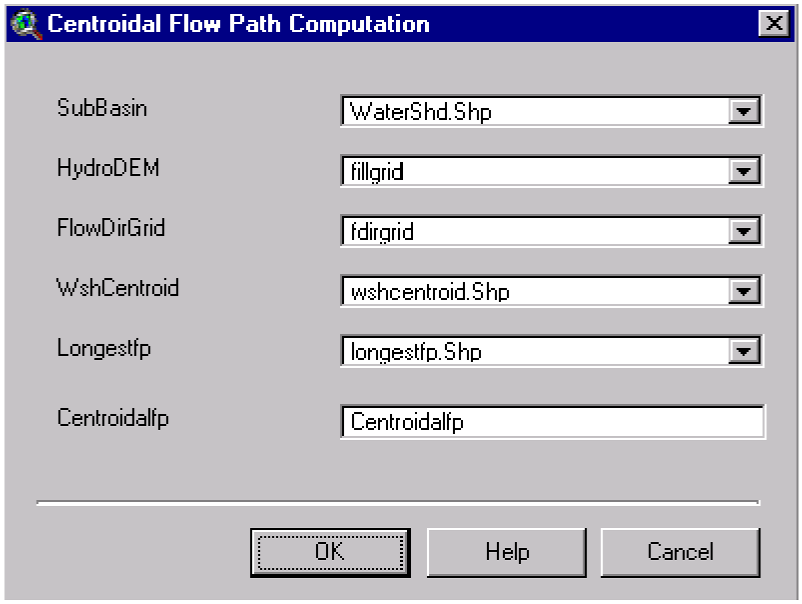


Figure 8–44. Centroidal flow path input and output files.

- Press OK at the confirmation message box as shown in Figure 8–45.

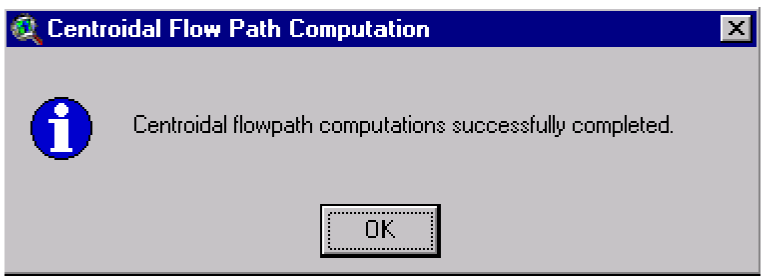


Figure 8–45. Centroidal flow path confirmation.

The result of the centroidal flow path operation is a line shapefile named "Centroidalfp.Shp" and its attribute table as shown in Figure 8–46 and Figure 8–47, respectively. The centroidal flow length in the "CentroidalFL" column is also stored in the "WaterShd.shp" attribute table as shown in Figure 8–48.

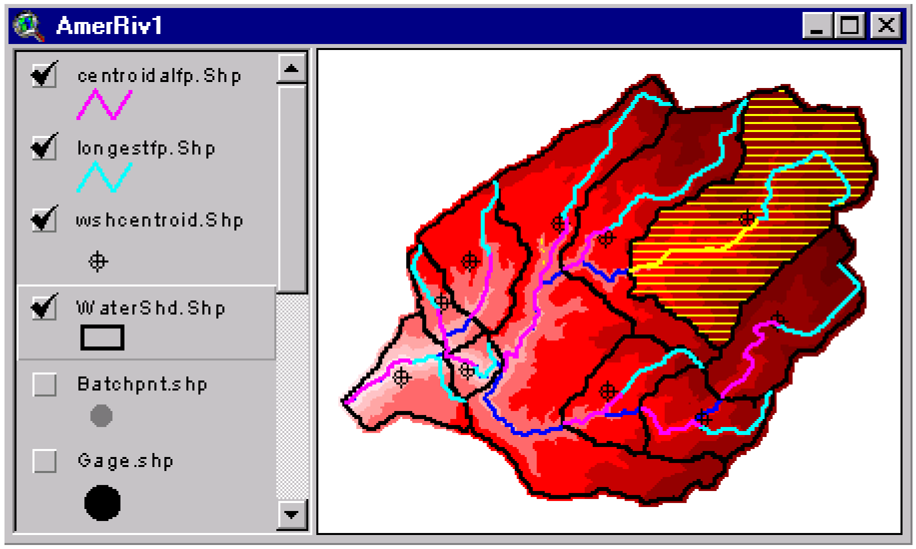


Figure 8–46. Centroidal flow path result.

Attributes of centroidalfp.Shp

Shape	Wshld	CentroidalFL
PolyLine	2	4224.518
PolyLine	5	1580.955
PolyLine	6	2909.483
PolyLine	7	1561.249
PolyLine	8	1785.807
PolyLine	10	1114.264
PolyLine	11	740.018
PolyLine	9	1907.939
PolyLine	12	3352.203
PolyLine	13	1653.381

Figure 8–47. Centroidal flow path attribute table.

Attributes of WaterShd.Shp

Elevation	DSElv	Slp_EndPt	Slp_1085	LongestFL	USElv	CentroidalFL
1487.0000	1186.5000	0.093	0.081	8449.037	1971.0000	4224.518
1545.2000	1391.8000	0.099	0.092	6563.818	2044.0000	1580.955
1821.1000	1624.6000	0.094	0.067	5890.509	2181.0000	2909.483
1509.5000	1256.9000	0.118	0.117	3434.924	1661.0000	1561.249
1597.2000	1516.5000	0.087	0.096	4108.600	1873.0000	1785.807
1456.5000	1056.2000	0.181	0.187	2792.498	1563.0000	1114.264
1092.1000	1059.8000	0.214	0.189	2020.660	1493.0000	740.018
1223.2000	925.9000	0.147	0.186	3839.483	1491.0000	1907.939
1657.4000	1451.2000	0.089	0.078	7618.082	2130.0000	3352.203
1534.9000	1411.8000	0.121	0.125	3998.011	1896.0000	1653.381

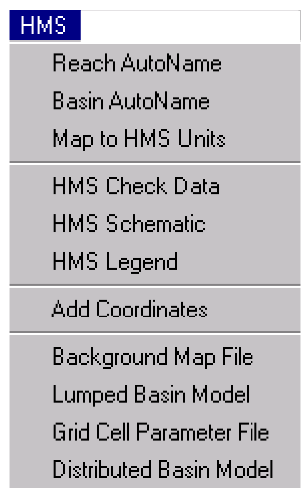
Figure 8–48. Centroidal flow path results populated in watershed attribute table.

CHAPTER 9

Hydrologic Modeling System

HEC-GeoHMS develops a number of hydrologic inputs for HEC-HMS: background-map file, lumped-basin schematic model file, grid-cell parameter file, and distributed-basin schematic model file. The capability includes automatic naming of reaches and subbasins, checking for errors in the basin and stream connectivity, producing HMS schematic, and generating the HMS related input files. The hydrologic data is then entered through HMS menus.

This chapter will discuss the tools for generating HMS model files that are available in the ***ProjView*** GUI under the **HMS** menu.



Contents

Reach AutoName

This process names reaches in sequence from upstream to downstream. The naming convention combines the letter "R" and a number. For example, the upstream reach starts with R10 and then R20, R30, R40, etc. are the reach names proceeding downstream. The intent of this tool is to quickly name the reaches; the user can change the default names to something more descriptive.

Steps

- Select **HMS ⇒ River AutoName** as shown in Figure 9–1.

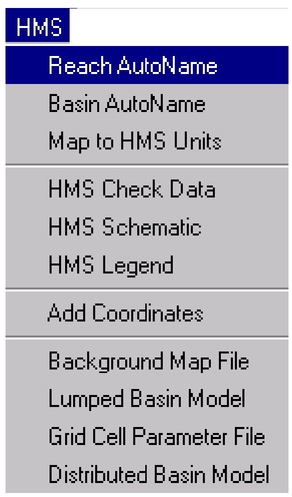
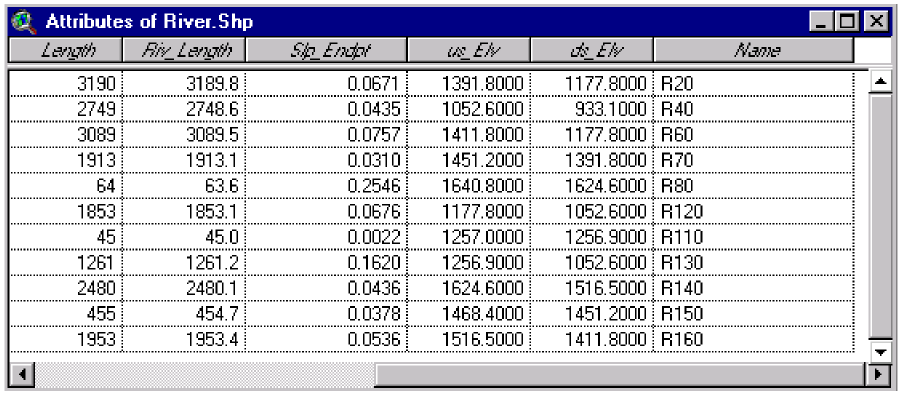


Figure 9–1. Reach autoname menu item.

- Press **OK** on the confirmation message box.

The Reach Autoname operation creates a "Name" column in the stream's attribute table as shown in Figure 9–2.



Length	Riv_Length	Slp_Endpt	us_Elv	ds_Elv	Name
3190	3189.8	0.0671	1391.8000	1177.8000	R20
2749	2748.6	0.0435	1052.6000	933.1000	R40
3089	3089.5	0.0757	1411.8000	1177.8000	R60
1913	1913.1	0.0310	1451.2000	1391.8000	R70
64	63.6	0.2546	1640.8000	1624.6000	R80
1853	1853.1	0.0676	1177.8000	1052.6000	R120
45	45.0	0.0022	1257.0000	1256.9000	R110
1261	1261.2	0.1620	1256.9000	1052.6000	R130
2480	2480.1	0.0436	1624.6000	1516.5000	R140
455	454.7	0.0378	1468.4000	1451.2000	R150
1953	1953.4	0.0536	1516.5000	1411.8000	R160

Figure 9–2. Reach autoname result.

The following steps can be used to edit the names in the attribute table.

- Open and activate the attribute table of "River.shp".
- Select **Table ⇒ Start Editing** as shown in Figure 9–3.

Figure 9–3. edit reach name.

- Select the (Edit) tool.
- Press on a name-field entry and revise it.
- When the revision is done, select **Table ⇒ Stop Editing** as shown in Figure 9–4.
- The user is prompted to **Save Edits?** Press **Yes** to save and **NO** to cancel the edit.

Figure 9–4. Stop and save revised reach name.

Basin AutoName

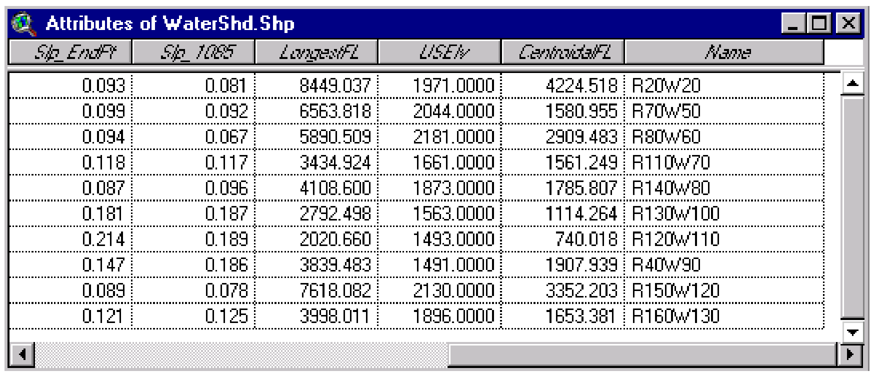
This process names the subbasins in sequence from upstream to downstream. The naming convention adds "W + 10, 20, and etc." to the receiving reach name to form the subbasin name. e.g., R20W20. The intent of this tool is to quickly name the reach, and the user can edit the default names to something more descriptive.

Steps

- Select **HMS ⇒ Basin AutoName** as shown in Figure 9–5.

Figure 9–5. Basin AutoName menu item.

- The Basin Autoname operation creates a "Name" column in the "WaterShd.shp" attribute table as shown in Figure 9–6.


Attributes of WaterShd.Shp

Slp_EndFt	Slp_1085	LongestFL	USElv	CentroidalFL	Name
0.093	0.081	8449.037	1971.0000	4224.518	R20W20
0.099	0.092	6563.818	2044.0000	1580.955	R70W50
0.094	0.067	5890.509	2181.0000	2909.483	R80W60
0.118	0.117	3434.924	1661.0000	1561.249	R110W70
0.087	0.096	4108.600	1873.0000	1785.807	R140W80
0.181	0.187	2792.498	1563.0000	1114.264	R130W100
0.214	0.189	2020.660	1493.0000	740.018	R120W110
0.147	0.186	3839.483	1491.0000	1907.939	R40W90
0.089	0.078	7618.082	2130.0000	3352.203	R150W120
0.121	0.125	3998.011	1896.0000	1653.381	R160W130

Figure 9–6. Subbasin autoname result.

Map to HMS Units

This step converts the physical characteristics of the reaches and subbasins from the map units to the HMS units. The map unit is the unit of the ArcView data; the terrain data is typically in meters. The user has the option to convert the map units to the English or the International System (SI) units supported by HMS. HEC-HMS only uses the subbasin area at this time; the other characteristics can be used for regional parameter estimation.

The Table 9-1 shows the HMS units in the English and International System.

Table 9-1. HMS Unit Systems

	Physical Characteristics (Table Heading)	**HMS EnglishUnits** (Table Heading)	**HMS SI Units** (Table Heading)
Stream (River.Shp)	Length (Riv_Length)	Feet (Riv_Length_HMS)	Meters (Riv_Length_HMS)
	Upstream elevation (US_Elv)	Feet (US_Elv_HMS)	Meters (US_Elv_HMS)
	Downstream elevation (DS_Elv)	Feet (DS_Elv_HMS)	Meters (DS_Elv_HMS)
Watershed (WaterShd.shp)	Area (Area)	Square miles (Area_HMS)	Square kilometers (Area_HMS)
	Centroid Elevation (Elevation)	Feet (Elevation_HMS)	Meters (Elevation_HMS)
	Longest Flow Length (LongestFP)	Feet (Longest_FL)	Meters (Longest_FL)
	Upstream elevation (US_Elv)	Feet (USElv_HMS)	Meters (USElv_HMS)
	Downstream elevation (US_Elv)	Feet (DSElv_HMS)	Meters (DSElv_HMS)
	Centroidal Length (CentroidalFL)	Feet (CentroidalFL_HMS)	Meters (CentroidalFL_HMS)

Steps

- Select **HMS ⇒ Map to HMS Units.**
- Select English from dropdown menu as shown in Figure 9–7. Press **OK**.

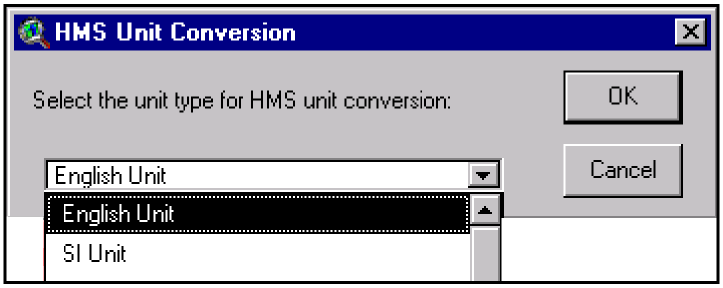


Figure 9–7. HMS unit conversion options.

- Press **OK** in confirmation message box.

The unit conversion operation results in three added columns for the stream attribute table as shown in Figure 9–8 and six added columns for the subbasin attribute table as shown in Figure 9–9. The units of the added columns are as specified in Table 9-1 for the selected unit system.

Attributes of River.Shp

Name	Riv_Length_HMS	us_Elv_HMS	ds_Elv_HMS
R20	10465.202	4566.264	3864.165
R40	9017.698	3453.405	3061.346
R60	10136.135	4631.880	3864.165
R70	6276.562	4761.145	4566.264
R80	208.661	5383.191	5330.042
R120	6079.712	3864.165	3453.405
R110	147.637	4124.007	4123.679
R130	4137.787	4123.679	3453.405
R140	8136.795	5330.042	4975.384
R150	1491.795	4817.576	4761.145
R160	6408.780	4975.384	4631.880

Figure 9–8. River attribute table populated with HMS units fields.

Attributes of WaterShd.Shp

Name	LongestFl_HMS	CentroidalFl_HMS	Elevation_HMS	USElv_HMS	DSElv_HMS	Area_HMS
R20W20	27719.882	13859.939	4878.599	6466.522	3892.709	7.257
R70W50	21534.793	5186.850	5069.544	6706.023	4566.264	3.436
R80W60	19325.778	9545.529	5974.726	7155.497	5330.042	2.428
R110W70	11269.413	5122.198	4952.418	5449.464	4123.679	1.695
R140W80	13479.632	5858.935	5240.147	6145.001	4975.384	1.490
R130W100	9161.721	3655.714	4778.534	5127.942	3465.216	0.647
R120W110	6629.449	2427.876	3582.998	4898.284	3477.027	0.426
R40W90	12596.704	6259.630	4013.115	4891.722	3037.724	1.425
R150W120	24993.657	10998.019	5437.653	6988.175	4761.145	5.696
R160W130	13116.808	5424.467	5035.751	6220.460	4631.880	1.459

Figure 9–9. Watershed attribute table populated with HMS units fields.

HMS Data Check

This step checks the data sets for consistency in describing the hydrologic structure of the model. For example, the program checks for unique names for the reaches, subbasins, and outlet points. In addition, the program also checks that the rivers and centroids are contained within the subbasins and that rivers are connected with relevant points created in the basin processing step. This is desirable for placement of the hydrologic elements' names and connectivities on the HMS basin schematic. In general, the program keeps track of the relationship between the stream segments, subbasins, outlet points, and other entities. These checks are necessary because the relationships between hydrologic elements may have been broken by unintentional use of the tools.

The program checks every spatial feature in the "River.shp", "WaterShd.shp", "Amerriv1.shp", and "Wshcentroid.shp" data files. It produces a text file, "SkelConsChk.txt", that presents the results on each feature and summarizes the results. This step does not fix any of the problem. However, the user can view the result and fix the problems manually in HEC-GeoHMS or HMS.

Steps

- Select **HMS ⇒ HMS Check Data**.
- Review the input data sets as shown in Figure 9–10. Press **OK**.

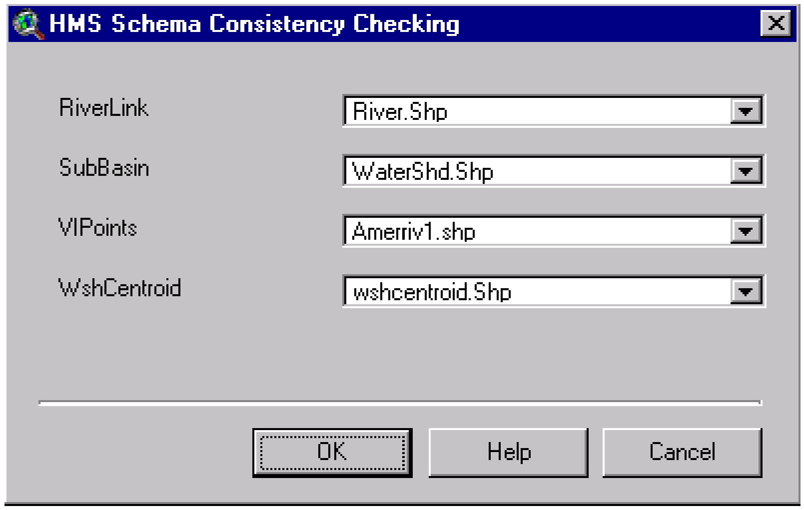


Figure 9–10. HMS Check Data Input and Output Files

- Make a note of the filename and its location as shown in Figure 9–11. Press **OK**.

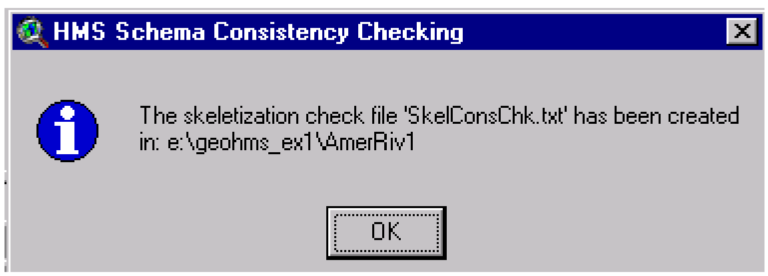


Figure 9–11. HMS check data result file location.

- Open the results file with a text editor and review the results.

The "Checking Summary" at the end of the file shows that 4 of the 5 items checked have no problems, see Figure 9–12. The "VIP Relevance" check shows two problems. The VIPs (very important points) represent locations of basin subdivision, outlets, centroids, etc. Sometimes, a few VIPs are no longer relevant or needed because the basin outlets may have changed as a result of basin processing.

```
CHECKING SUMMARY
****************

Unique names        - no problems.
River Containment   - no problems.
Center Containment  - no problems.
River Connectivity  - no problems.
VIP Relevance       - total of 2 problems.
```

Figure 9–12. HMS check data result summary.

- Scroll up the file and find that problems exist with BatchPoint1 and BatchPoint2 as shown in Figure 9–13.

After examining the subbasin delineation, Batch Points 1 and 2 appear to be relevant because they serve as basin outlets. Keep these problems in mind and fix them in HMS, if necessary. These problems can also be fixed with some effort in HEC-GeoHMS by editing various tables. Currently, the types of problems that can be easily fixed are reach and subbasin name revisions.

```
Checking VIP point:BatchPoint1
End of checking VIP point: BatchPoint1 - PROBLEM: the status could not be determined

Checking VIP point:BatchPoint2
End of checking VIP point: BatchPoint2 - PROBLEM: the status could not be determined
```

Figure 9–13. HMS check data problems.

HEC-HMS Basin Schematic

The HMS basin schematic is the GIS representation of the hydrologic basin model with basin elements and their connectivity. This step creates a point shapefile, "HMSPoint.shp", and a line shapefile, "HMSConnect.shp". The "HMSPoint.shp" contains point features, such as subbasin icon locations, outlets, and junctions. Subbasin icons are placed at the centroid of the area. The "HMSConnect.shp" contains line features, such as subbasin connectors and reaches. The subbasin connector joins a subbasin icon to the basin outlet.

Steps

- Select **HMS ⇒ HMS Schematic**.
- Review the input and output data sets as shown in Figure 9–14. Press **OK**.

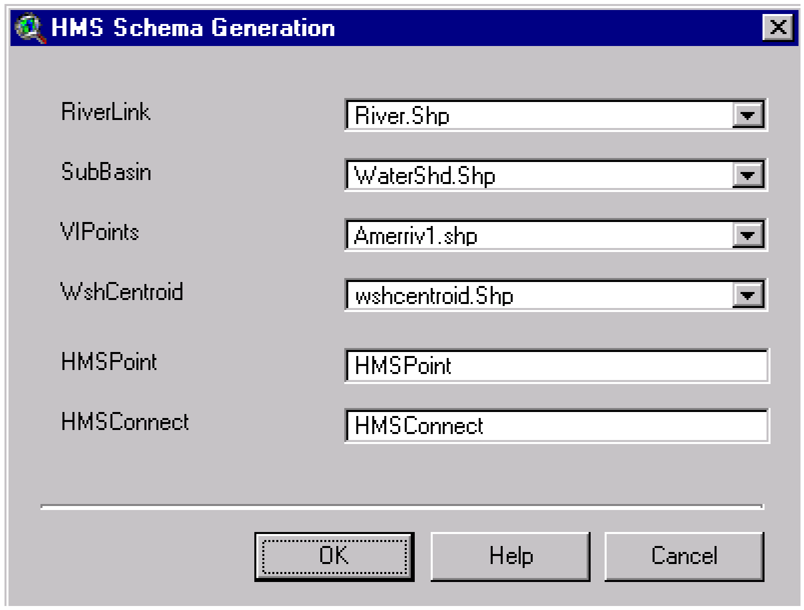


Figure 9–14. HMS schematic input and output files.

- Press **OK** at the confirmation message box.

The HMS schematic with ArcView symbols is shown in Figure 9–15.

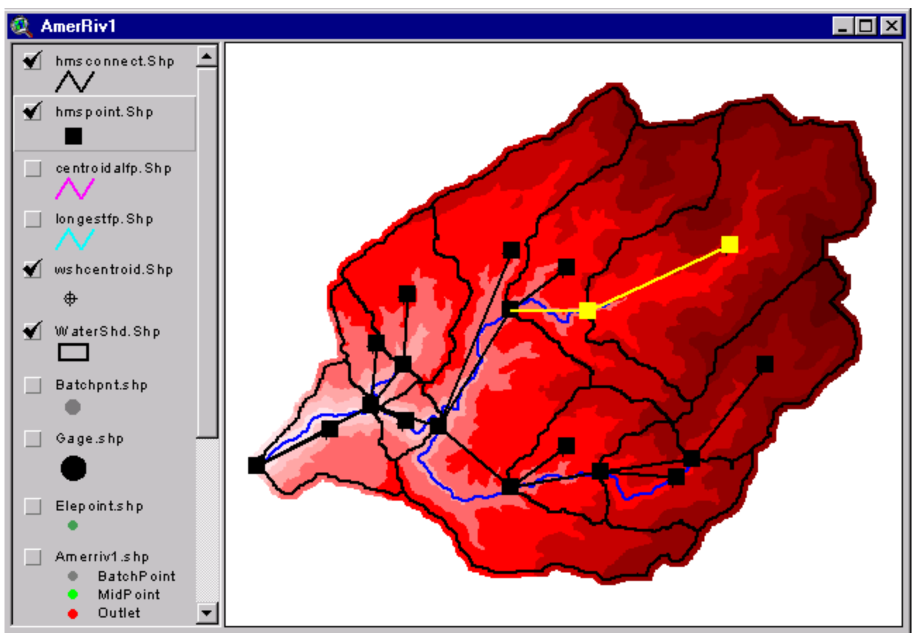


Figure 9–15. Initial HMS schematic result.

The attribute tables of the “HMSPoint.shp” and “HMSConnect.shp” shapefiles are shown in Figure 9–16 and Figure 9–17. The highlighted features are shown on the tables to display how the program uses the downstream element name, “Dstr_Name”, in both tables to establish element connectivity.

Attributes of hmspoint.Shp

Shape	NumId	Dstr_Name	Name	Type
Point	1		OutletAR	0
Point	2	R20	UserPoint2	2
Point	3	R140	UserPoint3	2
Point	4	R130	UserPoint4	2
Point	5	R160	UserPoint5	2
Point	6	R70	BatchPoint1	15
Point	7	R60	BatchPoint2	15
Point	8	R120	JR120	7
Point	2	JR120	R20W20	8
Point	5	UserPoint2	R70W50	8
Point	6	UserPoint3	R80W60	8
Point	7	UserPoint4	R110W70	8
Point	8	UserPoint5	R140W80	8
Point	9	R40	JR40	7
Point	10	JR40	R130W100	8
Point	11	JR40	R120W110	8
Point	9	OutletAR	R40W90	8
Point	12	BatchPoint1	R150W120	8
Point	13	BatchPoint2	R160W130	8

Figure 9–16. HMS schematic point attribute table.

Attributes of hmsconnect.Shp

Shape	NumId	Dstr_Name	Name	Type
PolyLine	2	JR120	R20W20	1
PolyLine	5	UserPoint2	R70W50	1
PolyLine	6	UserPoint3	R80W60	1
PolyLine	7	UserPoint4	R110W70	1
PolyLine	8	UserPoint5	R140W80	1
PolyLine	10	JR40	R130W100	1
PolyLine	11	JR40	R120W110	1
PolyLine	9	OutletAR	R40W90	1
PolyLine	12	BatchPoint1	R150W120	1
PolyLine	13	BatchPoint2	R160W130	1
PolyLine	2	JR120	R20	2
PolyLine	4	OutletAR	R40	2
PolyLine	6	JR120	R60	2
PolyLine	7	UserPoint2	R70	2
PolyLine	12	JR40	R120	2
PolyLine	13	JR40	R130	2
PolyLine	14	UserPoint5	R140	2
PolyLine	16	BatchPoint2	R160	2

Figure 9–17. HMS schematic line attribute table.

HMS Legend

This process implements HMS symbology to represent point and line features more descriptively as hydrologic elements, such as junction, subbasin, source, and others. The user has the option to toggle between **HMS Legend** and **Regular Legend**.

Steps

- Select **HMS ⇒ HMS Legend**.
- The user can toggle between **HMS Legend** and **Regular Legend** by selecting **HMS ⇒ HMS Legend** or **Regular Legend**.

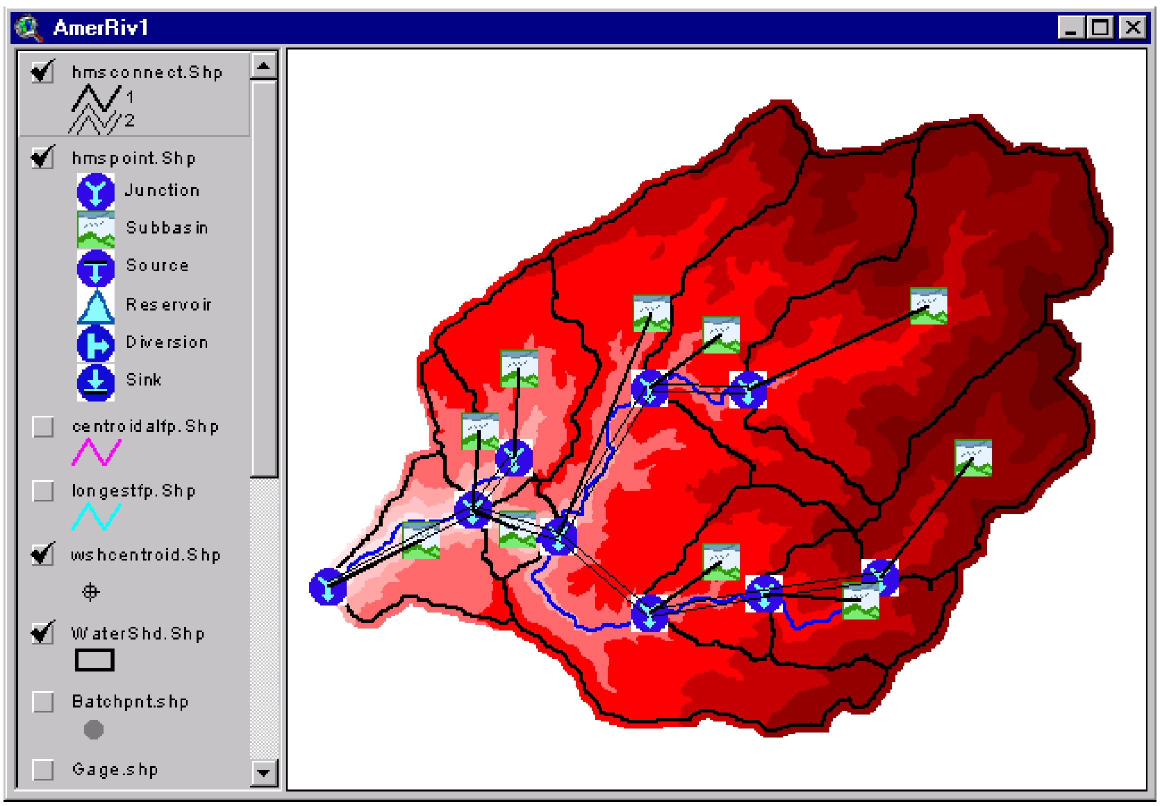


Figure 9–18. HMS schematic with symbols.

Add Coordinates

This step attaches geographic coordinates to hydrologic elements in the attribute tables of “HMSPoint.shp” and “HMSConnect.shp”. The attachment of coordinates allows GIS data to be exported to a non-proprietary ASCII format and still preserves the geospatial information.

Steps

- Select **HMS ⇒ Add Coordinates** as shown in Figure 9–19. Press OK.

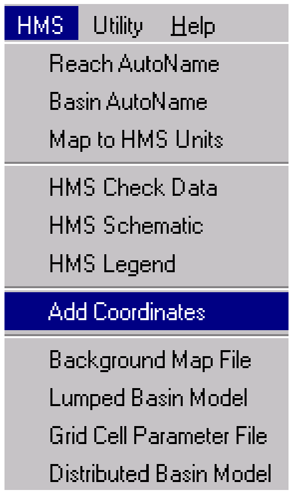
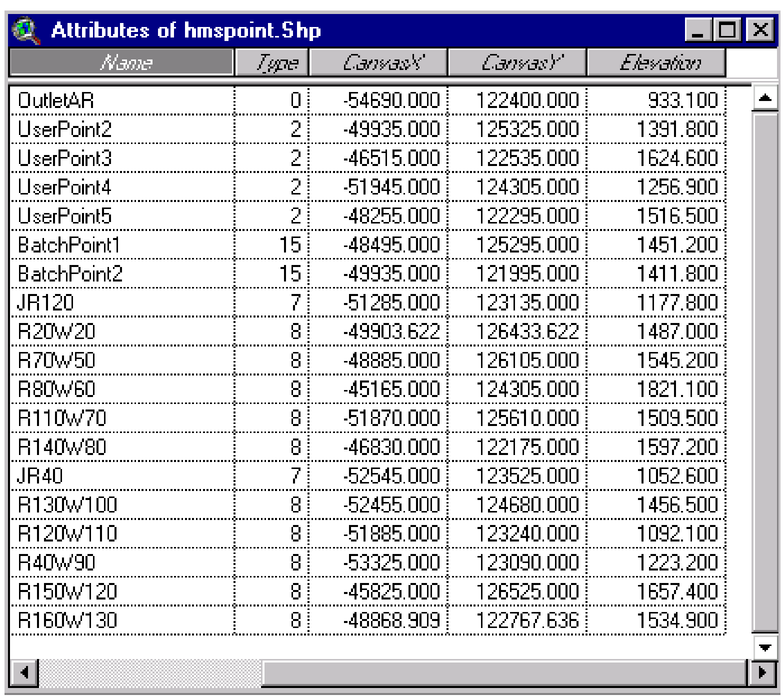


Figure 9–19. Add Coordinates menu item.

The results are shown in Figure 9–20 and Figure 9–21. For a point feature in Figure 9–20, the "CanvasX", "CanvasY", "Elevation" columns describe an outlet in 3-dimensional space. For a line feature in Figure 9–21, the coordinate pair ("FromCanvasX", "FromCanvasY") and ("CanvasX, CanvasY") describe a reach orientation with flow direction.



Attributes of hmspoint.Shp

Name	Type	CanvasX	CanvasY	Elevation
OutletAR	0	-54690.000	122400.000	933.100
UserPoint2	2	-49935.000	125325.000	1391.800
UserPoint3	2	-46515.000	122535.000	1624.600
UserPoint4	2	-51945.000	124305.000	1256.900
UserPoint5	2	-48255.000	122295.000	1516.500
BatchPoint1	15	-48495.000	125295.000	1451.200
BatchPoint2	15	-49935.000	121995.000	1411.800
JR120	7	-51285.000	123135.000	1177.800
R20W20	8	-49903.622	126433.622	1487.000
R70W50	8	-48885.000	126105.000	1545.200
R80W60	8	-45165.000	124305.000	1821.100
R110W70	8	-51870.000	125610.000	1509.500
R140W80	8	-46830.000	122175.000	1597.200
JR40	7	-52545.000	123525.000	1052.600
R130W100	8	-52455.000	124680.000	1456.500
R120W110	8	-51885.000	123240.000	1092.100
R40W90	8	-53325.000	123090.000	1223.200
R150W120	8	-45825.000	126525.000	1657.400
R160W130	8	-48868.909	122767.636	1534.900

Figure 9–20. Point attribute table populated with coordinates.

Attributes of hmsconnect.Shp

Name	Type	FromCanvasX	FromCanvasY	CanvasX	CanvasY
R20W20	1	-49903.622	126433.622	-51285.000	123135.000
R70W50	1	-48885.000	126105.000	-49935.000	125325.000
R80W60	1	-45165.000	124305.000	-46515.000	122535.000
R110W70	1	-51870.000	125610.000	-51945.000	124305.000
R140W80	1	-46830.000	122175.000	-48255.000	122295.000
R130W100	1	-52455.000	124680.000	-52545.000	123525.000
R120W110	1	-51885.000	123240.000	-52545.000	123525.000
R40W90	1	-53325.000	123090.000	-54690.000	122400.000
R150W120	1	-45825.000	126525.000	-48495.000	125295.000
R160W130	1	-48868.909	122767.636	-49935.000	121995.000
R20	2	-49935.000	125325.000	-51285.000	123135.000
R40	2	-52545.000	123525.000	-54690.000	122400.000
R60	2	-49935.000	121995.000	-51285.000	123135.000
R70	2	-48495.000	125295.000	-49935.000	125325.000
R120	2	-51285.000	123135.000	-52545.000	123525.000
R130	2	-51945.000	124305.000	-52545.000	123525.000
R140	2	-46515.000	122535.000	-48255.000	122295.000
R160	2	-48255.000	122295.000	-49935.000	121995.000

Figure 9–21. Line attribute table populated with coordinates.

Background-Map File

The background-map file captures the geographic information of the subbasin boundaries and stream alignments in an ASCII text file that can be read by HMS. The format specifications of the background map file are given in Appendix B.

Steps

- Select **HMS ⇒ Background Map File**.
- Make a note of the filename and its location as shown in Figure 9–22. Press **OK**.

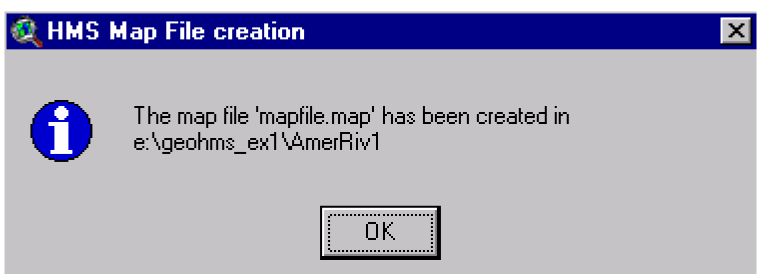


Figure 9–22. Background map file location.

The resulting background map file in ASCII format looks similar to Figure 9–23.

```
MapGeo:  BoundaryMap
MapSegment:  closed
    -48150, 121350
    -48120, 121350
    -48120, 121320
    -48090, 121320
    -48090, 121290
```

…many lines omitted …

```
MapGeo:  RiverMap
MapSegment:  open
    -49935, 125325
    -49965, 125295
    -49995, 125295
    -50145, 125145
    -50175, 125145
```

…many lines omitted …

Figure 9–23. HMS background map file example.

Lumped-Basin Model

The lumped-basin model captures the hydrologic elements, their connectivity, and related geographic information in an ASCII text file that can be input to HMS. This basin model should be used for a hydrologic model with lumped, not distributed, basin parameters. Lumped-basin models do not use gridded precipitation or the ModClark transform.

Steps

- Select **HMS ⇒ Lumped Basin Model**.
- Make a note of the filename and its location as shown in Figure 9–24. Press **OK**.

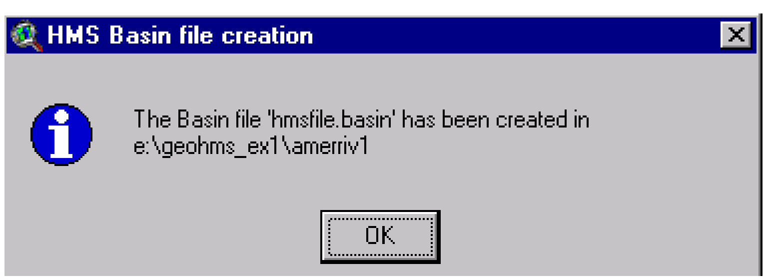


Figure 9–24. Lumped basin model file location.

The resulting lumped-basin model file in ASCII format looks similar to Figure 9–25.

```
Basin:  AmerRiv1
Description:  Basin model created with HEC-GeoHMS v1.0
Last Modified date:  27 February 2000
Last Modified Time:  17:19:13
Unit System:  English Unit
End:

Junction:  OutletAR
CanvasX:  -54690.000000
CanvasY:  122400.000000
Label X:  16
Label Y:  0
End:

Junction:  UserPoint2
CanvasX:  -49935.000000
CanvasY:  125325.000000
Label X:  16
Label Y:  0
Downstream:  R20
End:
```

Figure 9–25. HMS lumped-basin model example.

Grid-Cell Parameter File

The grid-cell parameter file represents subbasins as grid cells for the distributed-modeling approach. It is produced by intersecting a grid with the subbasin. A number of grid formats with various coordinate systems are available. However, it is recommended that the user select the "Standard Hydrologic Grid" (SHG) or the "Hydrologic Rainfall Analysis Project" (HRAP) instead of the "User Defined Method". With the radar rainfall reported in the HRAP grid format, the use of SHG or HRAP grids can ensure greater alignment and compatibility between radar rainfall and a gridded subbasin. More details on the selection of a grid format are available in the Appendix D.

The grid-cell parameter file contains the parameters and units as shown in Table 9-2. Irrespective of the selected unit system in HMS, the grid-cell parameter file is always in SI units to maintain alignment and compatibility with radar rainfall. HMS internally converts the results the selected unit system after computation.

Table 9-2. Grid-Cell Parameters Units

	Physical Characteristics *(Table Heading)*	***Units***
Grid Cell Parameter ***(ModClark2K.Shp)***	X Coordinates (Shg_X)	N/A
	Y Coordinates (Shg_Y)	N/A
	Grid-Cell Travel Distance (FlowLength)	Kilometers
	Grid-Cell Area (Mod_Area)	Square kilometers

Steps

- Select **HMS ⇒ Grid Cell Parameter File**.
- Select **SHG Method** from the dropdown menu as shown in Figure 9–26. Press **OK**.

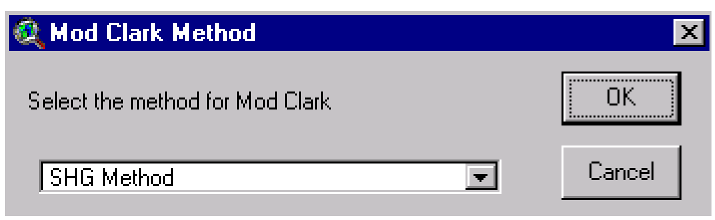


Figure 9–26. Grid types.

- The SHG grid uses the Albers Equal-Area projection as shown in Figure 9–27. Press **Yes**.

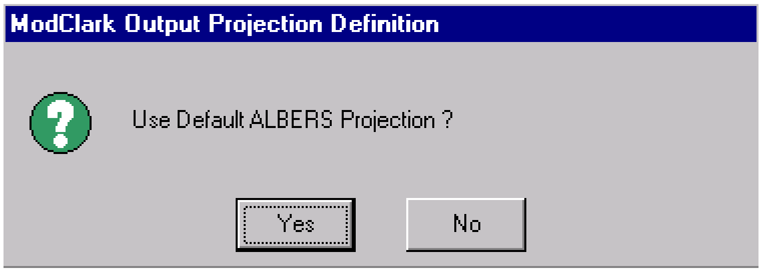


Figure 9–27. Default albers projection.

Select the cell resolution for the SHG grid at 2000 (meters implied). A grid-cell resolution of 2000 meters is often suggested when working with radar rainfall. At that resolution, a grid cell has an area of four square kilometers if it resides entirely within a subbasin. Along the subbasin boundaries, however, a grid cell is often broken into several pieces, which belong to several subbasins. Press **OK**.

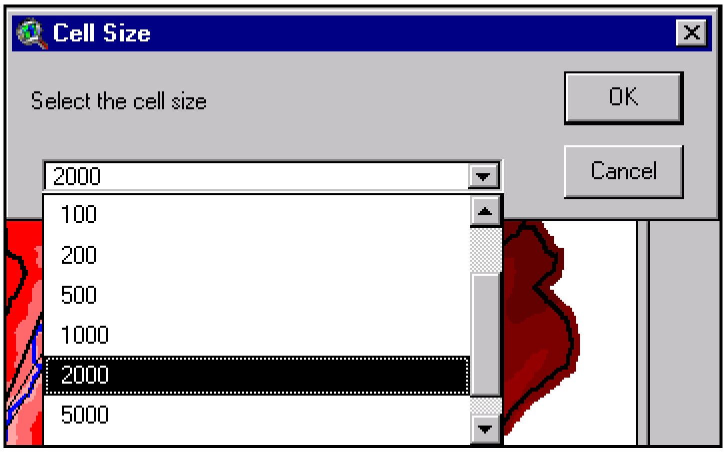


Figure 9–28. Grid-cell resolution for SHG.

- Make a note of the filename and its location as shown in Figure 9–29. Press **OK**.

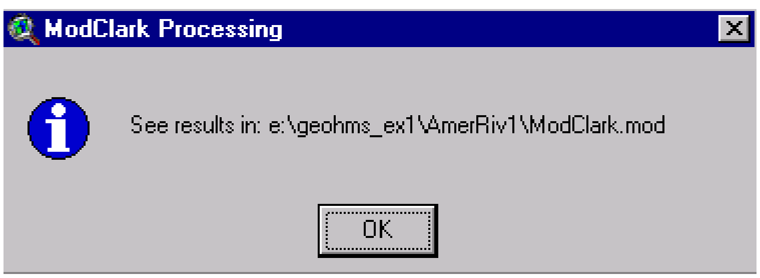


Figure 9–29. Grid-cell parameter file location.

A separate view is created to overlay the subbasin and the SHG grid and perform the intersection as shown in Figure 9–30.

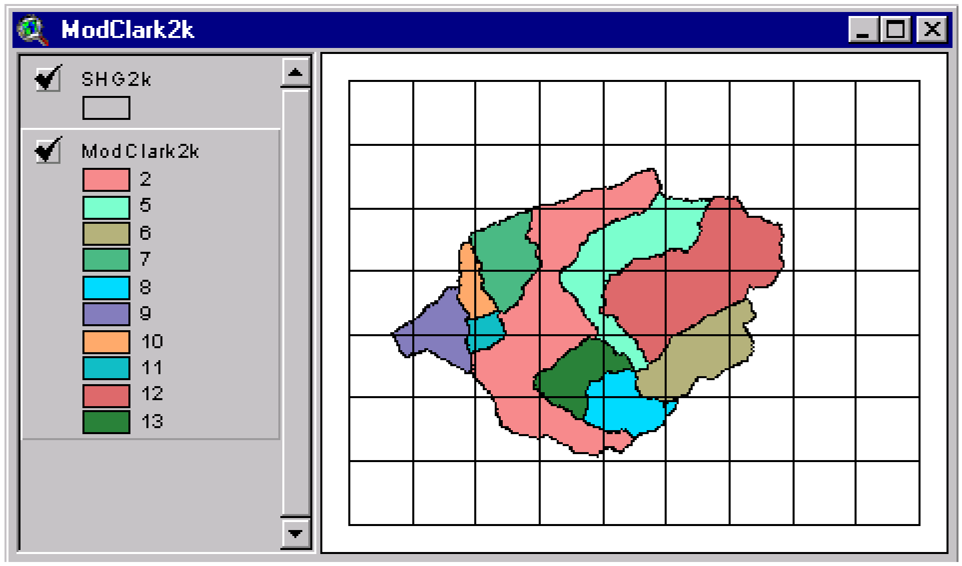


Figure 9–30. Intersection between subbasins and SHG grid.

This operation creates a grid-cell shapefile, “ModClark2K.shp”, and a raster data set, “FlowLength”, for computing grid-cell travel distances to the subbasin outlet as shown in Figure 9–31.

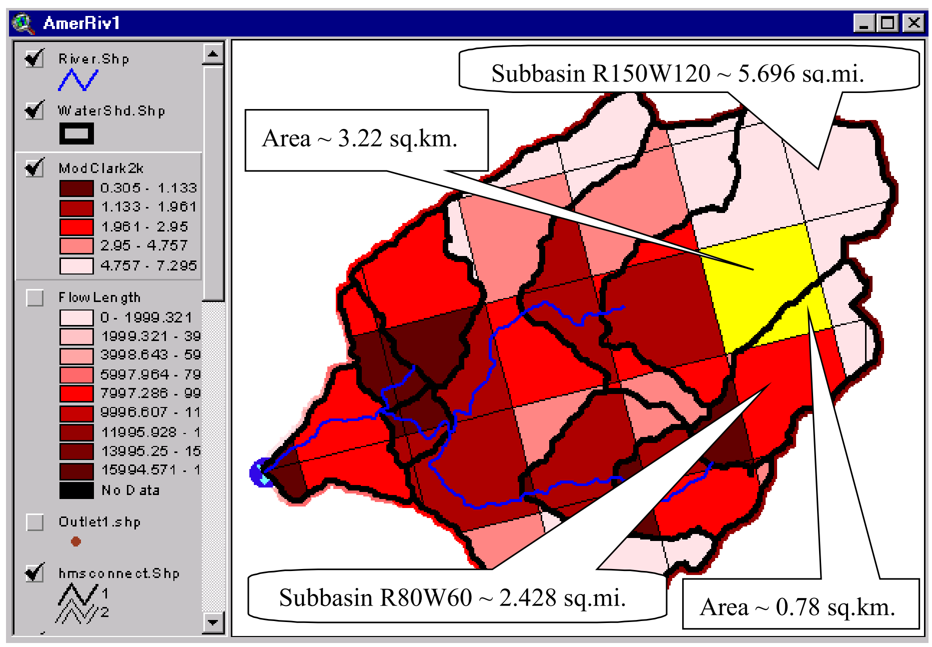
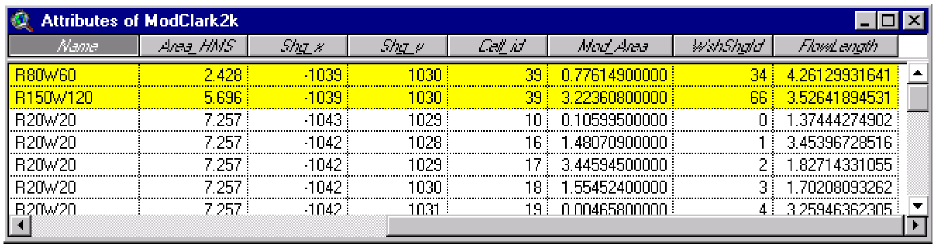


Figure 9–31. Grid-cell parameter file result.

The attribute table shown in Figure 9–32 displays the results for the selected cell.



Attributes of ModClark2k

Name	Area_HMS	Shg_x	Shg_y	Cell_id	Mod_Area	WshShgId	FlowLength
R80W60	2.428	-1039	1030	39	0.77614900000	34	4.26129931641
R150W120	5.696	-1039	1030	39	3.22360800000	66	3.52641894531
R20W20	7.257	-1043	1029	10	0.10599500000	0	1.37444274902
R20W20	7.257	-1042	1028	16	1.48070900000	1	3.45396728516
R20W20	7.257	-1042	1029	17	3.44594500000	2	1.82714331055
R20W20	7.257	-1042	1030	18	1.55452400000	3	1.70208093262
R20W20	7.257	-1042	1031	19	0.00465800000	4	3.25946362305

Figure 9–32. Grid-cell parameter attribute table.

The resulting grid-cell parameter file in ASCII format looks similar to Figure 9–33.

```
PARAMETER ORDER: Xcoord Ycoord TravelLength Area
END:
SUBBASIN:  R20W20
GRIDCELL:  -1043  1029  1.374443  0.105995
GRIDCELL:  -1042  1028  3.453967  1.480709
GRIDCELL:  -1042  1029  1.827143  3.445945
GRIDCELL:  -1042  1030  1.702081  1.554524
GRIDCELL:  -1042  1031  3.259464  0.004658
GRIDCELL:  -1042  1031  4.946023  0.399514
GRIDCELL:  -1042  1032  5.651498  0.007268
GRIDCELL:  -1041  1028  5.022047  2.119920
GRIDCELL:  -1041  1029  4.106799  1.067283
GRIDCELL:  -1041  1029  3.417962  0.019840
GRIDCELL:  -1041  1030  2.949917  2.369097
GRIDCELL:  -1041  1031  4.757159  3.010195
GRIDCELL:  -1041  1032  6.097099  0.675054
GRIDCELL:  -1040  1028  6.561974  0.506599
GRIDCELL:  -1040  1031  6.570029  0.444512
GRIDCELL:  -1040  1032  7.295388  1.584486
END:
```

… Many lines omitted …

Figure 9–33. HMS grid-cell parameter file in ASCII format.

Distributed-Basin Model

Similar to the lumped-basin model, the distributed-basin model has additional labeling that references the grid-based subbasin in conjunction with the grid-cell parameter file. The ModClark transform and gridded precipitation must be used with distributed models.

Steps

- Select **HMS ⇒ Distributed-Basin Model**.
- Make a note of the filename and its location as shown in Figure 9–34. Press **OK**.

Figure 9–34. Distributed-Basin Model File Location

The resulting distributed-basin model file in ASCII format looks similar to Figure 9–35.

```
Basin:  AmerRiv1
Description:  Basin model created with HEC-GeoHMS v1.0 Beta
Last Modified date:  27 February 2000
Last Modified Time:  17:22:52
Unit System:  English Unit
End:

... many lines omitted ...

Gridded Subbasin:  R20W20
CanvasX:  -49903.622000
CanvasY:  126433.622000
Area:  7.257000
Label X:  16
Label Y:  0
Downstream:  JR120
End:

... many lines omitted ...
```

Figure 9–35. HMS distributed-basin model file example.

Hydrologic Modeling System Connection

The purpose of this section is to illustrate the procedure for interfacing the inputs developed in HEC-GeoHMS within HEC-HMS models.

HEC-GeoHMS develops many components of an HMS model. GeoHMS capabilities extend from processing the terrain model to performing spatially intensive analysis for development of grid-based parameters. The results produced can be controlled somewhat by focusing on the spatial description of the landscape characteristics and stream networks. However, from a modeling standpoint, greater control over the model is often necessary to address difficult situations. HMS is powerful in that it offers full control over the model to address hydrologic connectivity, methodology, and parameters. For example, HMS can be used to change the connectivity and eliminate, add, and revise hydrologic elements and their properties.

The HMS project definition requires Basin, Meteorology, and Control Specifications components (HEC, 2000). The steps for setting up these three HMS components are discussed below.

Directory Setup

- Create the HMS project first, and then copy the background-map file, basin-model file, and grid-cell parameter file, if appropriate, into "**D:\hmsproj\ GeoHMS_Ex1**".

HMS Use

- Start HMS.
- Select **File ⇒ New Project** on the **HMS*PROJECT DEFINITION** screen.
- Enter the **Project** as "GeoHMS_Ex1" and **Description** as "GIS Application from HEC-GeoHMS" as shown in Figure 9–36.
- Press **OK**.

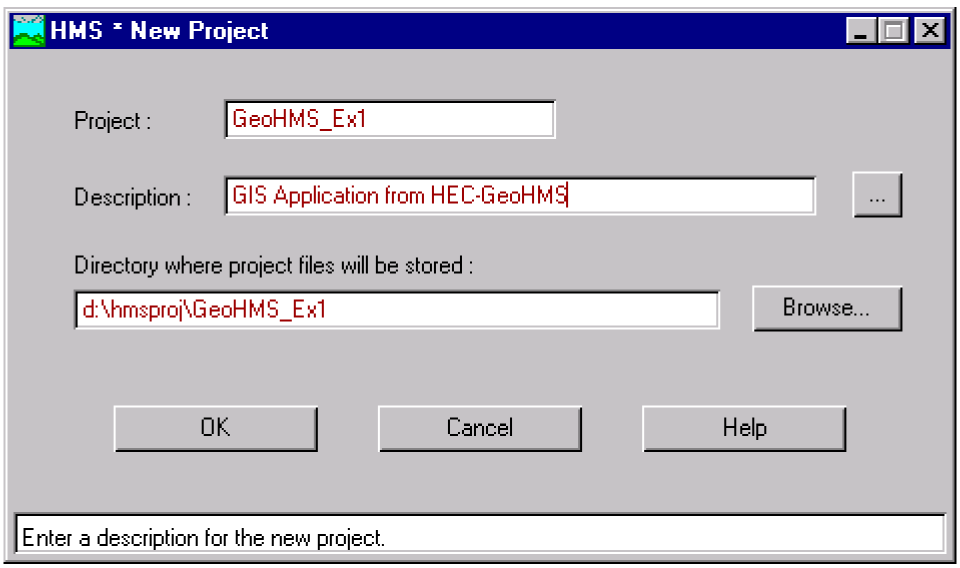


Figure 9–36. New HMS project definition window.

Basin Model

Import the Basin Model with the following steps.

- On the **HMS*PROJECT DEFINITION** screen, select **Component ⇒ Basin Model ⇒ Import** as shown in Figure 9–37.

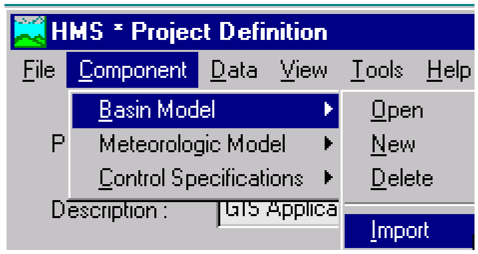


Figure 9–37. Basin model import.

- Navigate to "D:\hmsproj\ GeoHMS_Ex1".
- Select and import the "AmerRiv1" Basin Model.
- Press **Import** as shown in Figure 9–38.

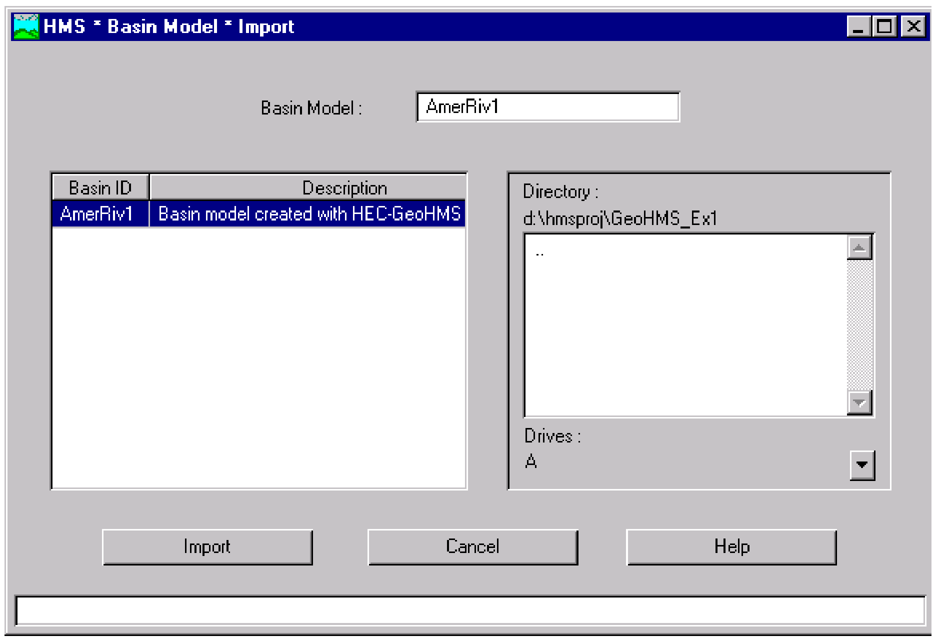


Figure 9–38. HMS basin model import window.

The following errors, shown in Figure 9–39 and Figure 9–40, warn the user that Batch Points 1 and 2 do not have a downstream element connection. Press **OK** in both message boxes and make note to fix the downstream connections later with HMS.

Figure 9–39. Critical error on batch point 2.

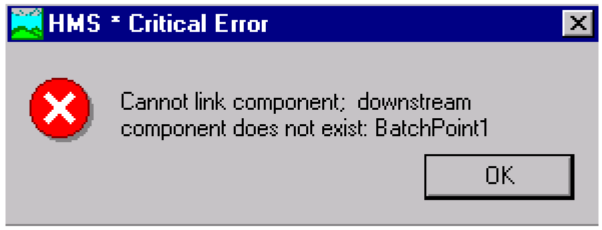


Figure 9–40. Critical error on batch point 1.

Background-Map File and Grid-Cell Parameter File

Specify the background-map file and grid-cell parameter file with the following steps.

- Specify the background-map file and grid-cell parameter file by selecting **File ⇒ Basin Model Attributes** menu item as shown in Figure 9–41. This produces the Basin Model Attributes screen shown in Figure 9–42.

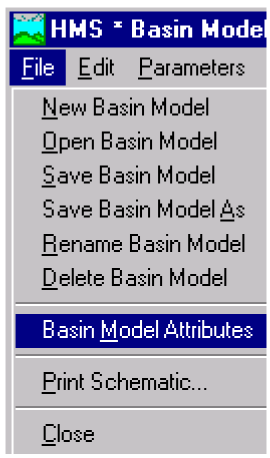


Figure 9–41. HMS basin model attributes menu item.

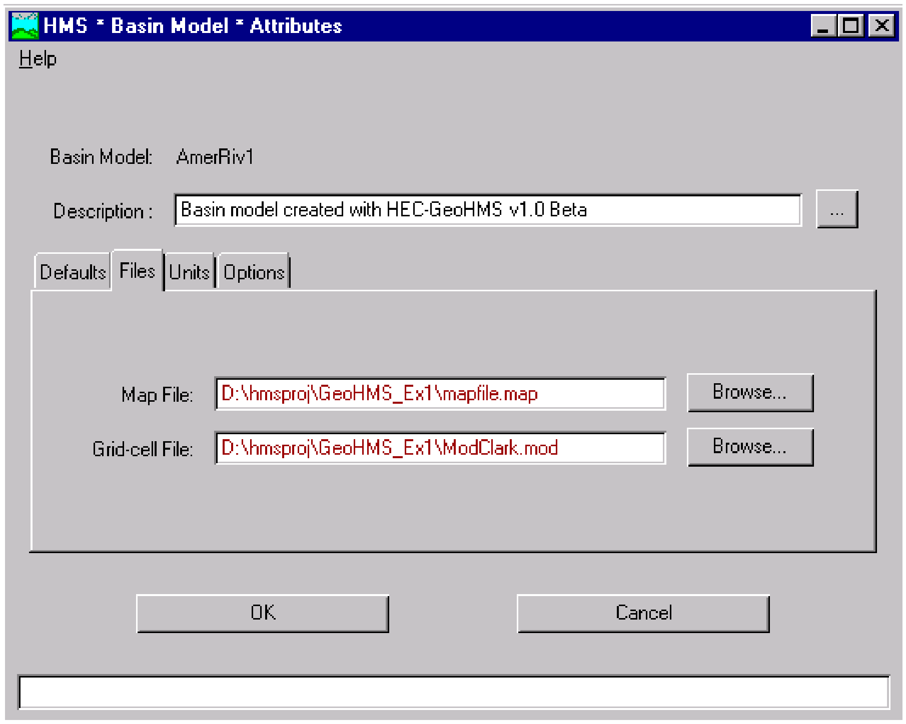


Figure 9–42. HMS basin model attributes specifications.

- Select the **Files** tab.
- To specify the Map File, press **Browse**.
- Navigate to the D:\hmsproj\ GeoHMS_Ex1 and select the file "Mapfile.map" as shown in Figure 9–42.

- To specify the Grid-cell File, press **Browse**.
- Navigate to the D:\hmsproj\ GeoHMS_Ex1 and select the file "ModClark.mod" as shown in Figure 9–42.

- To specify the default methods, select the **Default** tab. Then select a loss rate, ModClark for Transform (this is the grid-cell based unit graph), baseflow, and a routing method. Press **OK**.

The resulting basin model with the background map is shown in Figure 9–43. Notice that subbasins R150W120 and R160W130 are not connected to junctions (these were the problems noted for Batch Points 1 and 2 in the previous data checking).

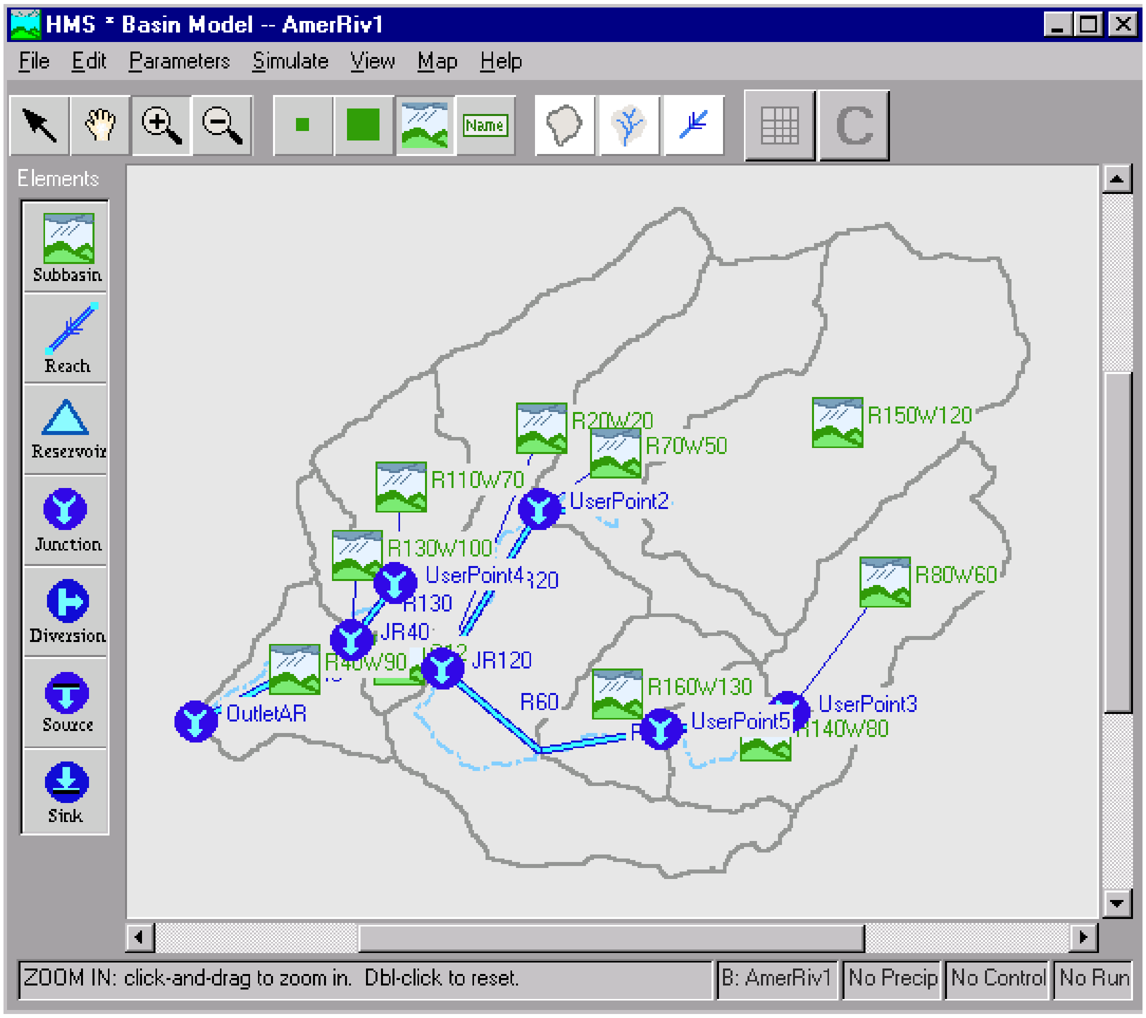


Figure 9–43. HMS basin model schematic.

To fix the missing junction, select the **Junction** element on the left side palette of the HMS Schematic screen and drag it onto the canvas and drop it at the outlet of subbasin R150W120.

Use HMS to connect subbasin R150W120 to Junction-1. Add routing reach R70 to connect Junction-1 to R70 as shown in Figure 9–44.

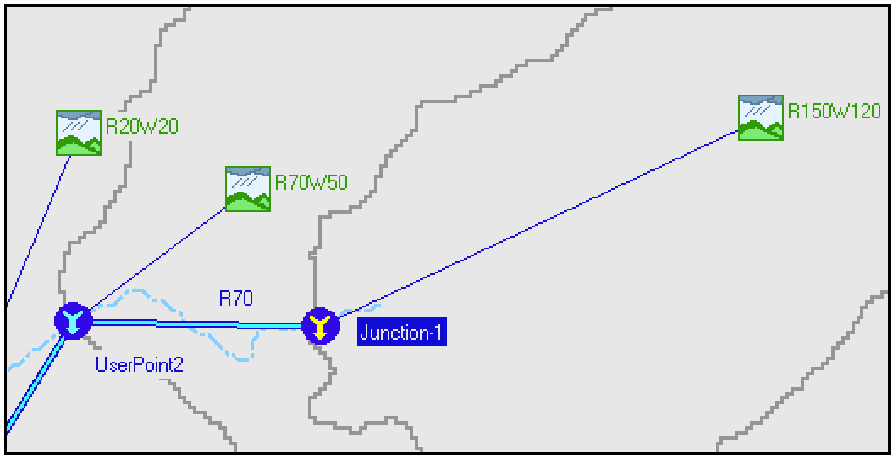


Figure 9–44. Revision to basin connectivity with junction-1.

To connect subbasin R160W130, first break the connection of R160 and R60. Then insert the Junction element on the left side palette by dragging and dropping it at the outlet of subbasin R160W130. Use HMS to connect subbasin R160W130 to Junction-2, then connect reach R160 to Junction-2, and finally Junction-2 to reach R60 as shown in Figure 9–45.

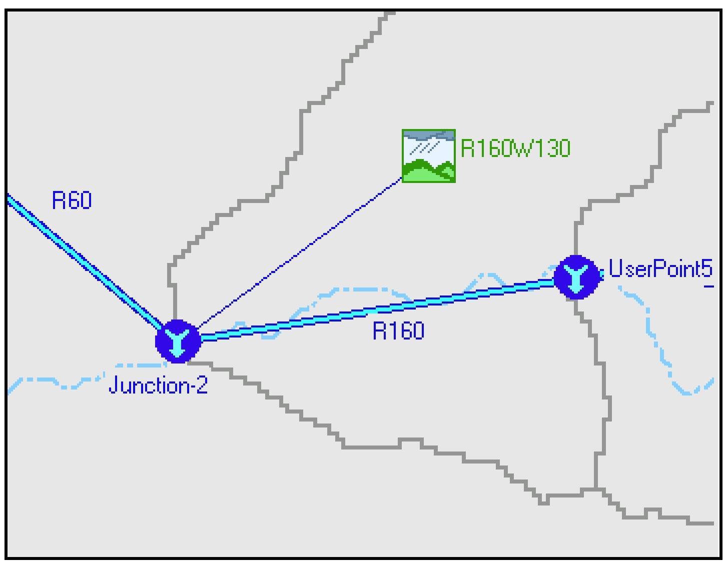


Figure 9–45. Revision to basin connectivity with junction 2.

The corrected basin model is shown in Figure 9–46.

- Select the **Parameters** menu to enter additional hydrologic parameters per menu items. Save and close the **HMS * Basin Model – AmerRiv1** window.

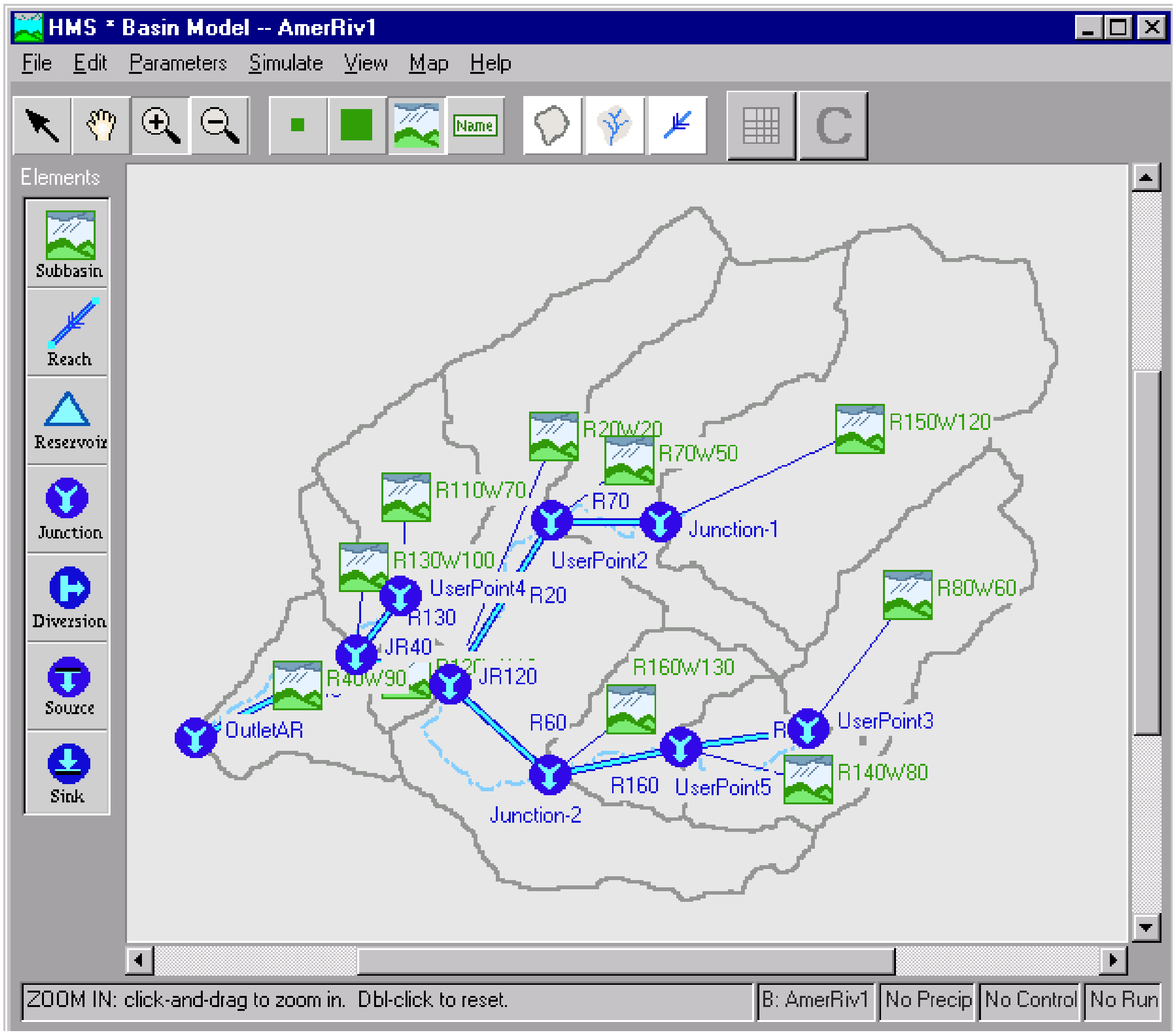


Figure 9–46. HMS basin model with correct connectivity.

Meteorologic Model

A number of methods are available to model the precipitation. The following steps illustrate the grid-based precipitation method that is often used in conjunction with the grid-cell parameter file. The gridded precipitation must be used with ModClark transform method. The grid-based precipitation for this example has been developed in SHG at 2000-meter resolution. The rainfall is stored as a series of grids at 1-hour intervals in the Data Storage System, HEC-DSS (HEC, 1994 and 2000). The rainfall may be directly from the National Weather Service (NWS) NexRad if the Hydrologic Rainfall Analysis Project (HRAP) cell format is used, modified to the HEC Standard Hydrologic Grid (SHG) format, or interpreted from point gages with another program, called GageInterp (HEC, 1999). The precipitation grid format is aligned with the grid-cell parameter file. The steps for developing the meteorologic model follow.

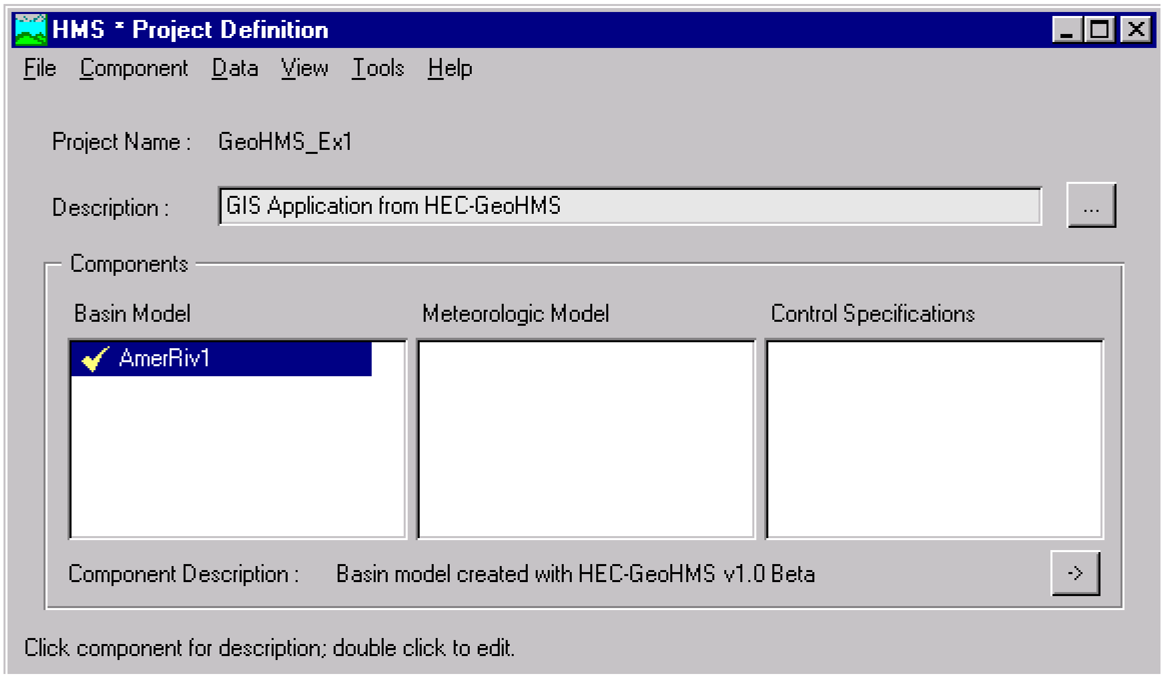


Figure 9–47. HMS Project with Basin Model

- From the **HMS * Project Definition** window as shown in Figure 9–47, select **Component ⇒ Precipitation Model ⇒ New** as shown in Figure 9–48. The result is shown in Figure 9–49.

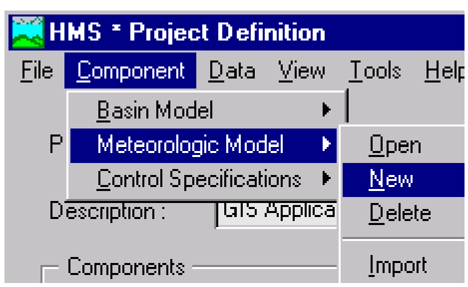


Figure 9–48. Met Model menu item

- Enter the **Meteorologic Model** name as “Radar” and the **Description** as “Grid-based precipitation” in Figure 9–49. Press **OK**.

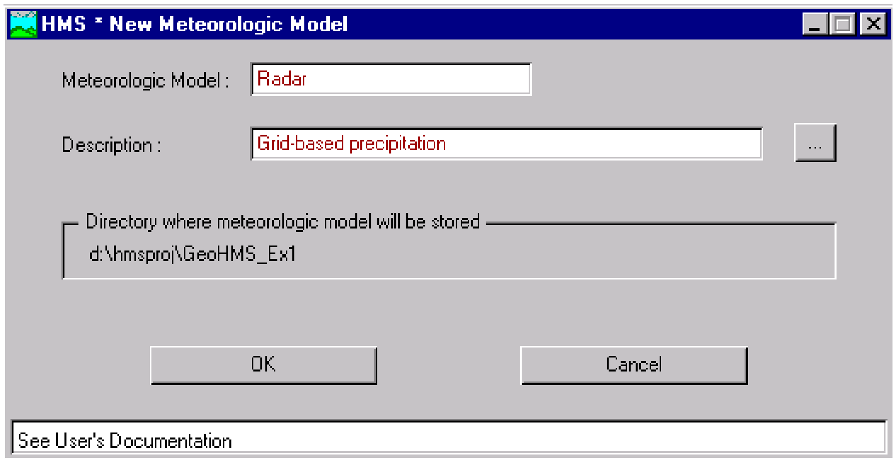


Figure 9–49. New meteorologic model.

- From the “Add subbasins from basin model:” dropdown menu, select “AmerRiv1”. Press **Add** button and the subbasins in the “AmerRiv1” basin model are added to the “Subbasin” heading as shown in Figure 9–50. Press **OK**.

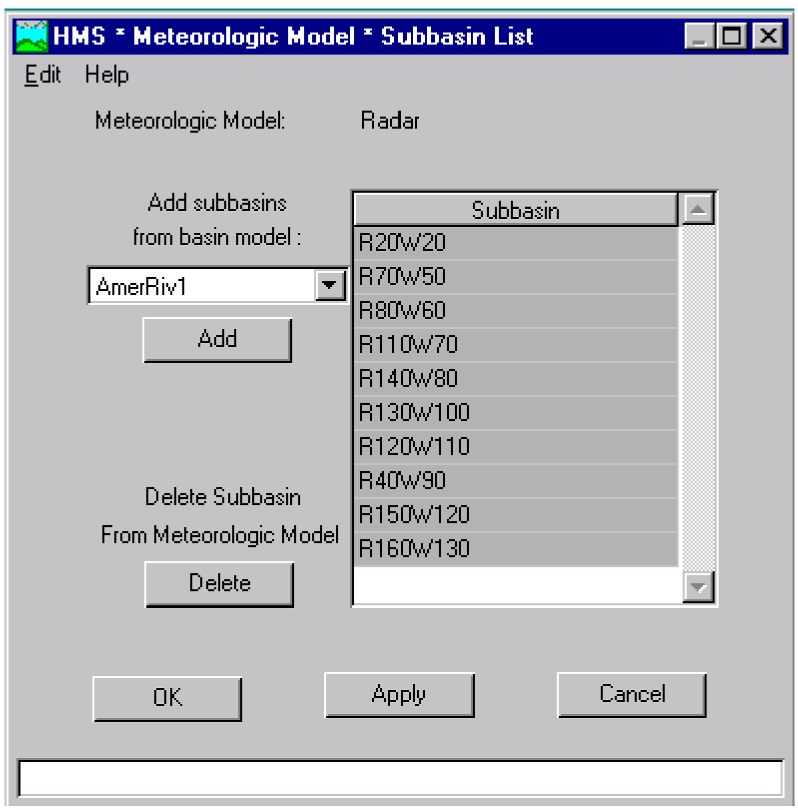


Figure 9–50. Meteorologic model subbasin list.

- With the "Precipitation" tab active, select "***Gridded Precipitation***" from the "***Method***:" dropdown list as shown in Figure 9–51.

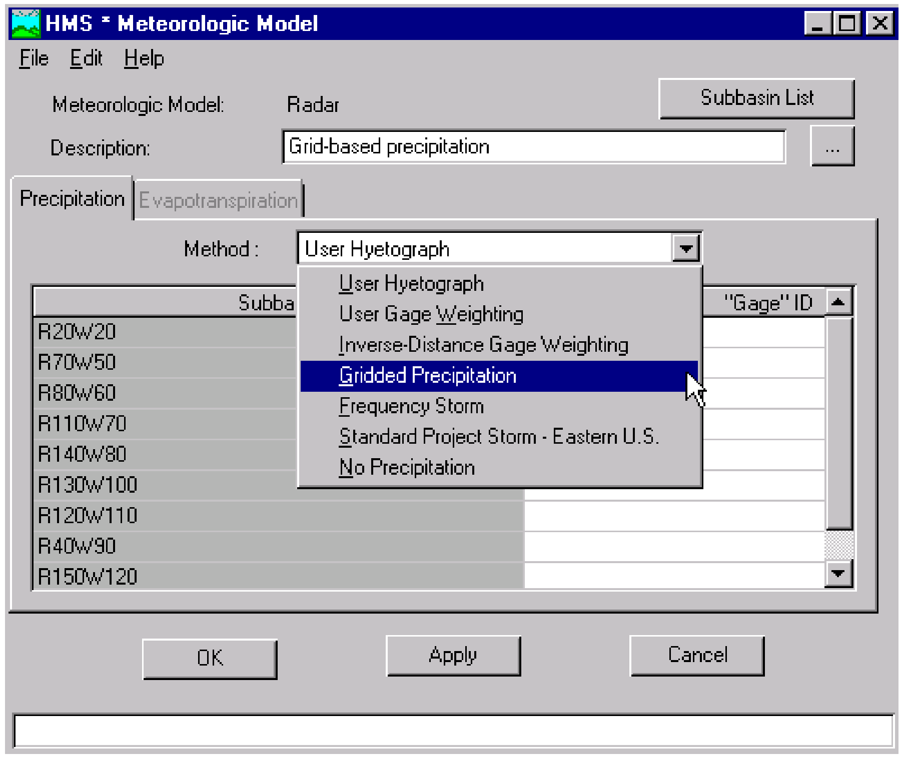


Figure 9–51. Meteorologic model methods.

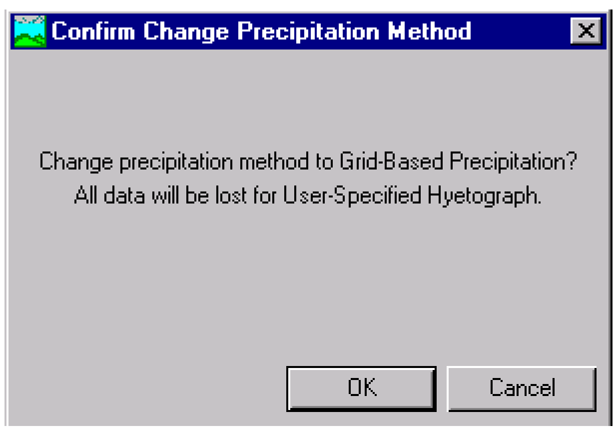


Figure 9–52. Confirmation of precipitation method.

- Press **OK** to the confirmation of precipitation method as shown in Figure 9–52.

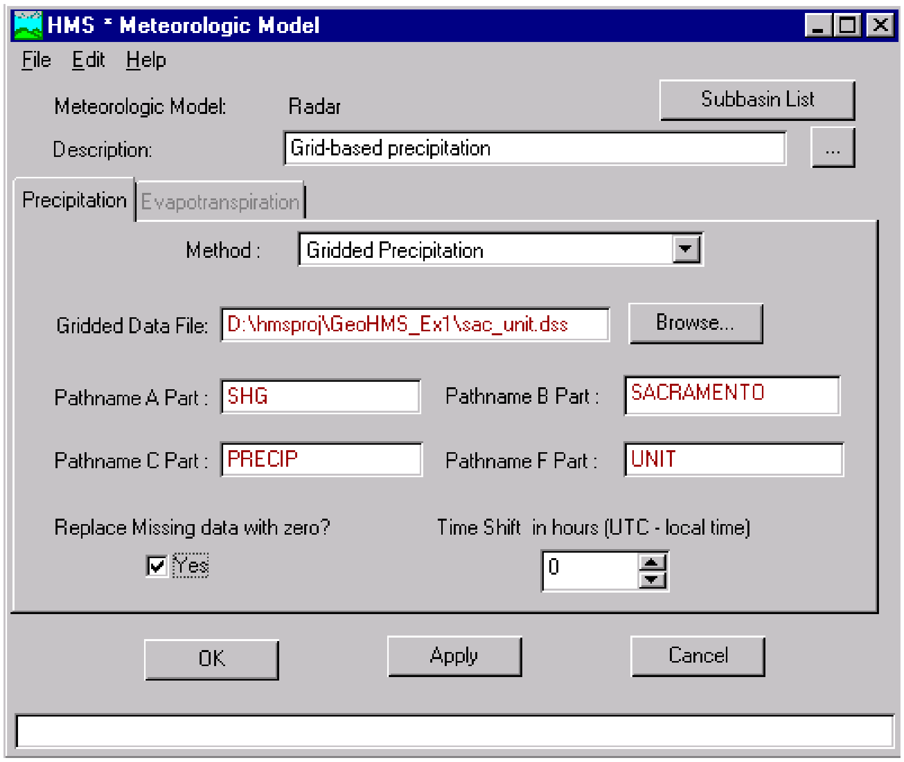


Figure 9–53. Gridded precipitation model options.

- To specify the "Gridded Data File:" in Figure 9–53, press the **Browse…** button and navigate to and select the "D:\hmsproj\GeoHMS_EX1\sac_unit.dss".
- Enter the following pathname parts that are applicable to the "sac_unit.dss" file. For "Pathname A Part:", enter "`SHG`", for "Pathname B Part:", enter "`SACRAMENTO`", for "Pathname C Part:", enter "`PRECIP`", and for "Pathname F Part:", enter "`UNIT`".
- Check **Yes** to "Replace Missing data with zero?" shown in Figure 9–53.

Control Specifications

The control specifications component contains time-related data (HEC, 2000). The following steps illustrate the creation of control specifications component with the time window and interval that are compatible with the precipitation. HMS does not currently interpolate gridded precipitation to other time intervals; the simulation must be performed at the same 1-hour interval as the gridded rainfall. It identifies a time window from 29 February to 3 March 2000. The computational time interval is set at 1 hour. The time-related data input steps for the control specifications are shown below.

- From the **HMS * Project Definition** window, select **Component** ⇒ **Control Specifications** ⇒ **New** as shown in Figure 9–54.

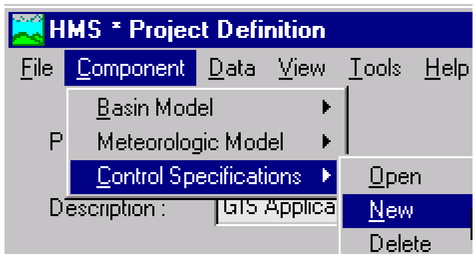


Figure 9–54. Control Specifications menu item

- Enter "`Control Specs Feb 2000`" for "Control Specs:" and "`Time related specifications for Feb 2000 storm`" for the "Description:" as shown in Figure 9–55. Press OK.

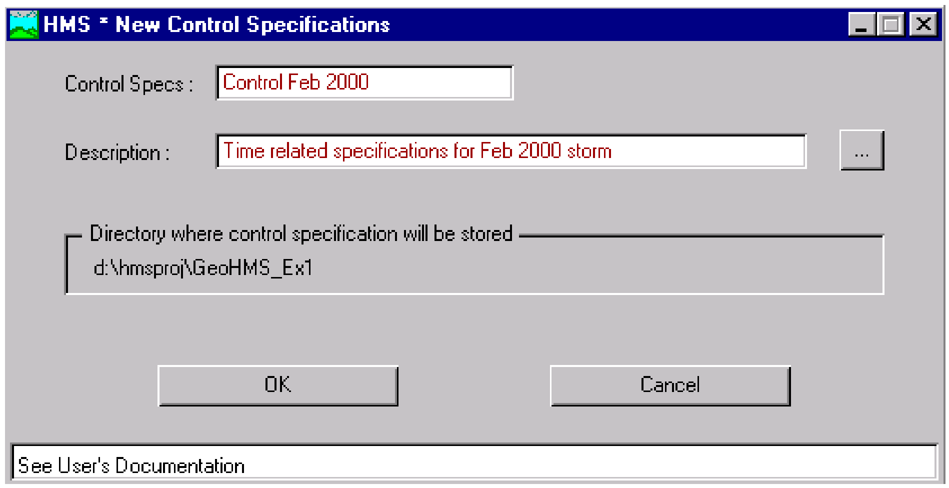


Figure 9–55. New Control Specifications

- Enter the Starting Date as "`29Feb2000`", the Starting Time as "`0000`", the Ending Date as "`03Mar2000`", and the Ending Time as "`0000`". The time interval is 1 hour, which matches with the grid-based precipitation at "`1 Hour`" interval as shown in Figure 9–56. Press **OK**.

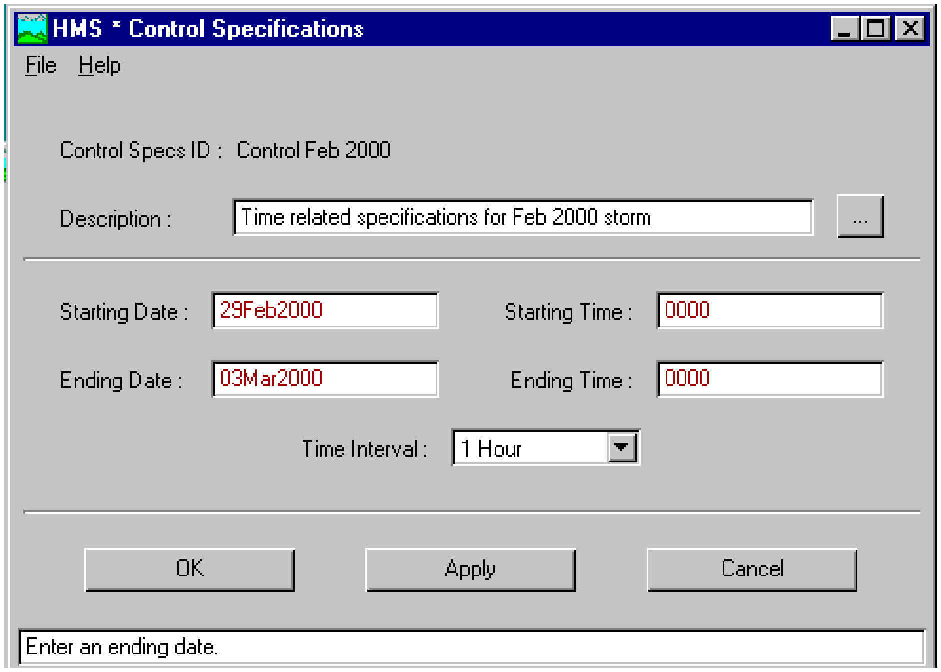


Figure 9–56. Control specifications time window.

HEC-HMS Simulation

An HMS run consists of basin, meteorologic, and control specifications components (HEC, 2000) as shown in Figure 9–57. With these three components completed, HMS can compute flow. The HMS parameter optimization capability can also be used with gridded models. Refer to the HMS User's Manual for examples of gridded basin simulations.

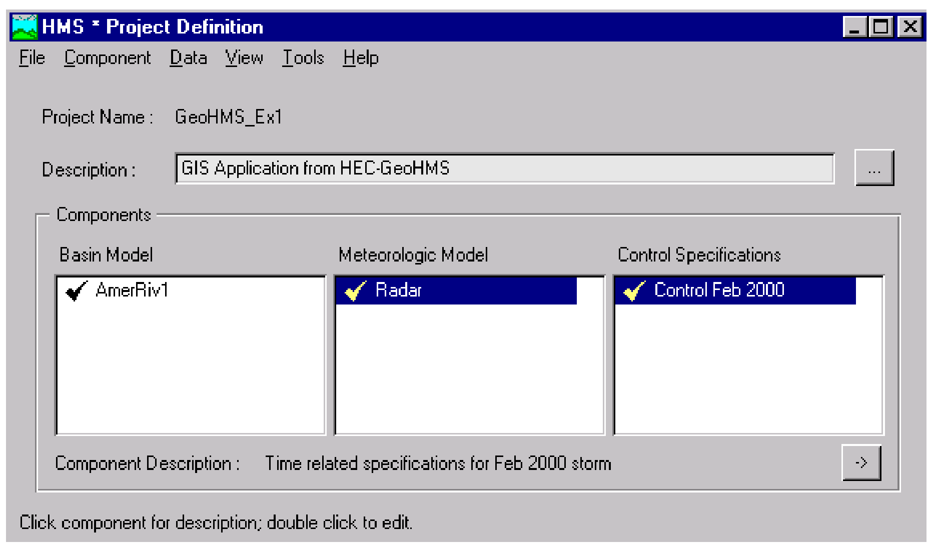


Figure 9–57. HMS components for simulation.

CHAPTER 10

Example Application - American River Basin

The purpose of this chapter is to illustrate the major steps in the development a hydrologic model using GeoHMS. The study watershed is the American River Basin tributary to Folsom Dam, just east of Sacramento, California. The watershed consists of 4,817 square kilometers (1,860 square miles). The digital elevation model has been assembled to represent the watershed terrain. In addition, streamflow gages have been compiled into a data layer of gage locations, names, drainage areas, and other attributes.

Overview

This chapter provides a detailed example of how to perform drainage analysis on a digital terrain model for development of an HEC-HMS model. Eight additional data sets are derived that collectively describe the drainage patterns of the watershed. This information will be used to perform a preliminary delineation of the streams and subbasins. The first five data sets in the grid representation are the flow direction, flow accumulation, stream definition, stream segmentation, and watershed delineation grids. The next two data sets are the vectorized representation of the watersheds and streams, and they are the watershed polygons and the stream segments. The last data set, the aggregated watersheds, is used primarily to improve the performance in watershed delineation.

The following tasks will be performed in the presentation of this example. Figures and tables numbers are not used as the information follows in the direct order of when the tasks and results are described. Processing times for most tasks are shown based on a Pentium III 500 MHz with 256 MB of memory. Besides the hardware specifications, the terrain grid size is the most important factor in determining the time required to perform most of the operation.

The sample data for this exercise includes the DEM ("AmerRiver_dem") and gage outlet locations ("hec1ga.shp"). The sample data is stored under the "AmerRiverData" directory on the CD-ROM.

The completed ArcView project ("AmerRiver.apr") with the HMS model files illustrating the results of Tasks I to III is saved under the "AmerRiver" directory on the CD-ROM.

Task I. Preprocess the Terrain Model

1. Open ArcView and load HEC-GeoHMS.
2. Setup the working directory with terrain and stream flow gage data.
3. Perform drainage analysis by processing the terrain using the 8-pour point approach.
4. Extract pertinent spatial data and setup a hydrologic model.

Task II. Basin Processing

5. Revise subbasin delineation.
6. Extract physical characteristics of streams and subbasins.
7. Develop HMS Inputs.

Task III. Hydrologic Modeling System

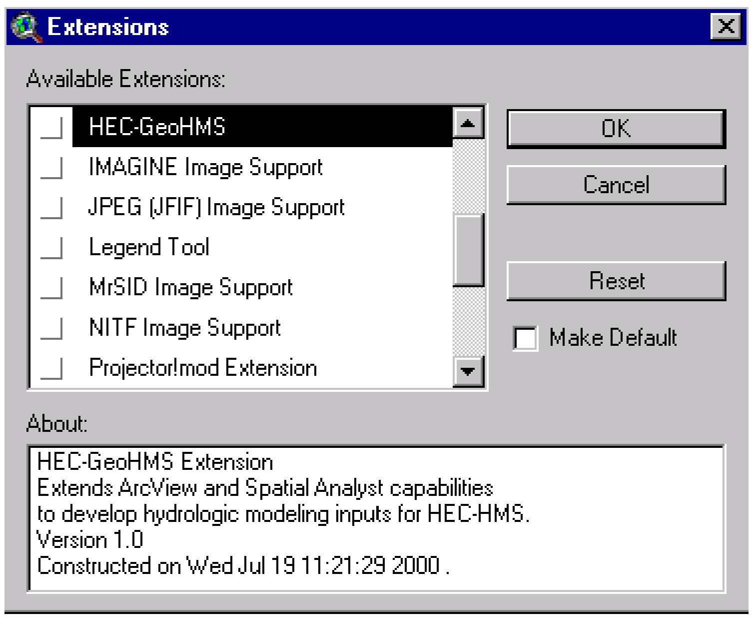
8. Setup an HMS model with inputs from HEC-GeoHMS.

Tasks

<u>Task I. Preprocess the Terrain Model</u>

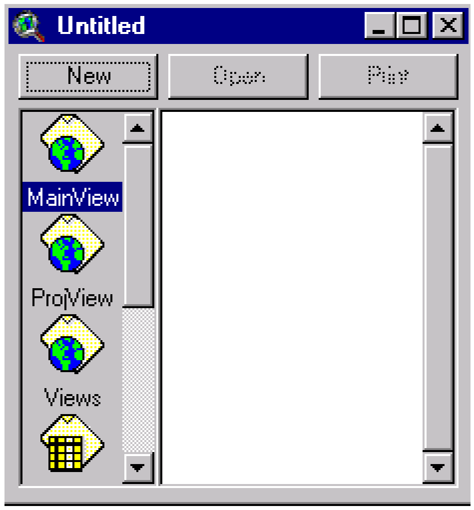
1. Open ArcView and load HEC-GeoHMS

- Create an empty folder called "\AmerRiver" on the hard drive. This folder serves as the working directory for your project. In this case E:\AmerRiver.
- Open ArcView and create a new project as **a Blank Project**.
- Select the **File ⇒ Extensions…**
- When the Extensions dialog appears, scroll down until the HEC-GeoHMS is visible.



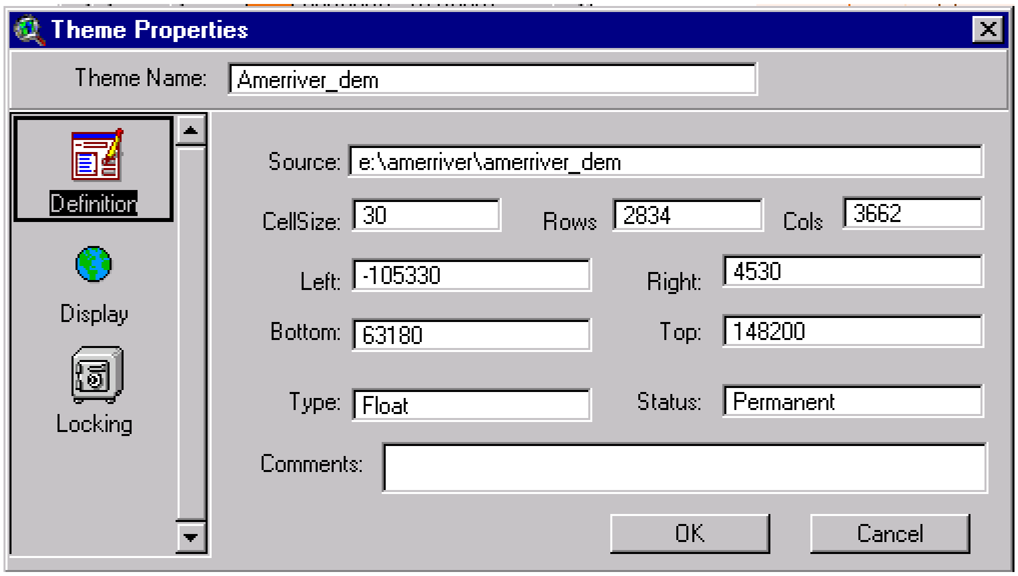
- Press on the name label (HEC-GeoHMS) to access the About information.
- Check the box next to it to turn it on.
- Press OK to close the dialog and watch the status bar in the lower left-hand corner for the loading messages.

It is not necessary to load the Spatial Analyst extension because GeoHMS will automatically load it. When properly installed and loaded, HEC-GeoHMS will create two custom views, "MainView" and "ProjView" as shown below.



2. **Setup the working directory with terrain and streamflow gage data**

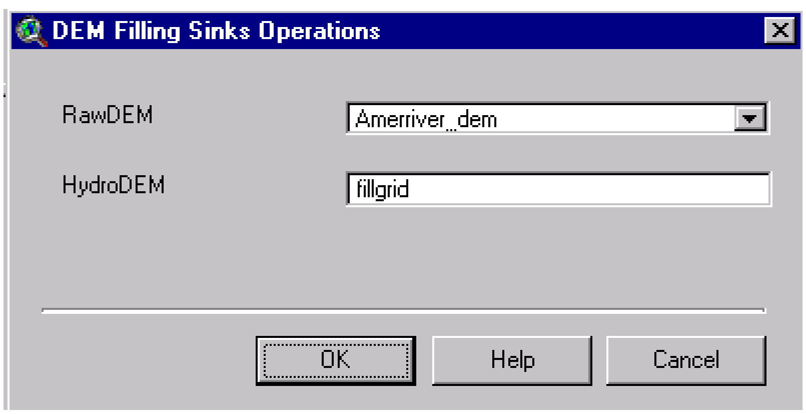
- Open a New MainView
- Select the **File ⇒ Manage Data Sources**…
- Navigate to the "CD-ROM\AmerRiverData"
- Copy the DEM called "AmerRiver_dem" to your working directory
- Add the "AmerRiver_dem" as a grid theme in the MainView
- Select **Theme ⇒ Properties**. Note that there are about 10 million (2834 rows * 3662 columns) cells at 30 meters resolution that cover a rectangular area of 9340 sq km (3606 sq mi), which encompasses this study watershed of 4817 sq km (1860 sq mi).
- Save the project as "AmerRiver.apr" in the working directory "E:\AmerRiver". The location of the project is important because subsequent derived data sets are stored relative to the project.



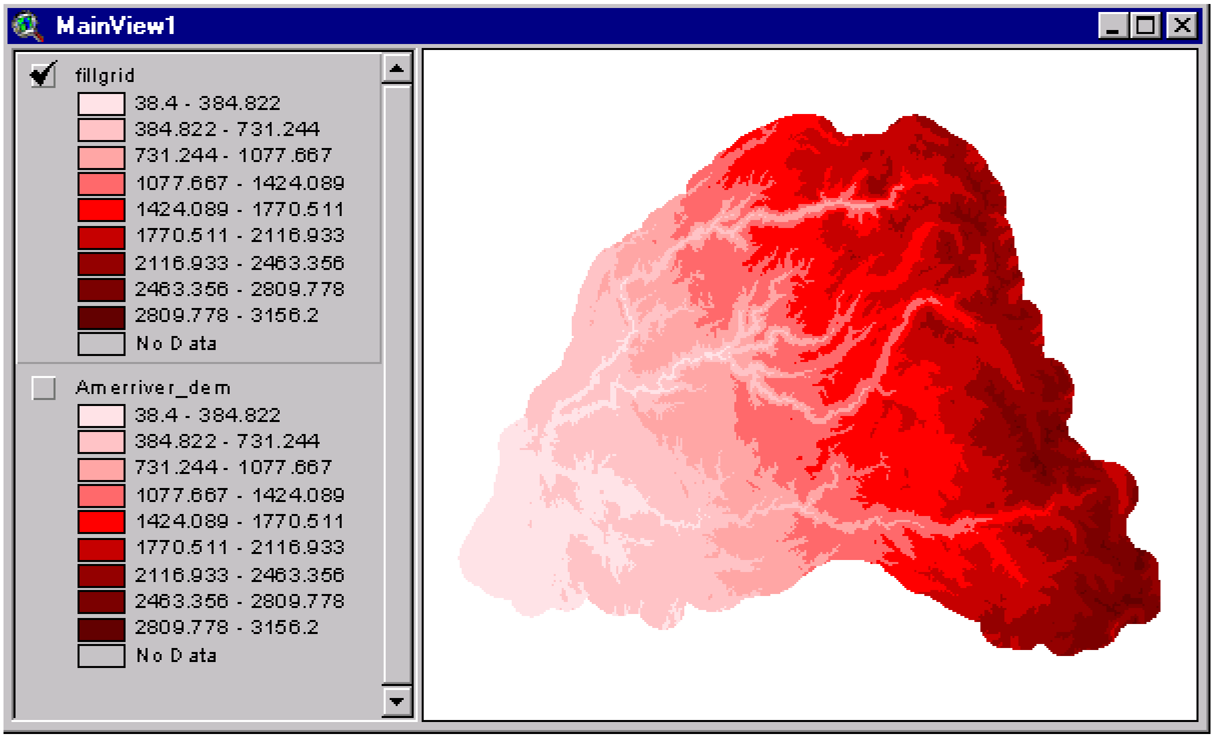
3. Perform drainage analysis by processing the terrain using the 8-point pour-down approach

A. Fill Sinks

- Select **Terrain Preprocessing ⇒ Fill Sinks**.
- Confirm that the input of the RawDEM (also refer to as the unfilled DEM) is "AmerRiver_dem". The output of the HydroDEM is "FillGrid". "FillGrid" is a default name that can be overwritten by the user.

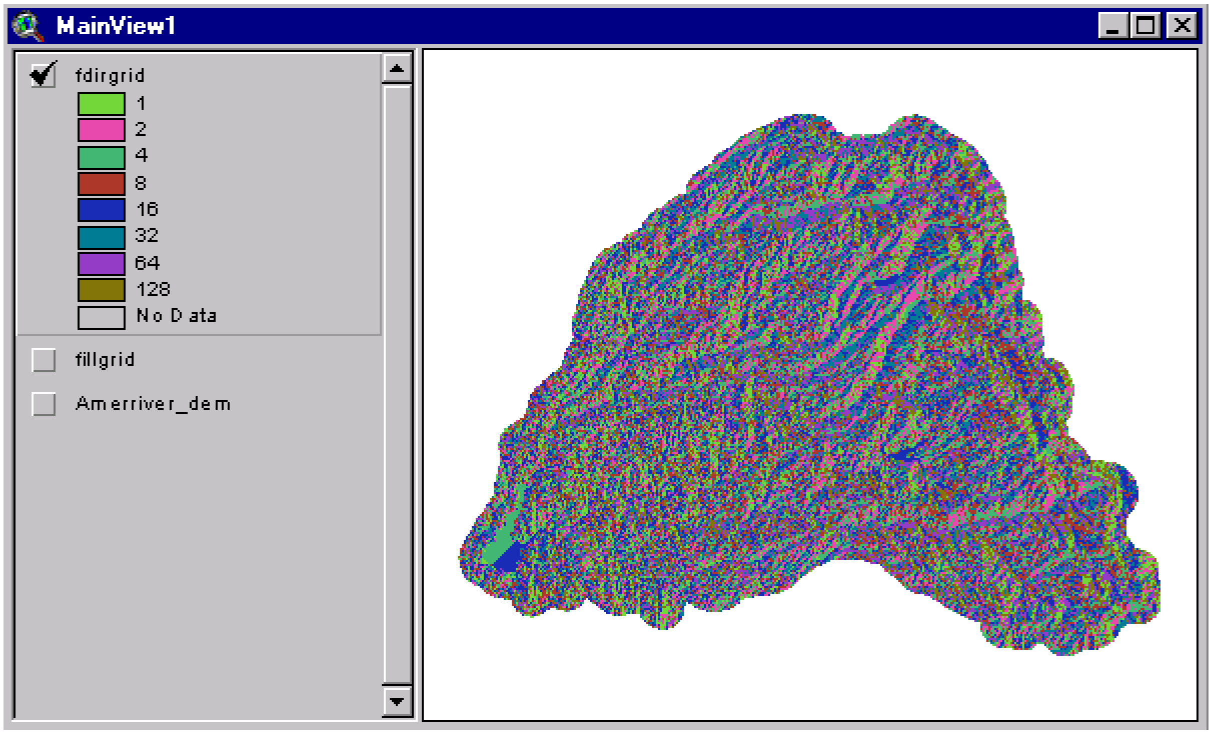


- Press OK. (This step takes about 45 minutes.)



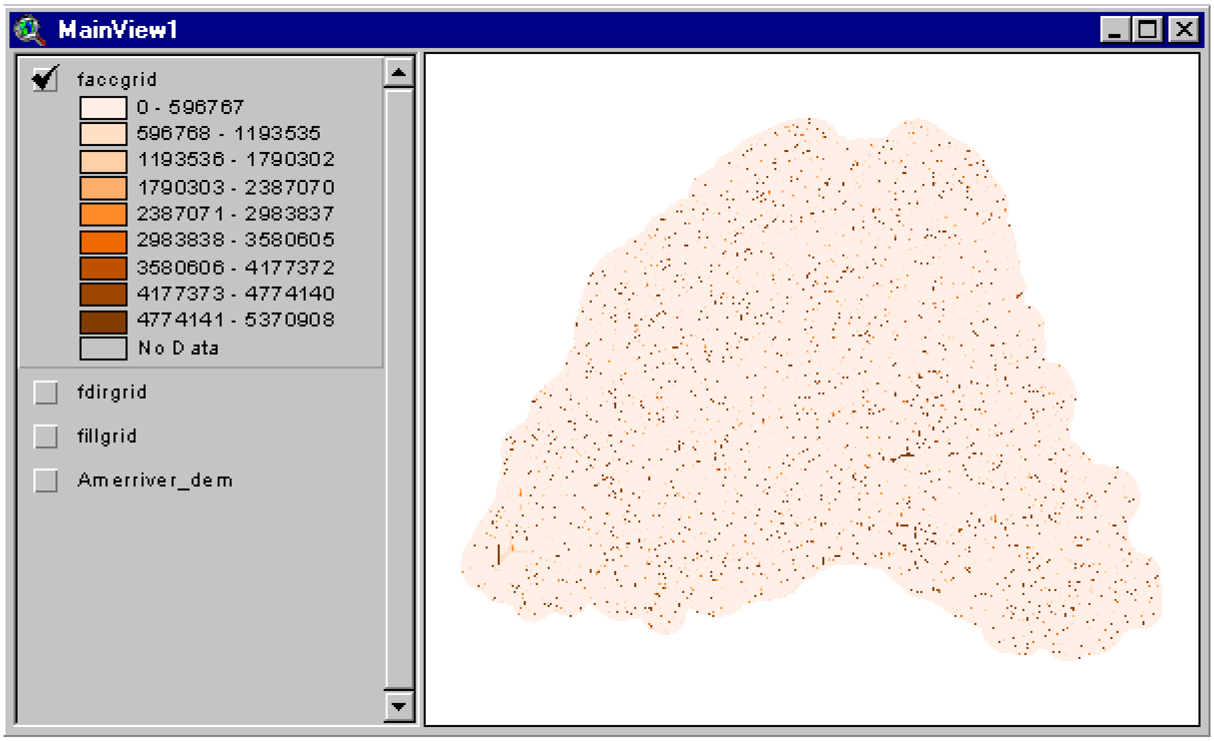
B. Flow Direction

- Select **Terrain Preprocessing ⇒ Flow Direction**.
- Confirm that the input of the HydroDEM is “Fillgrid”. The output of the FlowDirGrid is “FdirGrid”. “FdirGrid” is a default name that can be overwritten by the user.
- Press OK. (This step takes about 2 minutes.)

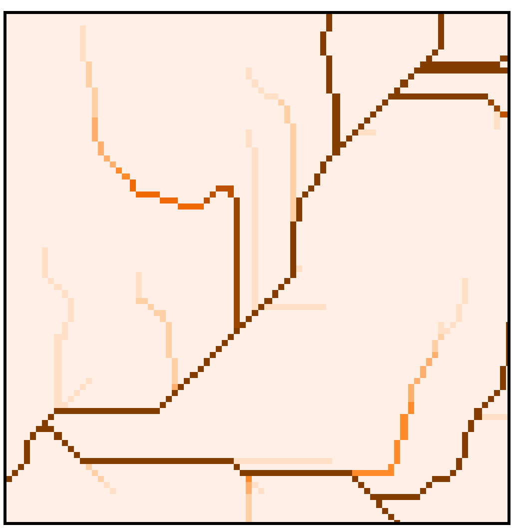


C. Flow Accumulation

- Select **Terrain Preprocessing ⇒ Flow Accumulation**.
- Confirm that the input of the FlowDirGrid is "FdirGrid". The output of the FlowAccGrid is "FaccGrid". "FaccGrid" is a default name that can be overwritten by the user.
- Press OK. (This step takes about 21 minutes.)

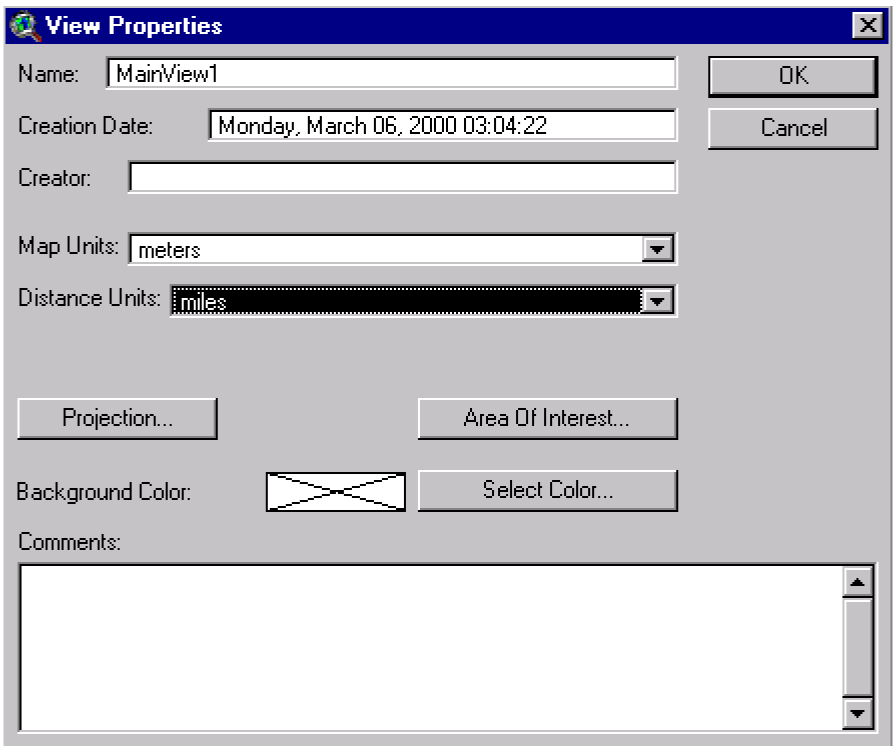


The above screen does not appear complete, but it is. Zoom-in to a part of the basin to display the details of the grid cells that make up the flow accumulation grid as shown below.



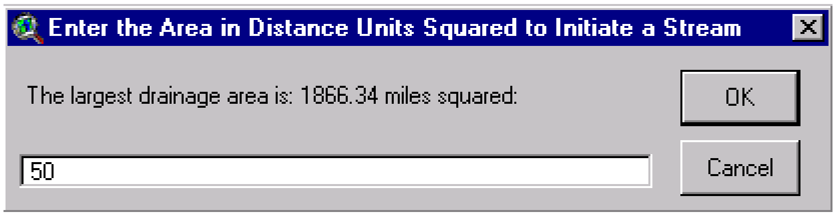
D. Stream Definition

- Select **View ⇒ Properties**.
- The Map Units are the data units. In this case, the DEM data units are measured in meters.
- Specify the Map Units as “meters”.
- The Distance Units are the reporting units in ArcView. In this case, the Distance Units are chosen as miles so that the information reported from ArcView can be compared with the streamflow gage drainage area reported in square miles.
- Specify the Distance Units as miles.
- Press OK.

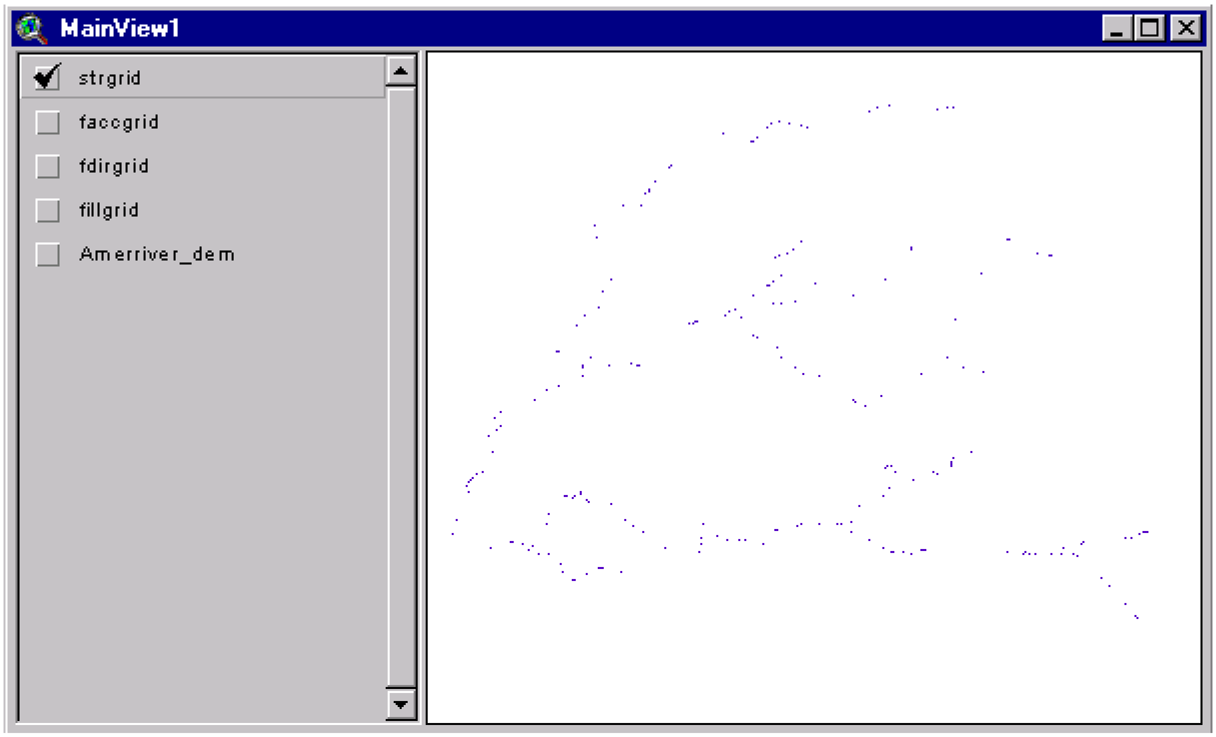


- Save the project as “AmerRiver.apr” in the working directory “E:\AmerRiver”.
- Select **Terrain Preprocessing ⇒ Stream Definition**.
- Confirm that the input of the FlowAccGrid is “FaccGrid”. The output of the StreamGrid is “StrGrid”. “StrGrid” is a default name that can be overwritten by the user.
- Press OK.
- Select the threshold type as “Area in Distance Units squared”.
- Enter the threshold for stream initiation at “50” square miles.

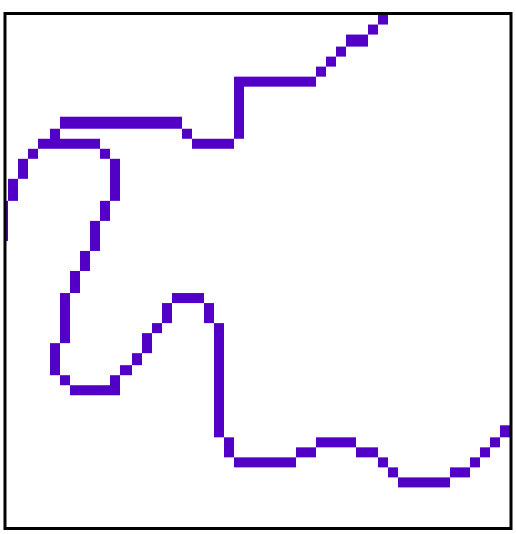
- Press OK. (This step takes about 30 seconds.)



The result of the Stream Definition operation is the “StrGrid” shown below.

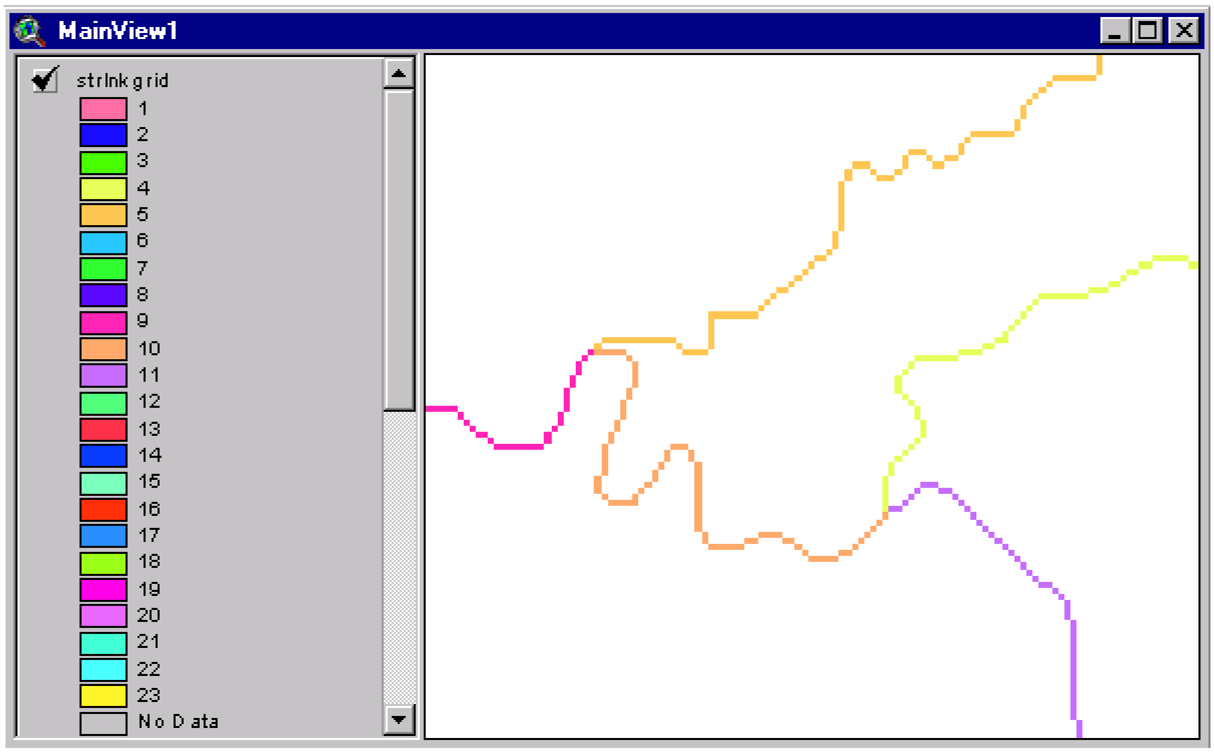


Zoom-in to display the details of the grid cells that make up the stream definition grid.



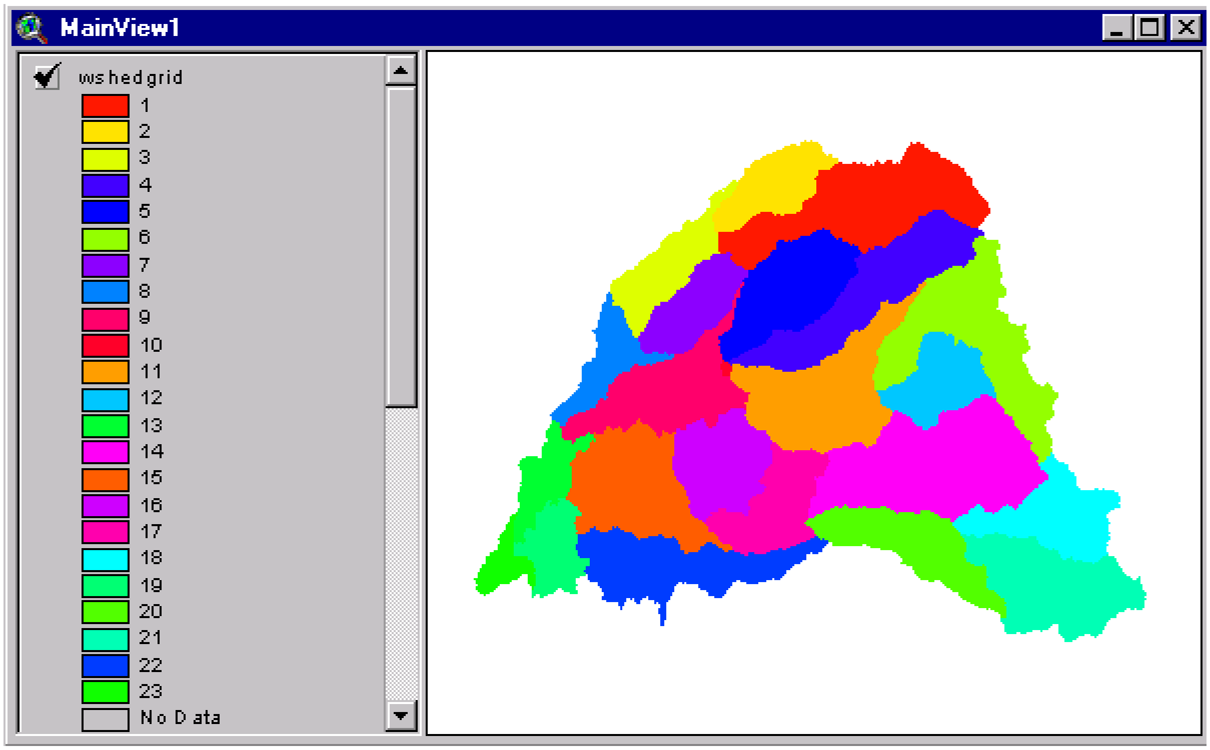
E. Stream Segmentation

- Select **Terrain Preprocessing ⇒ Stream Segmentation**.
- Confirm that the input of the FlowDirGrid is "FdirGrid" and StreamGrid is "StrGrid". The output of the LinkGrid is "StrLnkGrid". "StrLnkGrid" is a default name that can be overwritten by the user.
- Press OK. (This step takes about 30 seconds.)



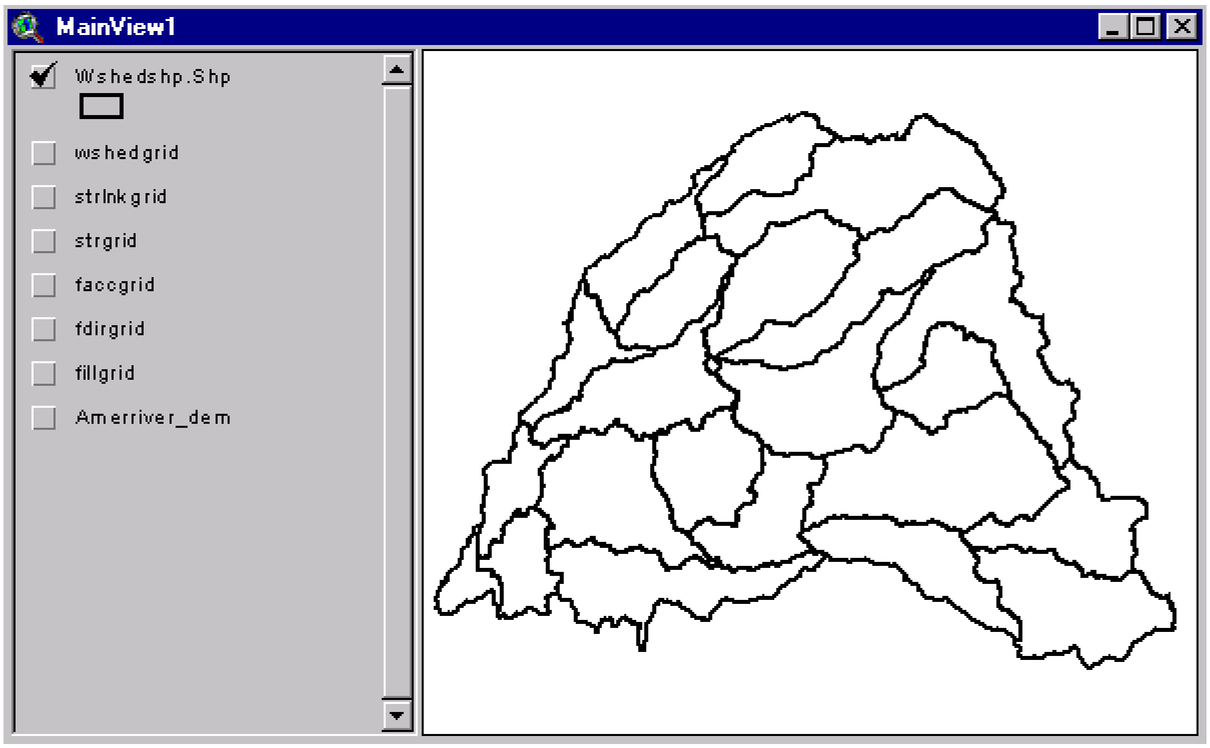
F. Watershed Delineation

- Select **Terrain Preprocessing ⇒ Watershed Delineation**.
- Confirm that the input of the FlowDirGrid is "FdirGrid" and LinkGrid is "StrLnkGrid". The output of the WaterGrid is "WshedGrid". "WshedGrid" is a default name that can be overwritten by the user.
- Press OK. (This step takes about 6 minutes.)



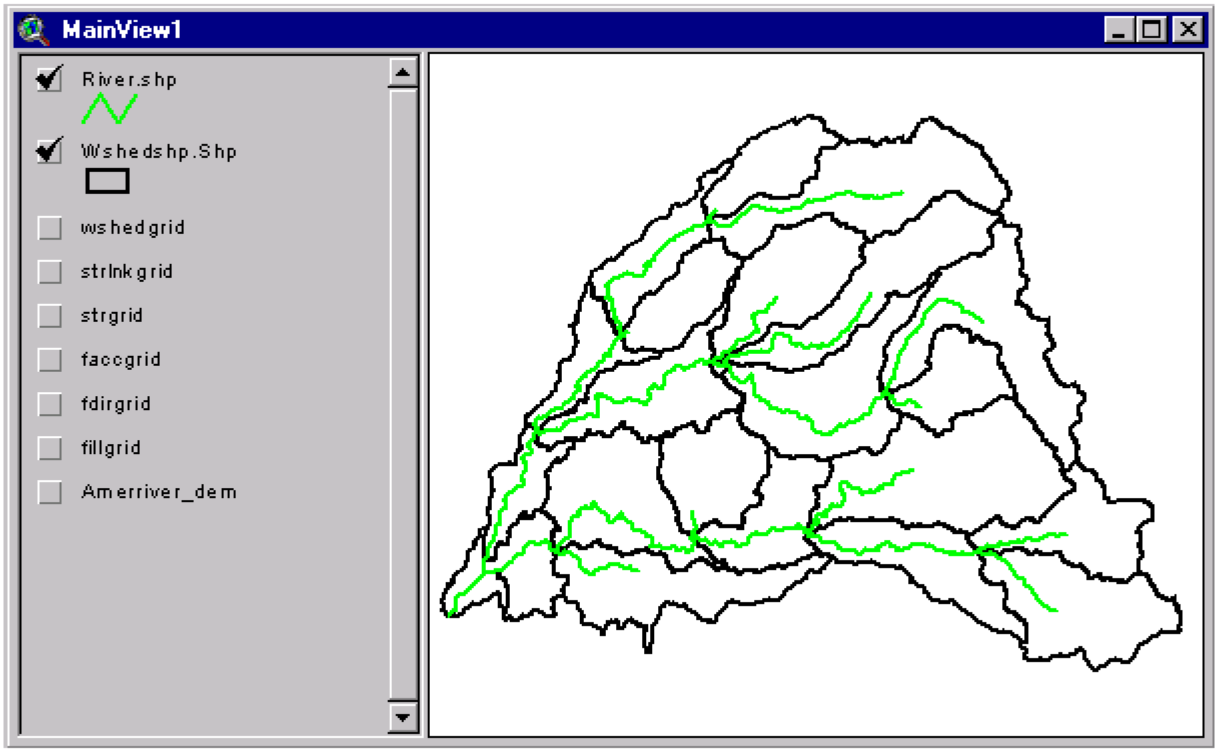
G. Watershed Polygon Processing

- Select **Terrain Preprocessing ⇒ Watershed Polygon Processing**.
- Confirm that the input of the WaterGrid is "WshedGrid". The output of the Watershed is "Wshedshp.Shp". "Wshedshp.Shp" is a default name that can be overwritten by the user.
- Press OK. (This step takes about 10 seconds.)



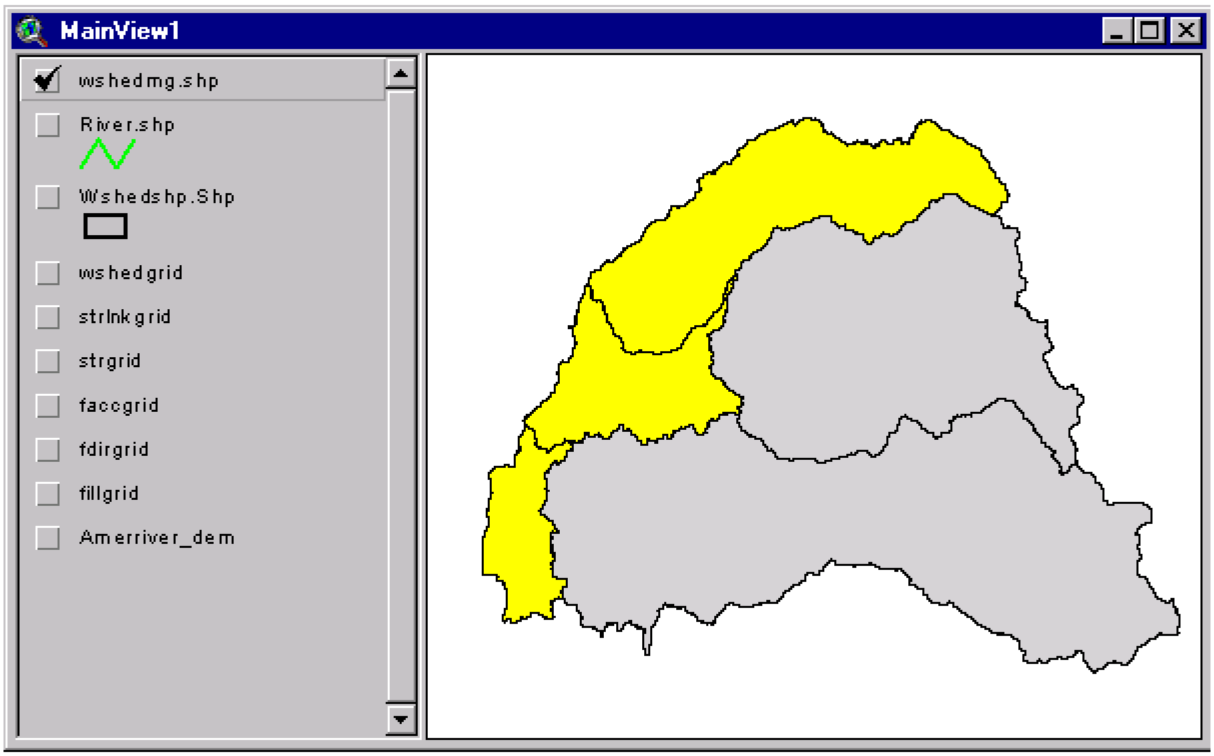
H. Stream Segment Processing

- Select **Terrain Preprocessing ⇒ Stream Segment Processing**.
- Confirm that the input of the LinkGrid is StrLnkGrid and FlowDirGrid is FDirGrid. The output of the River is River. River is a default name that can be overwritten by the user.
- Press OK. (This step takes about 10 seconds.)



I. Watershed Aggregation

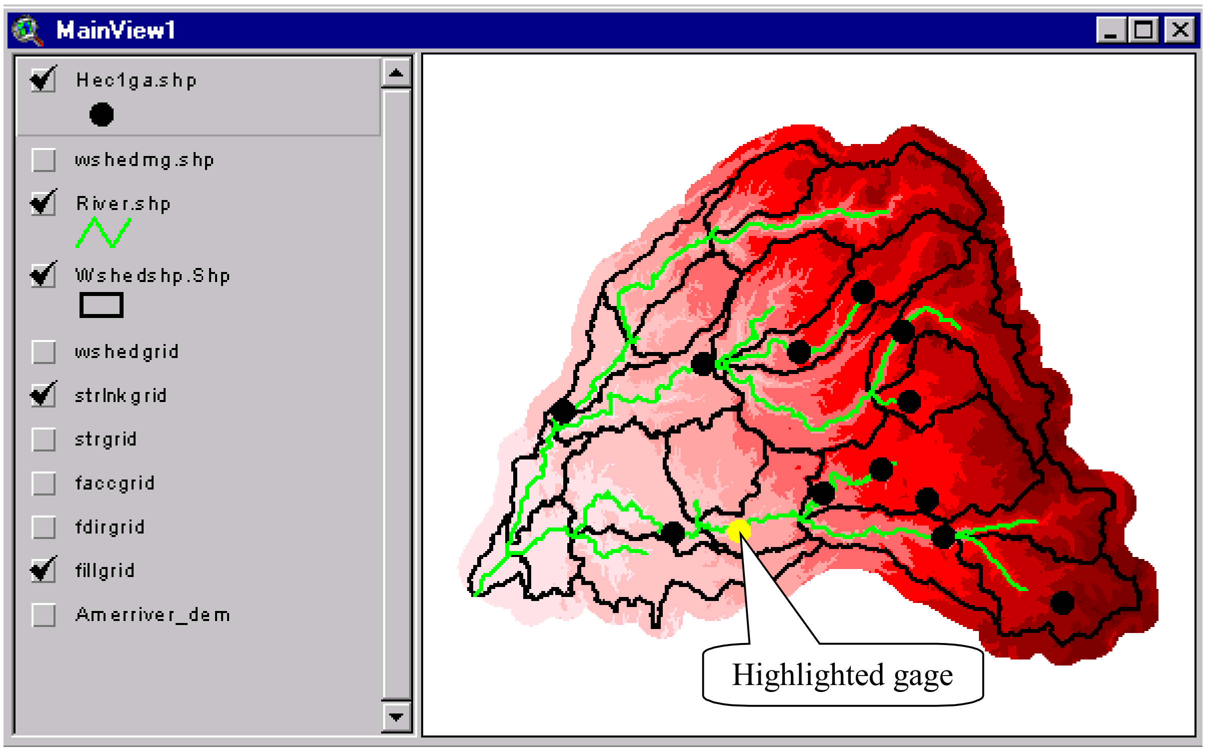
- Select **Terrain Preprocessing ⇒ Watershed Aggregation**.
- Confirm that the input of the River is "River.shp" and Watershed is "Wshedshp.shp". The output of the AggregatedWatershed is "WshedMg.shp". "WshedMg.shp" is a default name that can be overwritten by the user.
- Press OK. (This step takes about 30 seconds.)



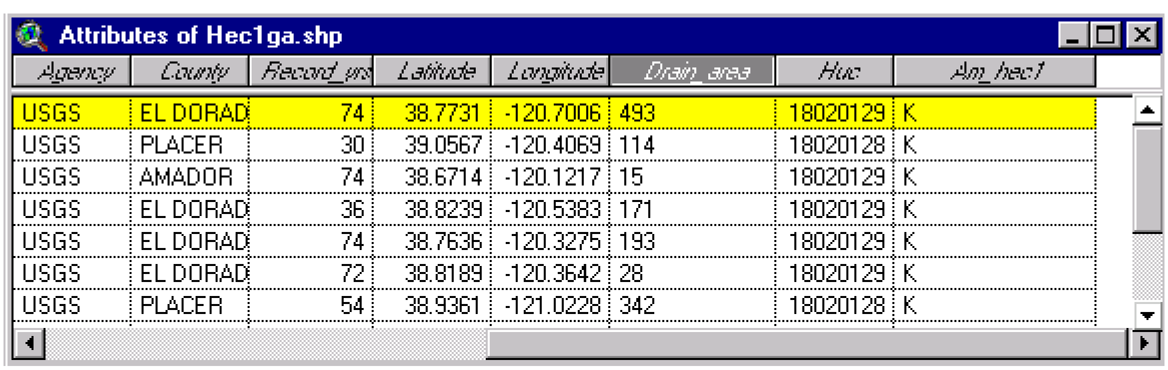
4. Extract pertinent spatial data and setup a hydrologic model

In this step, a watershed is defined by its outlet. A watershed can also be defined by an outlet and one or more source points which represent inflows from other drainage basins. The watershed outline is delineated by GeoHMS, and a project view is created which contains the newly delineated subbasins, or project model.

- Add the streamflow gage theme called "HEC1ga.shp" to the MainView to help determine the outlet location.
- Make the "HEC1ga.shp" active and identify the gages shown below.

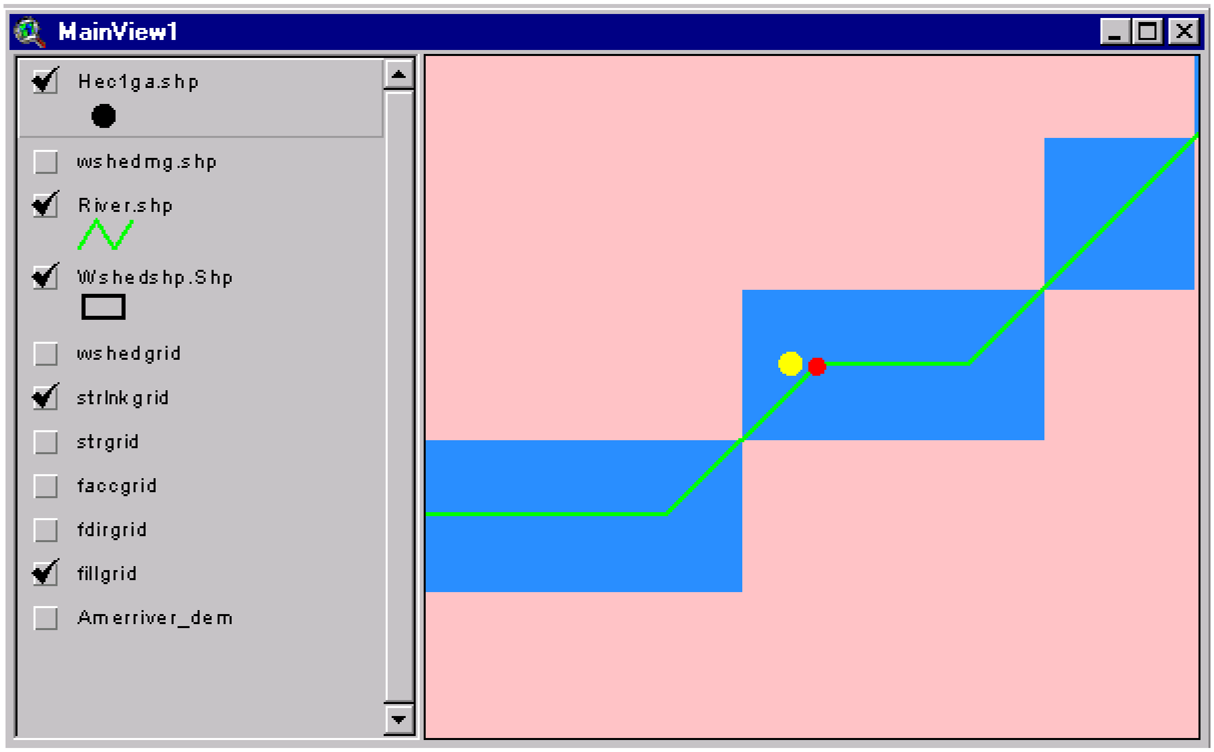


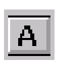
- The identified gage has a drain area of about 493 sq. miles under the "Drain_area" heading.


Attributes of Hec1ga.shp

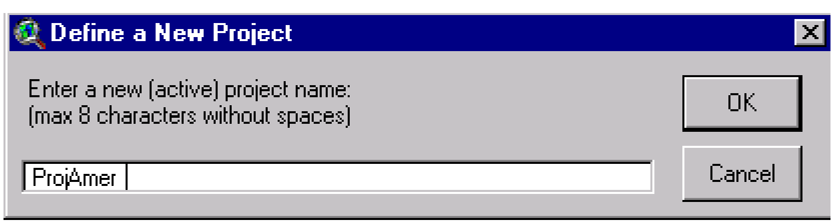
Agency	County	Record_yrs	Latitude	Longitude	Drain_area	Huc	Am_hec1
USGS	EL DORAD	74	38.7731	-120.7006	493	18020129	K
USGS	PLACER	30	39.0567	-120.4069	114	18020128	K
USGS	AMADOR	74	38.6714	-120.1217	15	18020129	K
USGS	EL DORAD	36	38.8239	-120.5383	171	18020129	K
USGS	EL DORAD	74	38.7636	-120.3275	193	18020129	K
USGS	EL DORAD	72	38.8189	-120.3642	28	18020129	K
USGS	PLACER	54	38.9361	-121.0228	342	18020128	K

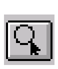
- Zoom in on the gage and make the "StrlnkGrid" theme visible.

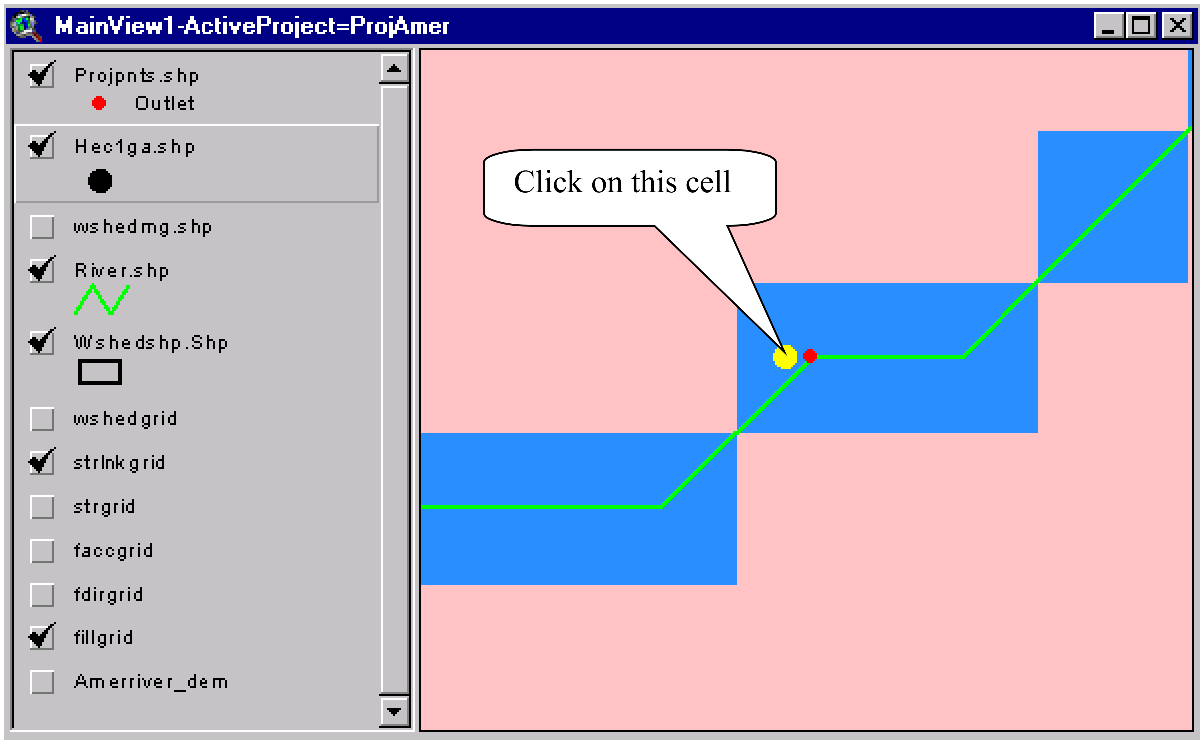


- Use the  tool and click on the grid cell with the identified gage. The grid cell has 492.009 sq mi drainage area. The result The area is : 492.009 miles squared. is shown in the lower left corner. This cell has a drainage area that is adequately close to that of the gage.
- Now analyze the watershed that is tributary to this grid cell.

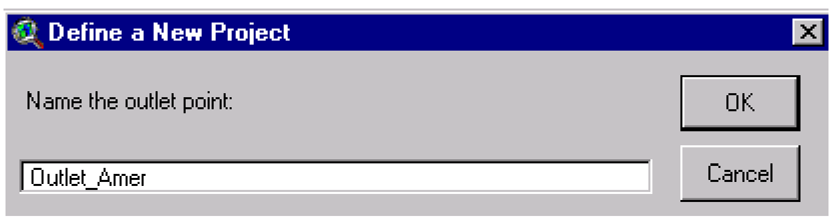
- Select **HMS Project Setup ⇒ Start New Project**.
- Enter "ProjAmer" as the project name.
- Press OK.



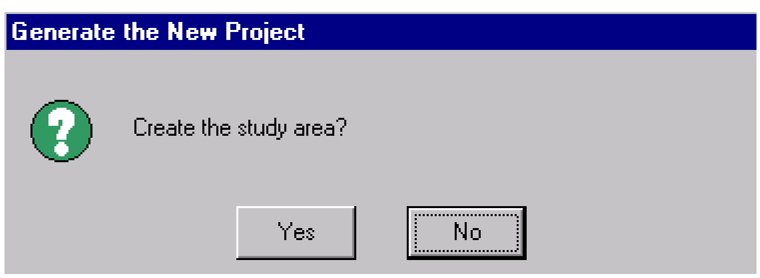
- Select  and click on the cell to specify the outlet location.



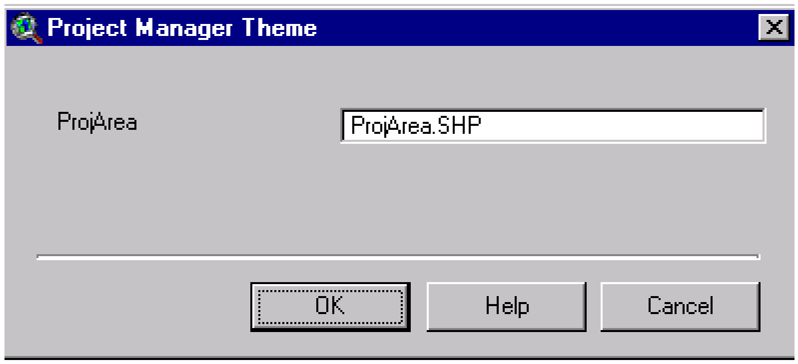
- Name the outlet point as "Outlet_Amer".



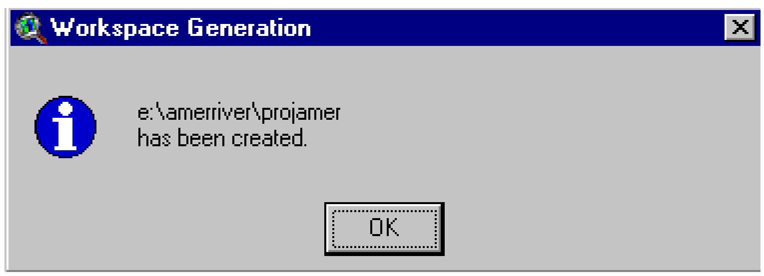
- Press OK.



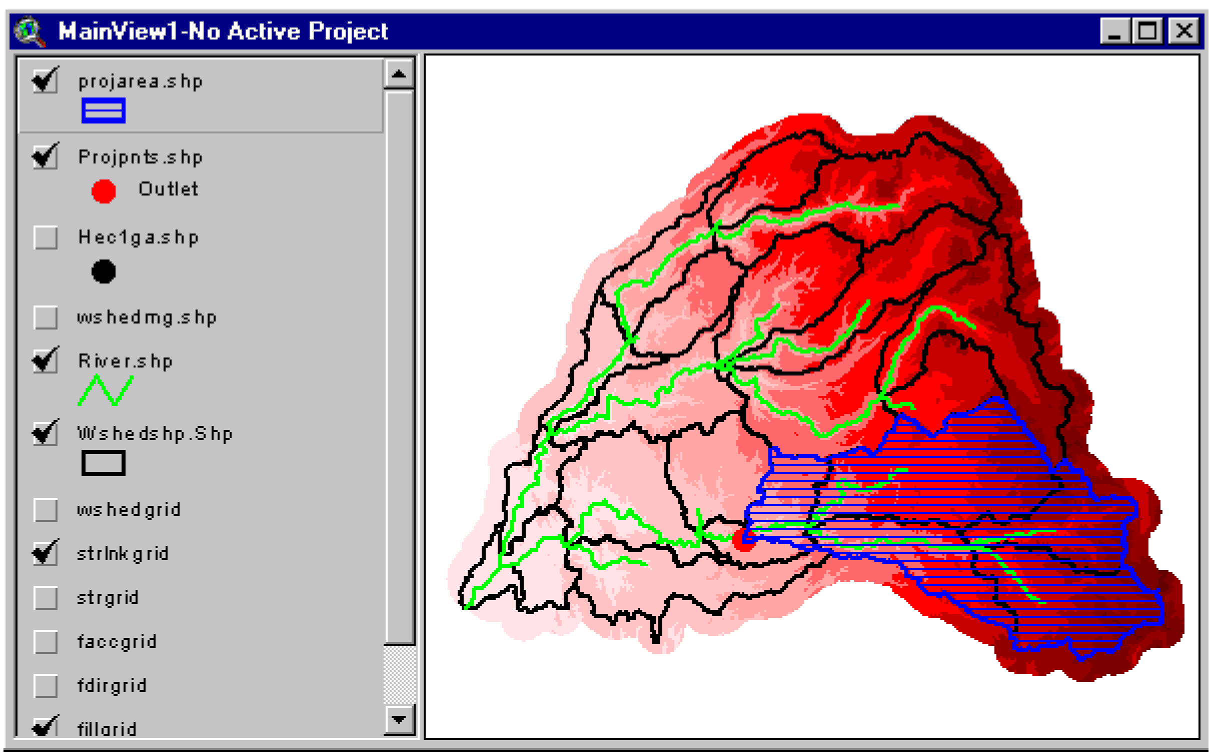
- Select **HMS Project Setup ⇒ Generate Project**.
- Select the "Original stream definition" from the dropdown menu.
- Press OK.
- Verify the watershed outline boundary and press Yes.



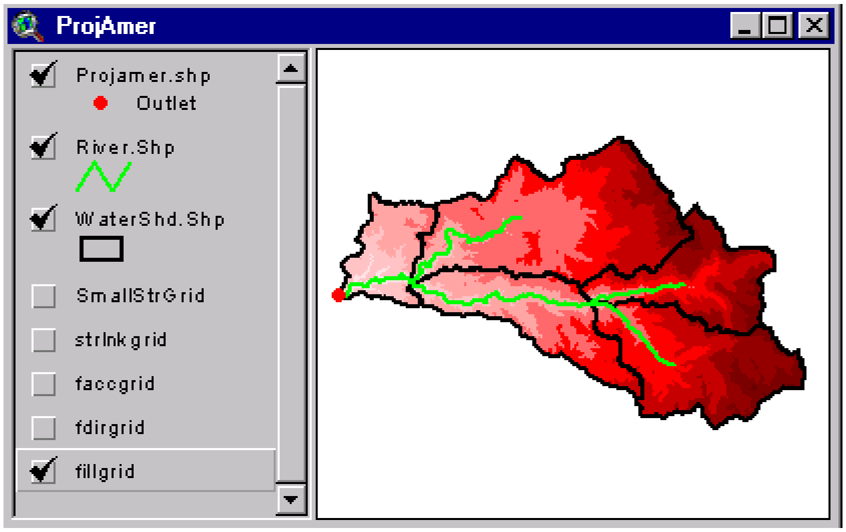
- Verify the project area shapefile and then press OK.



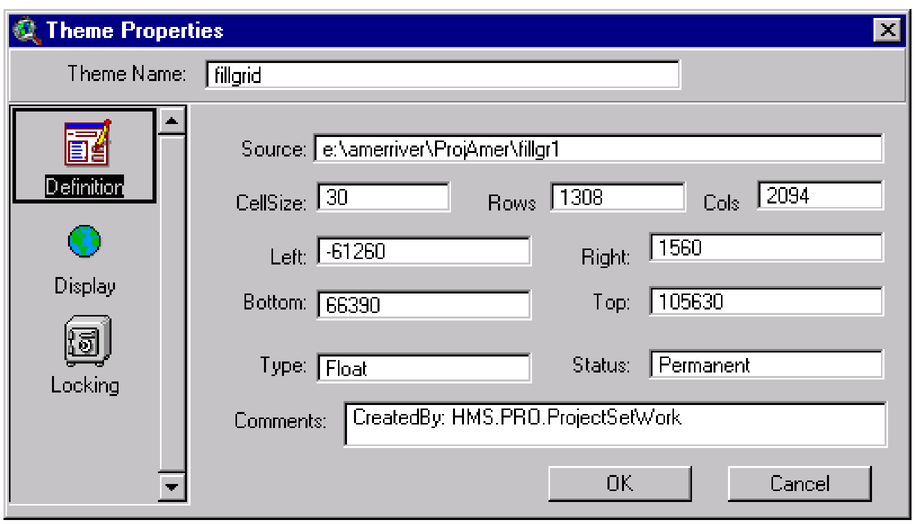
- Note the workspace location and press OK.
- Turn on the "ProjArea.shp" theme to show the area extracted for an HMS model.



The pertinent data sets are extracted from the specified outlet location. A ProjView named "ProjAmer" is used for basin processing, basin characteristics, and HMS inputs.



The extracted data sets are smaller. For example, the extracted data for the "fillgrid" has 1308 rows and 2094 columns as compared to the original 2834 rows and 3662 columns. The following window can be accessed by activating the "FillGrid" theme and selecting **Theme ⇒ Properties**.

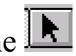
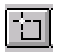


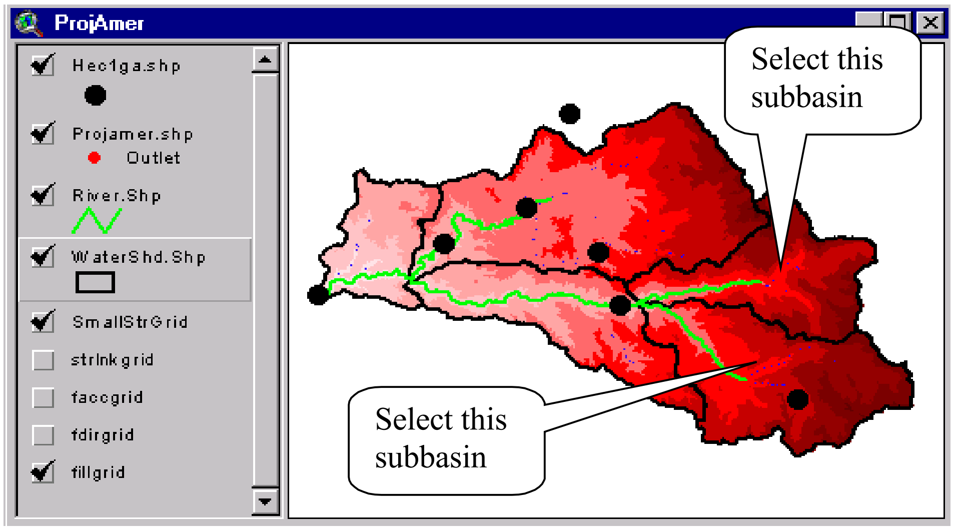
Task II. Basin Processing

5. Revise subbasin delineation

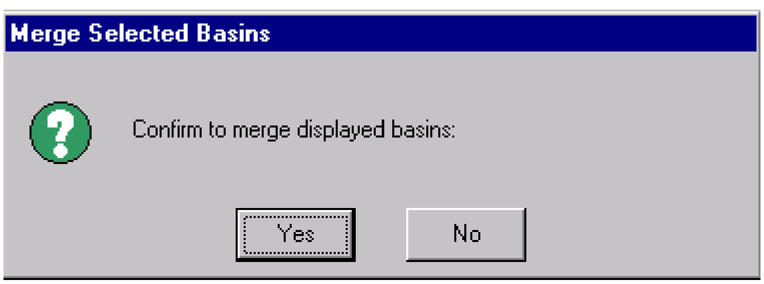
A. Merge Basins

This process merges selected subbasins into one.

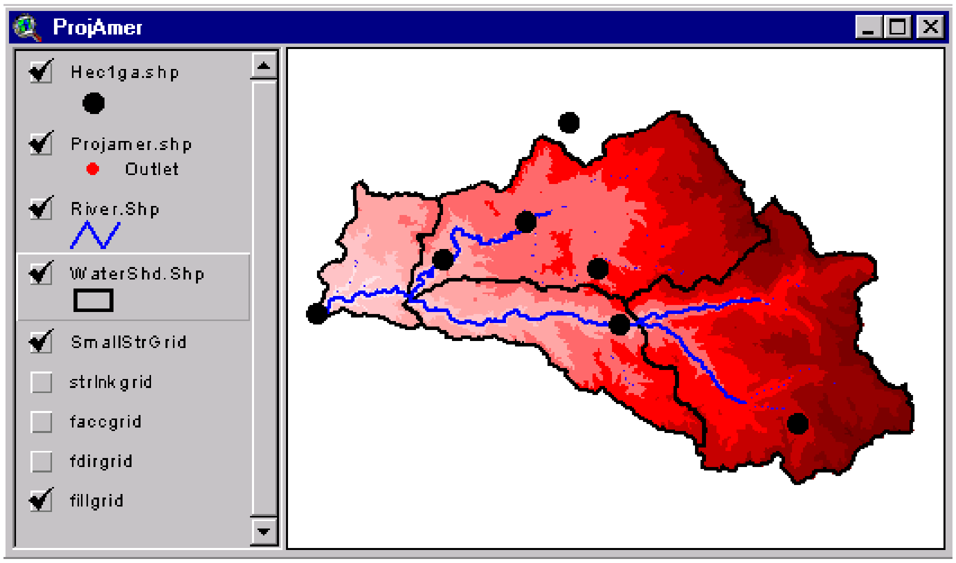
- Make the "WaterShp.Shp" active by clicking on the theme with the  (pointer) tool. The active theme appears raised.
- Use the  (select) tool and select the two subbasins shown below.



- Select **Basin Processing ⇒ Basin Merge**.
- The result of the merged subbasin is shown with a red outline.
- Press **Yes** to accept the resulting merged subbasin.

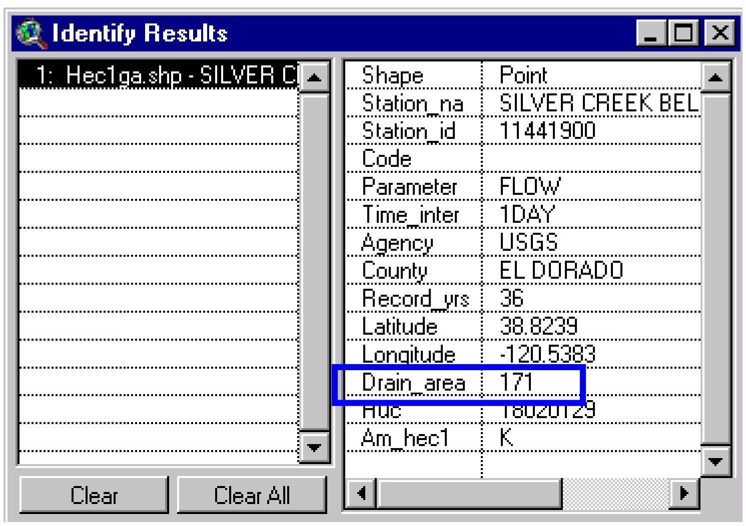


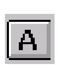
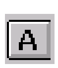
The result of the merged basin is committed as shown below.

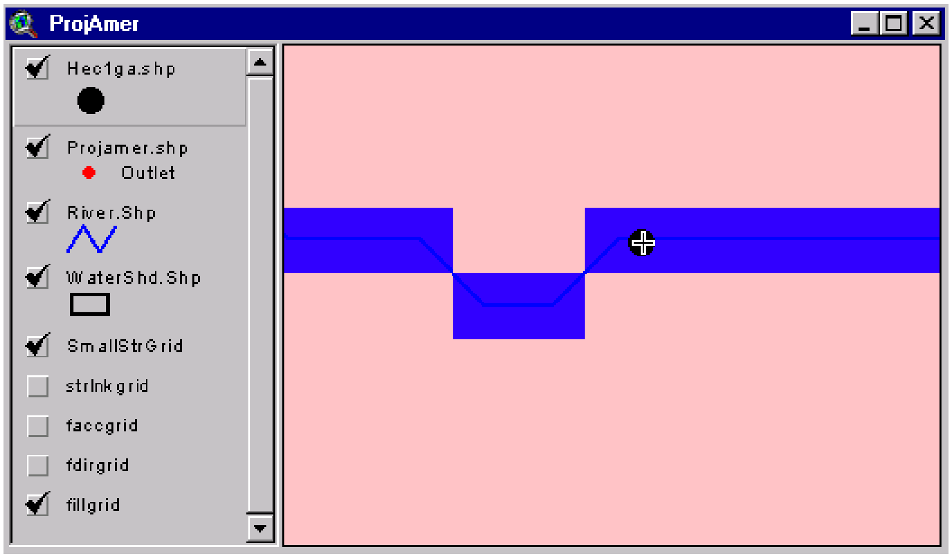


B. Subdivide a Basin

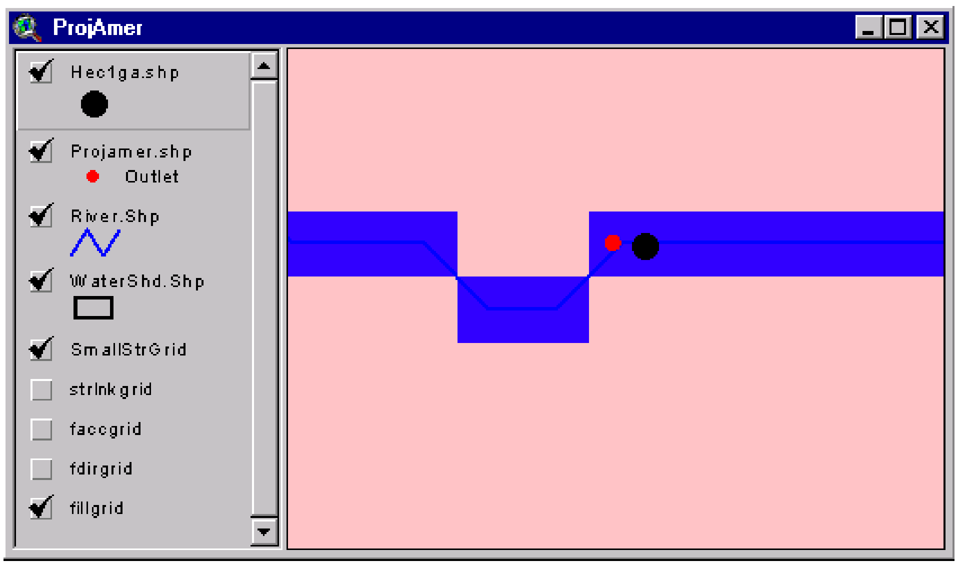
- Make the Hec1ga.shp active on the "ProjAmer" window.
- Using the Identify tool on the streamflow gage with Station_ID 1144190.
- Notice that the reported drainage area is 171 sq.miles.

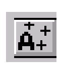


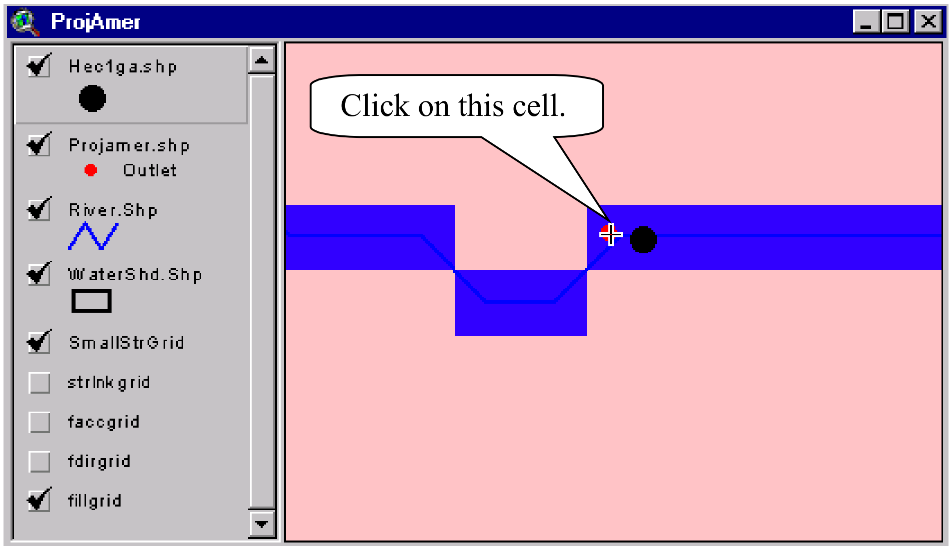
- Zoom in on the gage location.
- Use the  (Identify Area) tool to find the computed drainage area.
- Select the  tool.
- With the "SmallStrGrid" visible, click on the cells near the gage to compute drainage areas.



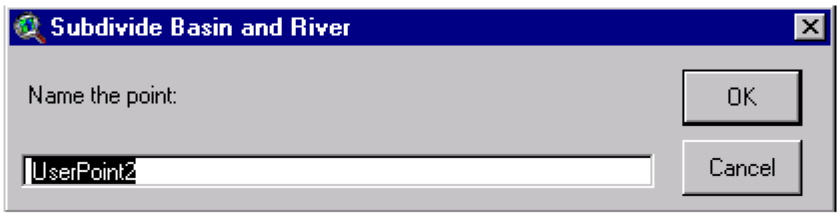
- After searching nearby cells, the cell shown below is an adequate location for an outlet. The computed drainage area is The area is : 171.065 miles squared.



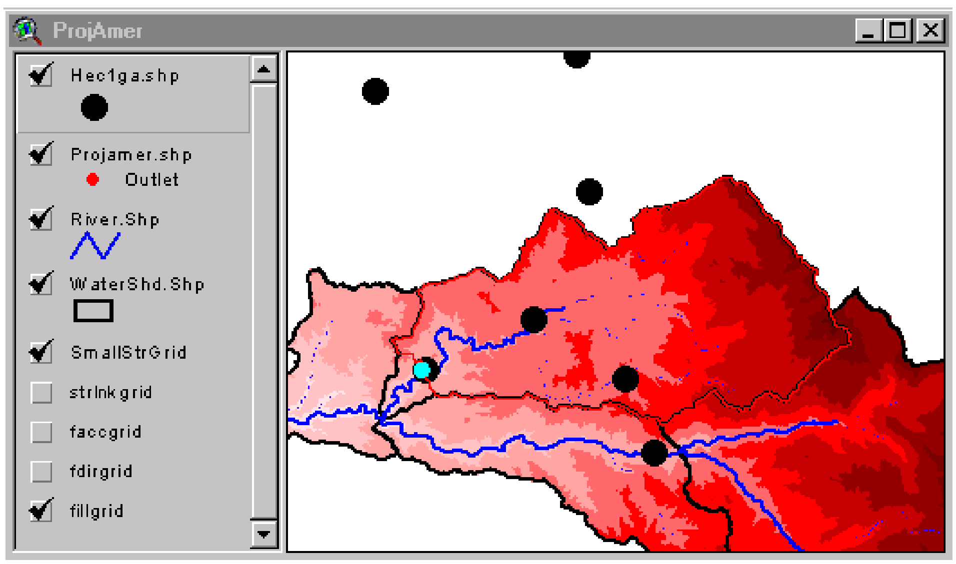
- Select the  tool.
- Click on the cell shown below to subdivide the basin.



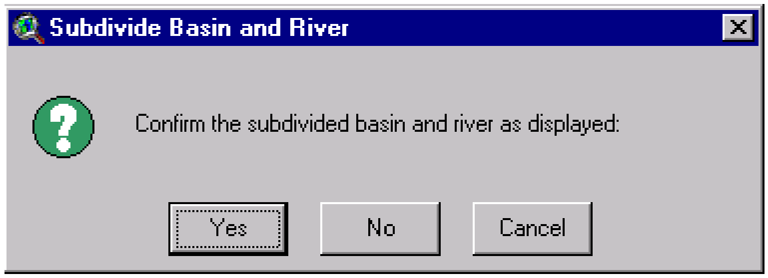
- Press OK



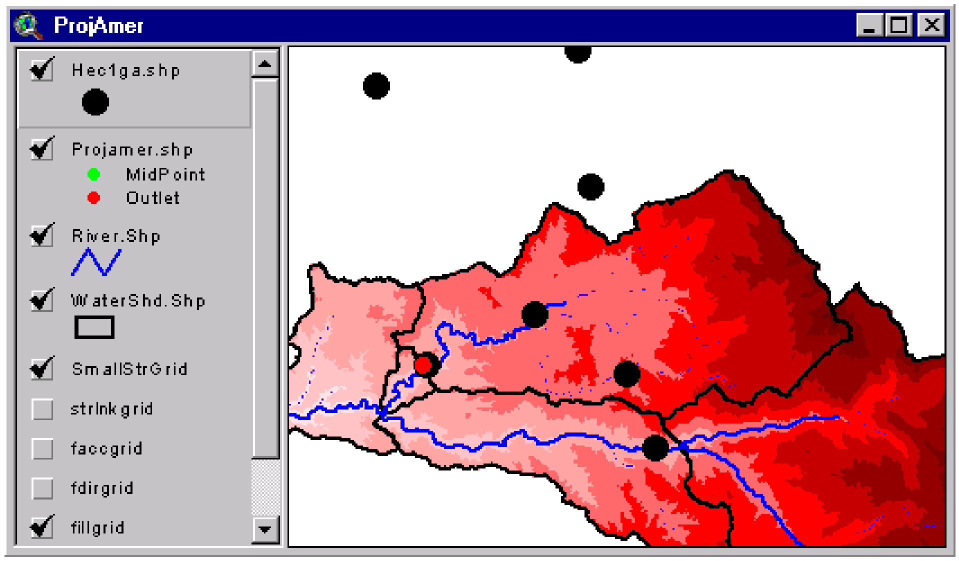
- Verify the result shown below.



- Press Yes

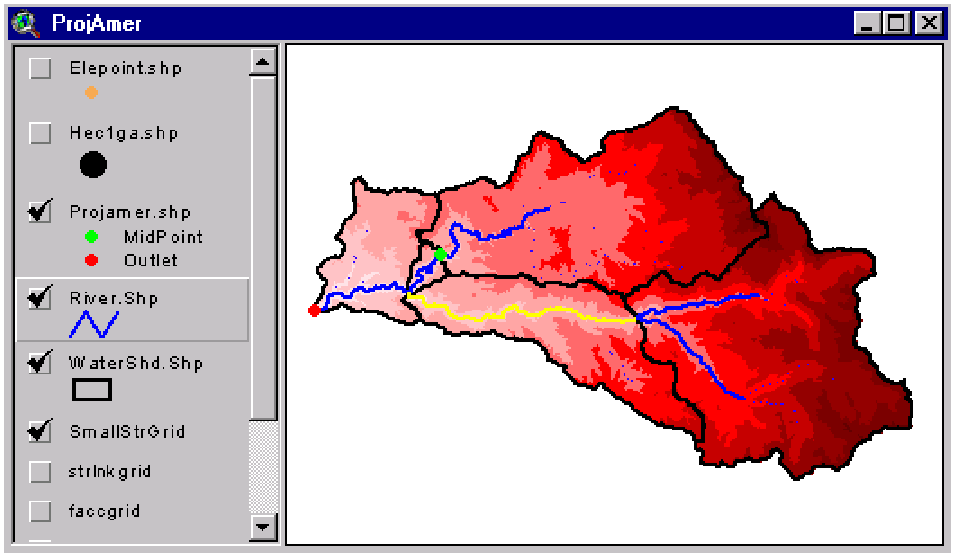


The result of basin subdivision is shown below.

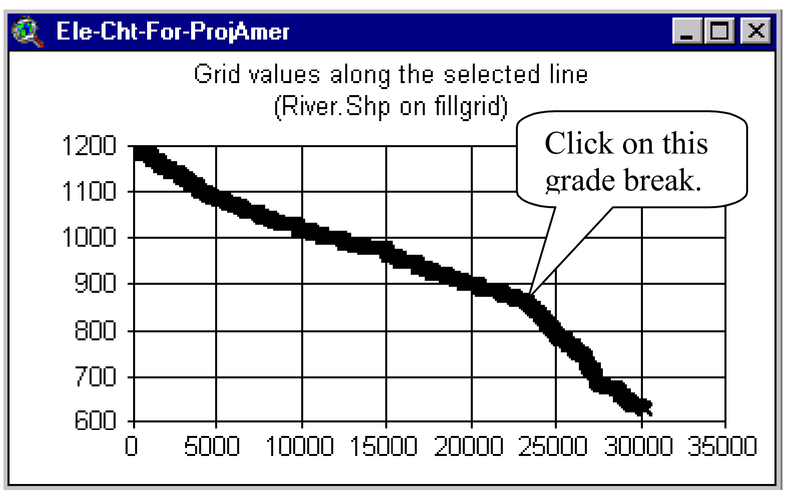


C. Obtain River Profile and subdivide from the grade break

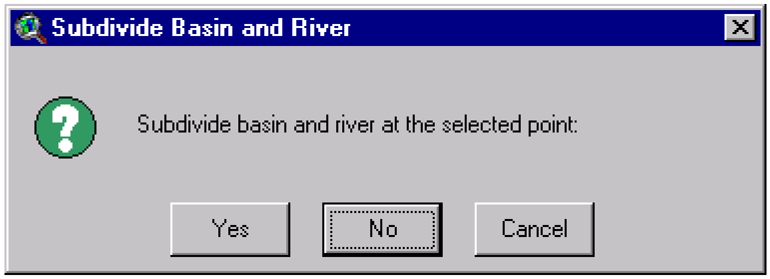
- Activate the "River.Shp".
- Select the stream segment shown in figure below with the  (select) tool.



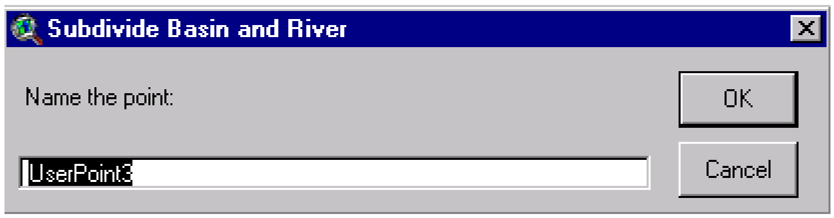
- Select **Basin Processing ⇒ River Profile**.



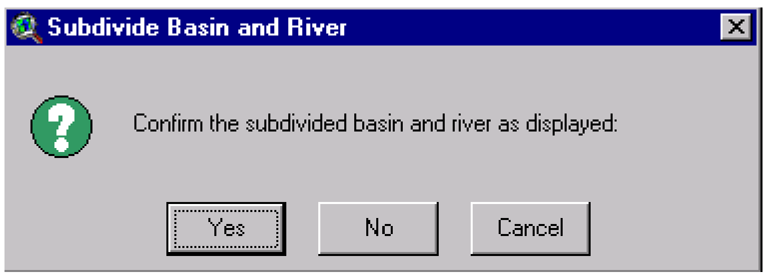
- Review the stream profile.
- The user can subdivide the basin based on the grade break shown in the above figure.
- Select the  (point delineate) tool.
- Click on the profile approximately where the grade break as shown in the profile.



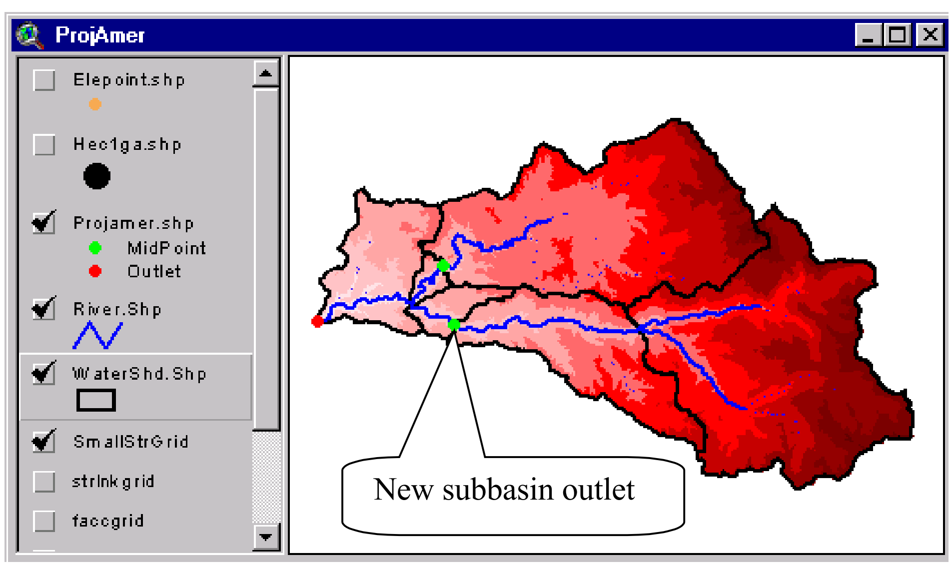
- Click Yes.



- Press OK
- Review the result and press Yes.



The result of the basin subdivision is shown below.



6. Extract Physical Characteristics of Streams and Subbasins

The physical characteristics of the streams and subbasins are extracted and saved in attribute tables.

A. River Length

- Select **Basin Characteristics ⇒ River Length**.
- Press OK at the message box.
- A "Riv_Length" column is added to the "River.Shp" attribute tables.

Attributes of River.Shp

Shape	Arcid	Grid_code	From_node	To_node	Wshld	RivId	Length	Riv_Length
PolyLine	1	14	1	2	14	14	8074	8074.5
PolyLine	2	17	2	4	17	17	13826	13826.1
PolyLine	3	18	3	5	18	18	14767	14766.5
PolyLine	4	20	5	2	20	20	6691	6690.7
PolyLine	5	21	6	5	18	21	16439	16439.1
PolyLine	0	14	0	0	21	22	21041	21040.8
PolyLine	0	20	0	0	22	23	23624	23624.5

B. River Slope

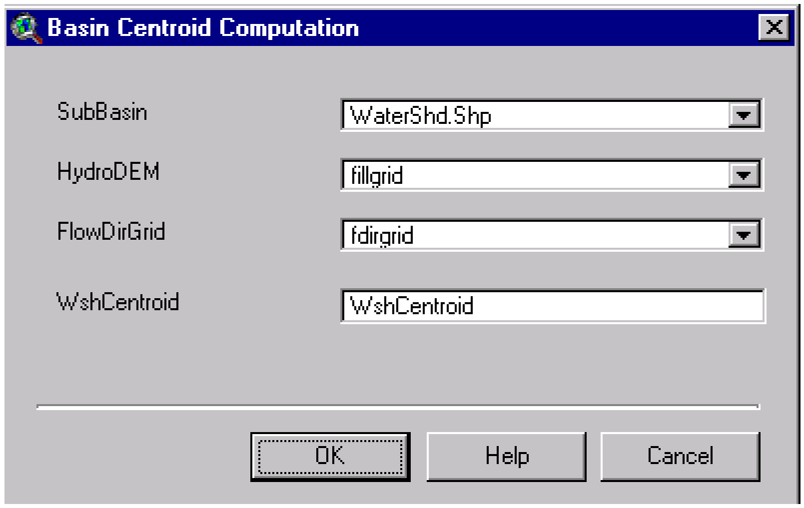
- Select **Basin Characteristics ⇒ River Slope**.
- Select the DEM Vertical Units as meters because the terrain data has both the vertical and horizontal units in meters.
- Press OK
- "Slp_Endpt", "US_Elv", and "DS_Elv" columns are added to the "River.Shp" attribute table.

Attributes of River.Shp

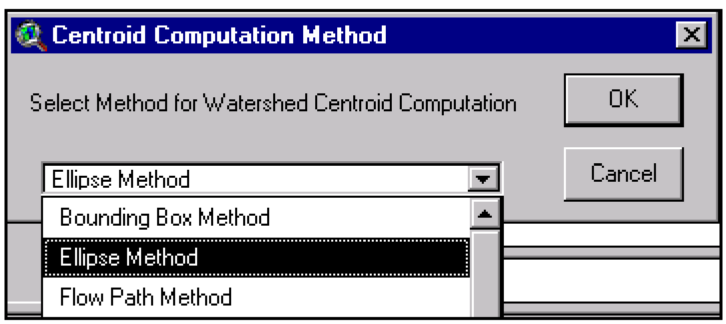
Wshld	RivId	Length	Riv_Length	Slp_Endpt	us_Elv	ds_Elv
14	14	8074	8074.5	0.0225	811.7000	629.8000
17	17	13826	13826.1	0.0096	629.8000	497.7000
18	18	14767	14766.5	0.0312	1657.3000	1196.7000
20	20	6691	6690.7	0.0328	849.3000	629.8000
18	21	16439	16439.1	0.0355	1780.9000	1196.7000
21	22	21041	21040.8	0.0316	1476.0000	811.7000
22	23	23624	23624.5	0.0147	1196.7000	849.3000

C. Basin Centroid

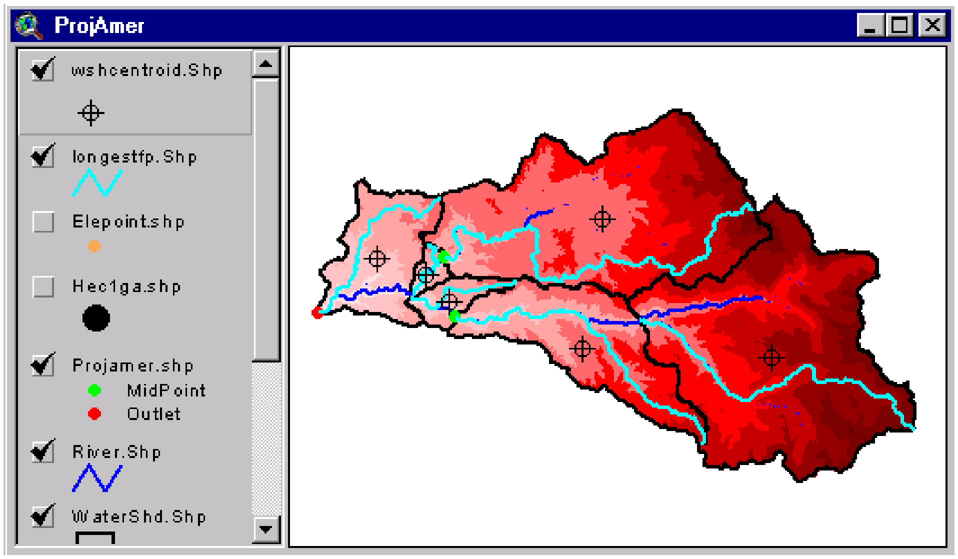
- Select **Basin Characteristics ⇒ Basin Centroid**.
- Confirm the three inputs and one output in the operation as shown below.



- Press OK.
- Select the Ellipse Method from the dropdown menu.



- Press OK.
- A new theme, “WshCentroid.Shp”, is created to represent the centroid locations.



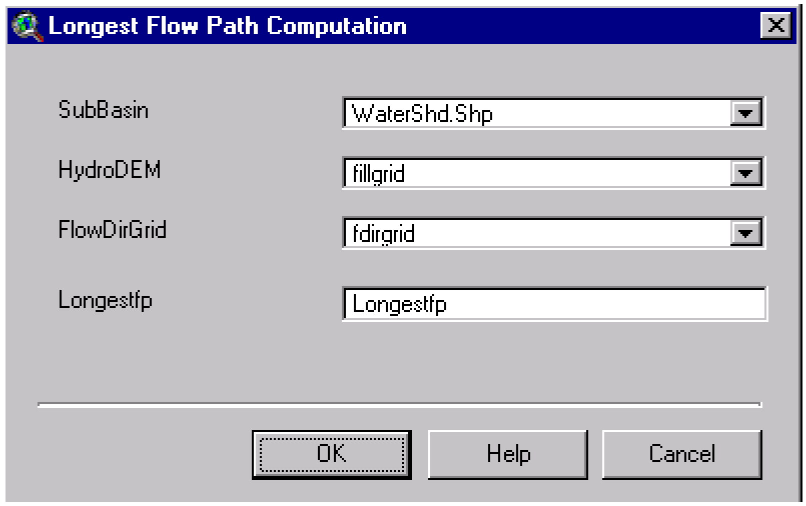
The centroidal elevation is saved under the "Elevation" column in the "Watershd.Shp" attribute table.

Attributes of WaterShd.Shp

Gridcode	Area	Wshid	TopoDone	Perimeter	Elevation
14	13374900.00	14	0	21120.00000	821.3000
17	117179100.0	17	0	75960.00000	1133.0000
18	489244500.0	18	0	156600.0000	2235.5000
20	30275100.00	20	0	38100.00000	1145.0000
14	443059200.0	21	0	141960.0000	1550.0000
20	181171800.0	22	0	102540.0000	1573.1000

D. Longest Flow Path

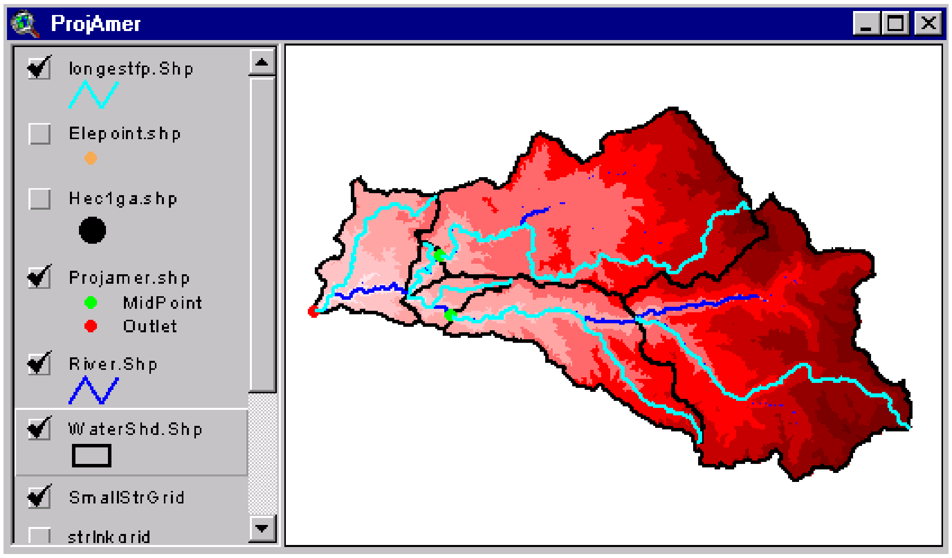
- Select **Basin Characteristics ⇒ Longest Flow Path**.



- Review the input and output themes. Press OK. (This step takes about 5 minutes.)

- Press OK on the confirmation screen.

The results of the longest flow path operation are shown below.



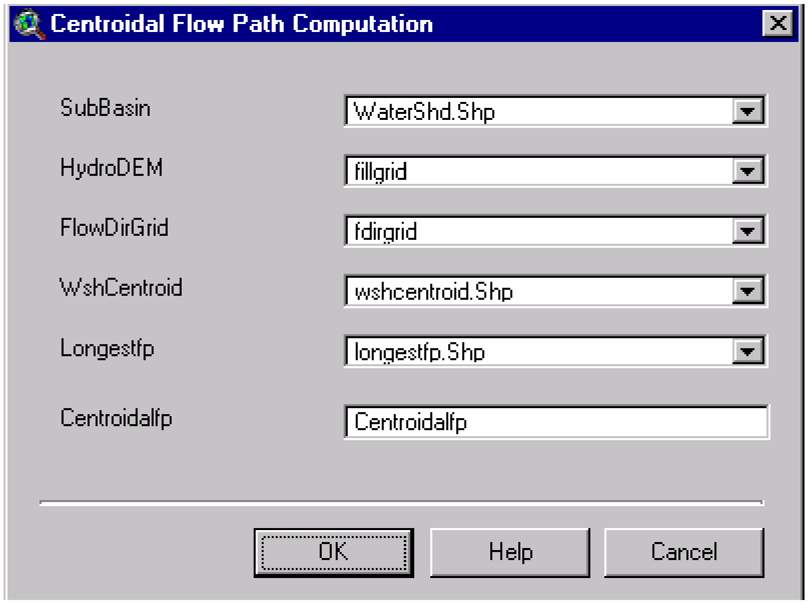
The longest flow path computation also stores the physical parameters in the

Attributes of WaterShd.Shp

Elevation	DSElv	Slp_EndPt	Slp_1085	LongestFL	USElv
821.3000	630.1000	0.084	0.089	9909.991	1465.0000
1133.0000	497.7000	0.044	0.043	24127.922	1556.0000
2235.5000	1198.2000	0.043	0.034	41774.747	2983.0000
1145.0000	629.1000	0.060	0.066	14610.580	1508.0000
1550.0000	811.7000	0.033	0.021	61271.277	2854.0000
1573.1000	849.3000	0.036	0.034	38839.162	2235.0000

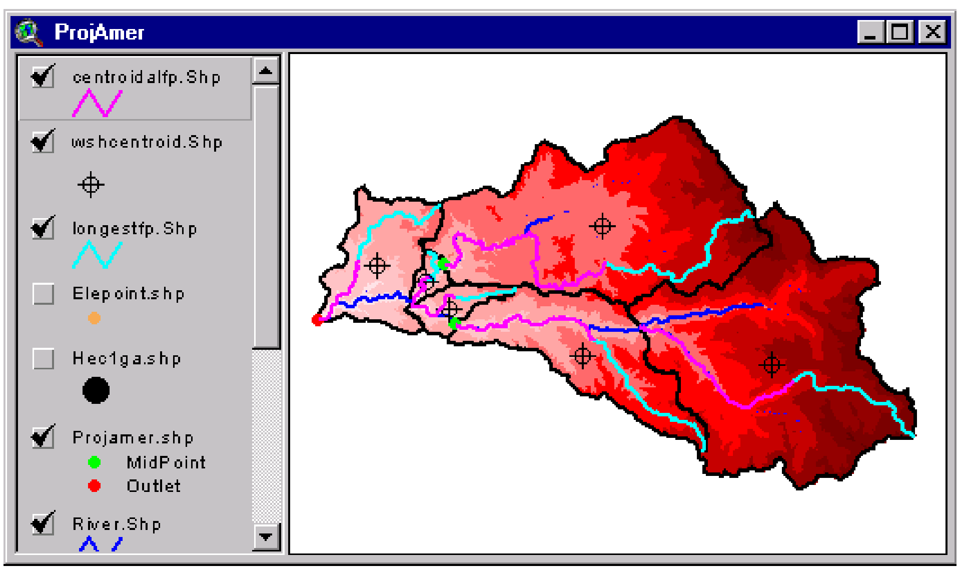
E. Centroidal Flow Path

- Select **Basin Characteristics ⇒ Centroidal Flow Path**.
- The program prompts the user to verify the five data inputs and one output.



- Press OK.

The result of the centroidal flow path operation are the line shapefile named "Centroidalfp.Shp" and its attribute table as shown in the figures below. The centroidal flow length in the "CentroidalFL" column is also stored in the "WaterShd.shp".



Attributes of WaterShd.Shp

DSElv	Slp_EndPt	Slp_1085	LongestFL	USElv	CentroidalFL
630.1000	0.084	0.089	9909.991	1465.0000	4760.437
497.7000	0.044	0.043	24127.922	1556.0000	9742.052
1198.2000	0.043	0.034	41774.747	2983.0000	22982.775
629.1000	0.060	0.066	14610.580	1508.0000	7155.290
811.7000	0.033	0.021	61271.277	2854.0000	37148.868
849.3000	0.036	0.034	38839.162	2235.0000	18743.149

7. Develop HMS Inputs

A. Reach AutoName

- Select **HMS** ⇒ **River AutoName**.
- Press OK on the confirmation message box.

The Reach Autoname creates a "Name" column in the stream's attribute table as shown in the table below.

Attributes of River.Shp

Slp_Endpt	us_Elv	ds_Elv	Name
0.0225	811.7000	629.8000	R140
0.0096	629.8000	497.7000	R170
0.0312	1657.3000	1196.7000	R180
0.0328	849.3000	629.8000	R200
0.0355	1780.9000	1196.7000	R210
0.0316	1476.0000	811.7000	R220
0.0147	1196.7000	849.3000	R230

B. Basin AutoName

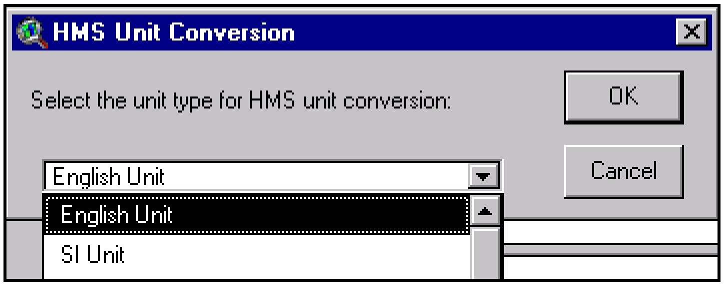
- Select **HMS** ⇒ **Basin AutoName**.
- The Basin Autoname creates a "Name" column in the subbasin's attribute table as shown in the table below.

Attributes of WaterShd.Shp

Slp_1085	LongestFL	USElv	CentroidalFL	Name
0.089	9909.991	1465.0000	4760.437	R140W140
0.043	24127.922	1556.0000	9742.052	R170W170
0.034	41774.747	2983.0000	22982.775	R180W180
0.066	14610.580	1508.0000	7155.290	R200W200
0.021	61271.277	2854.0000	37148.868	R220W210
0.034	38839.162	2235.0000	18743.149	R230W220

C. Map to HMS Units

- Select **HMS ⇒ Map to HMS Units**.
- Select English from dropdown menu.



- Press OK and press OK again to confirmation message box.

The results of the unit conversion are three added columns for the stream attribute table and six added columns for the subbasin attribute table. The added columns contain the ending "_HMS".

Attributes of River.Shp

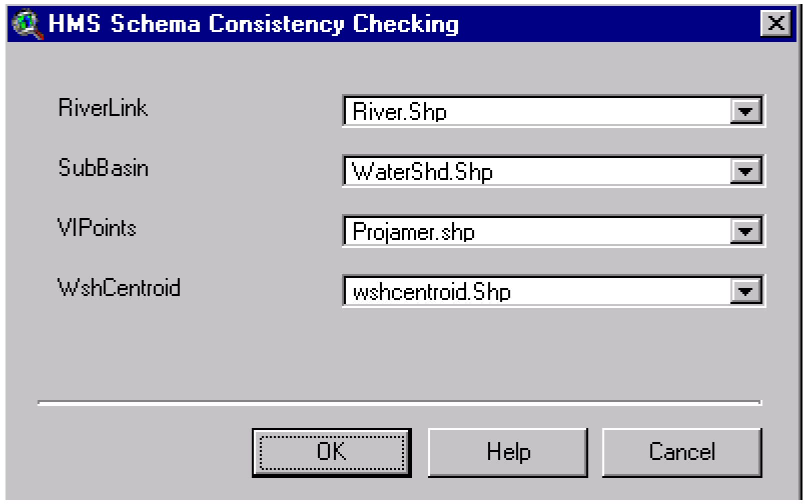
Name	Riv_Length_HMS	us_Elv_HMS	ds_Elv_HMS
R140	26491.089	2663.052	2066.269
R170	45361.130	2066.269	1632.871
R180	48446.425	5437.325	3926.173
R200	21951.072	2786.412	2066.269
R210	53933.947	5842.836	3926.173
R220	69031.358	4842.510	2663.052
R230	77508.047	3926.173	2786.412

Attributes of WaterShd.Shp

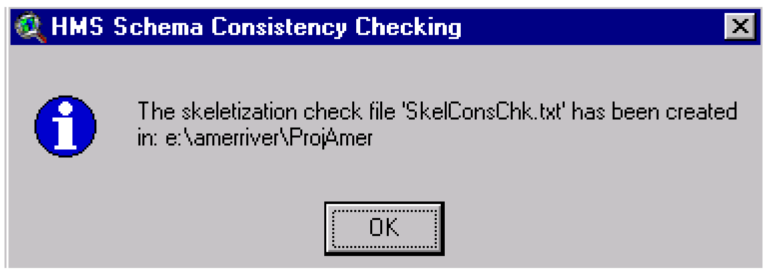
Name	LongestFl_HMS	CentroidalFl_HMS	Elevation_HMS	USElv_HMS	DSElv_HMS	Area_HMS
R140W140	32513.029	15618.200	2694.548	4806.421	2067.253	5.164
R170W170	79159.691	31962.049	3717.184	5104.977	1632.871	45.243
R180W180	137055.982	75402.654	7334.303	9786.726	3931.094	188.898
R200W200	47934.878	23475.314	3756.554	4947.497	2063.972	11.689
R220W210	201020.848	121879.244	5085.292	9363.498	2663.052	171.065
R230W220	127424.817	61493.148	5161.079	7332.662	2786.412	69.951

D. HMS Check Data

- Select HMS ⇒ HMS Check Data.
- Verify the input data sets below.



- Press OK.



- Make a note of the filename and its location. Press OK.

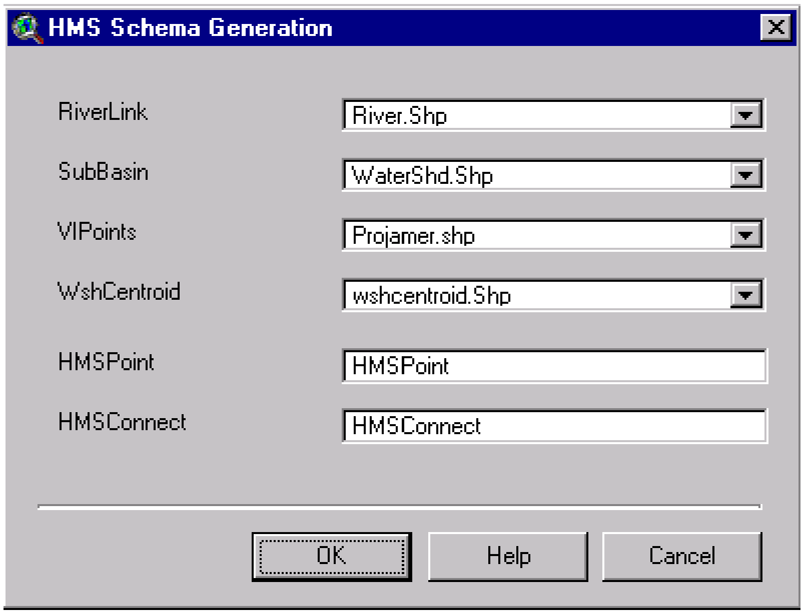
The output file, "SkelConsChk.txt", contains the results of the check results. The end portion of the file is shown below.

```
CHECKING SUMMARY
****************

Unique names        - no problems.
River Containment   - no problems.
Center Containment  - no problems.
River Connectivity  - no problems.
VIP Relevance       - no problems.
```

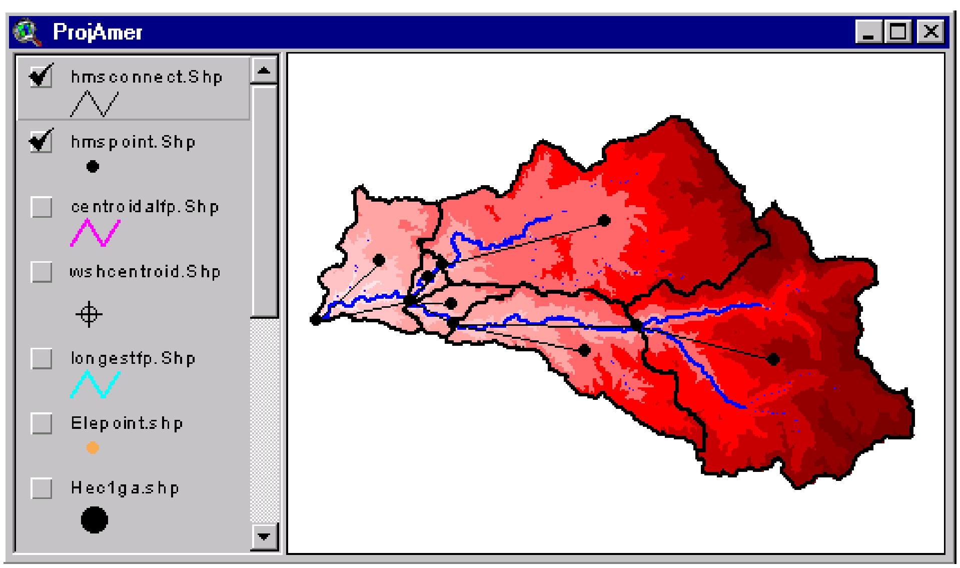
E. HMS Schematic

- Select **HMS ⇒ HMS Schematic**.
- Review the input and output data sets as shown the window below.



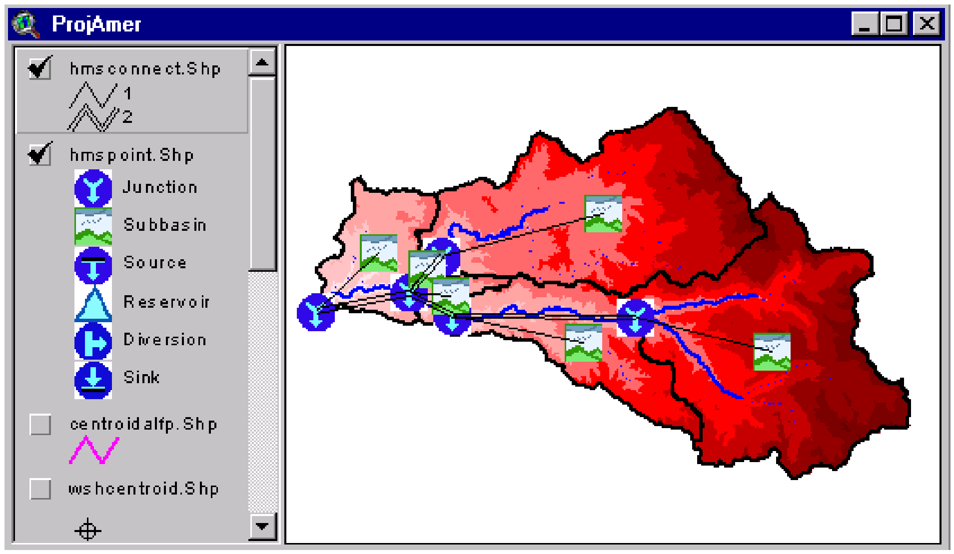
- Press OK and press OK again at the confirmation message box.

The HMS schematic with ArcView symbols is shown in the figure below.



F. HMS Legend

- Select **HMS ⇒ HMS Legend**.
- The user can toggle between HMS Legend and Regular Legend by selecting **HMS ⇒ HMS or Regular Legend**.



G. Add Coordinates

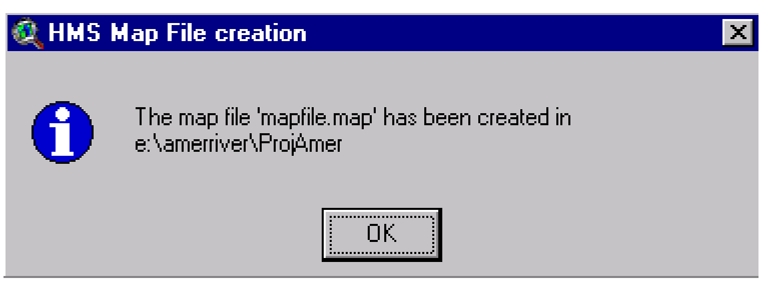
This step attaches geographic coordinates to hydrologic elements in the attribute tables of "HMSPoint.shp" and "HMSConnect.shp". The attachment of coordinates allows GIS data to be exported to a non-proprietary ASCII format and still preserves the geographic information.

- Select **HMS ⇒ Add Coordinates**. Press OK.

H. Background-Map File

The background-map file captures the geographic information of the subbasin boundaries and stream alignments in an ASCII text file that can be read by HMS.

- Select **HMS ⇒ Background-Map File**.



- Make a note of the filename and its location. Press OK.

I. Lumped-Basin Model

The lumped-basin model captures the hydrologic elements, their connectivity, and related geographic information in an ASCII text file that can be read by into HMS. This basin model should be used for hydrologic model with lumped, not distributed, basin parameters.

- Select **HMS ⇒ Lumped-Basin Model**.

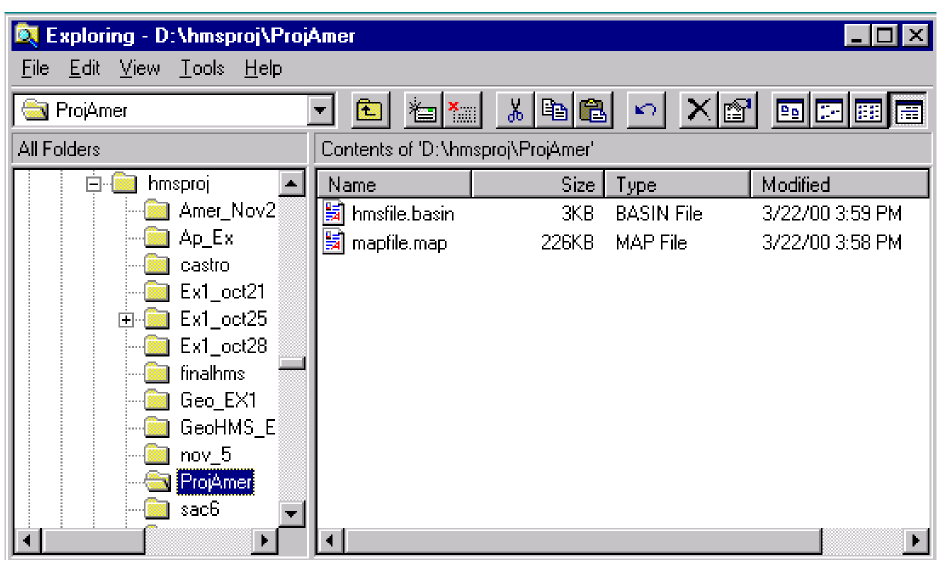
- Make a note of the file name and its location. Press OK.

<u>Task III. Hydrologic Modeling System</u>

8. Setup an HEC-HMS model with inputs from HEC-GeoHMS

A. Directory Setup

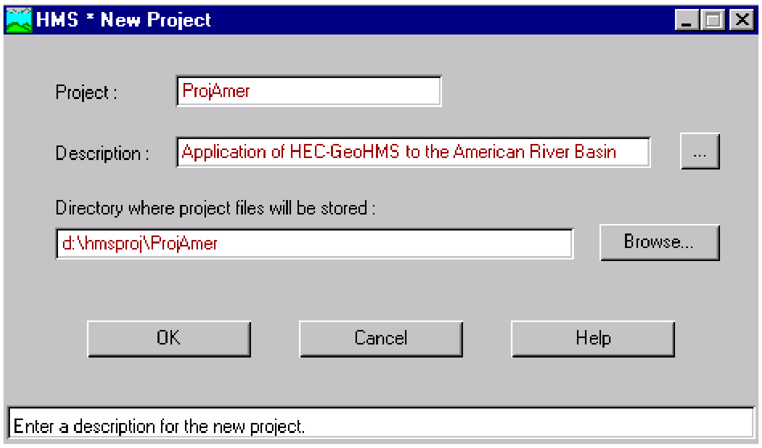
- Create the HMS project first, and then copy the background-map file, basin-model file, and grid-cell parameter file, if appropriate, into D:\hmsproj\ ProjAmer.



B. HMS Setup

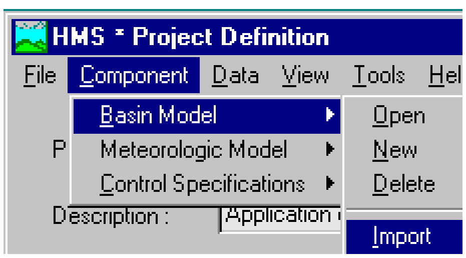
- Start the HMS program.

- Select **File ⇒ New Project**.
- Enter the Project as "ProjAmer" and Description as "GIS Application of HEC-GeoHMS to the American River Basin".

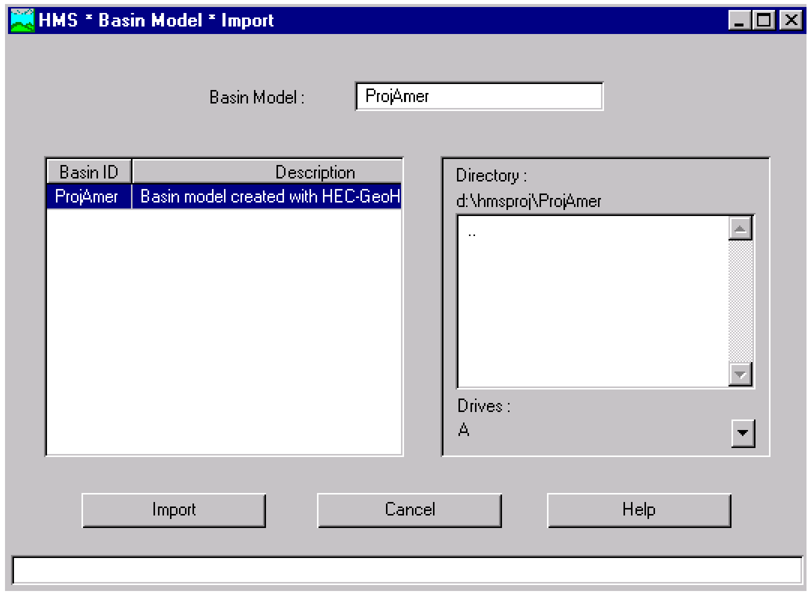


- Press OK.

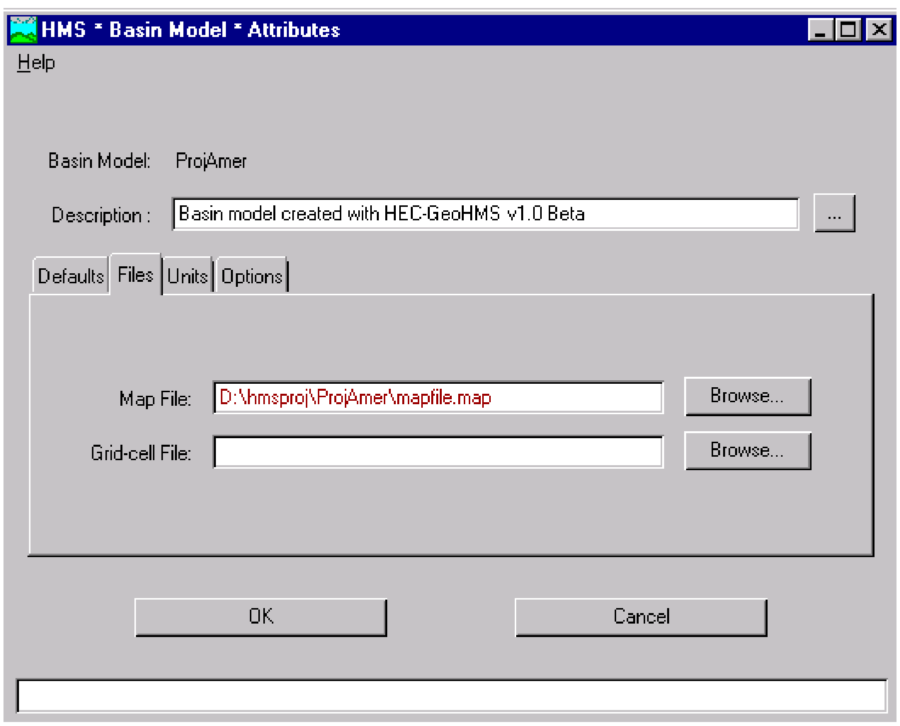
- Import the Basin Model on the **HMS * Project Definition** window, select the **Component ⇒ Basin Model ⇒ Import.**



- Navigate to "D:\hmsproj\ ProjAmer".
- Select the "ProjAmer" under the Basin ID.

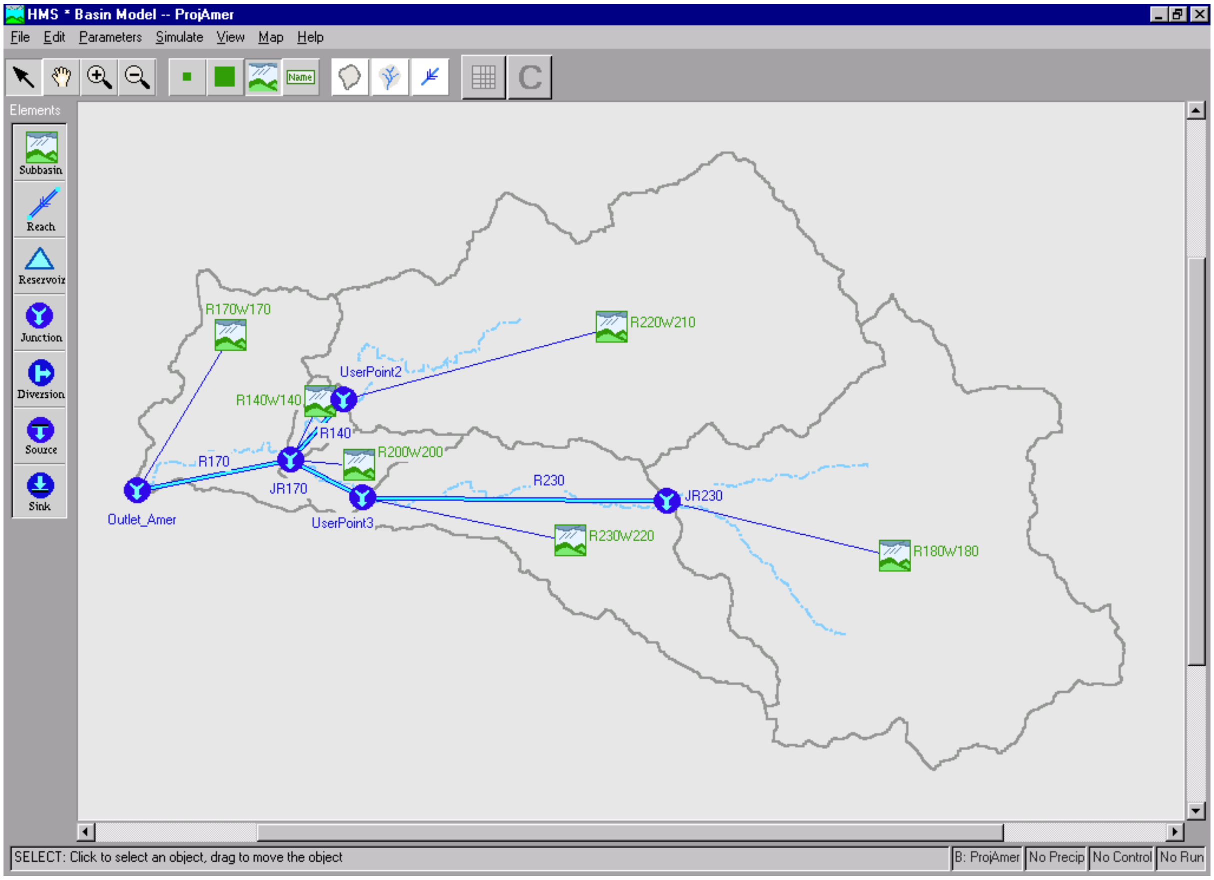


- Press Import.
- Specify the background-map file by selecting **File ⇒ Basin Model Attributes**.
- To specify the Map File, press on "Browse…" button.
- Navigate to the "D:\hmsproj\ ProjAmer" and select the file "Mapfile.map".



- Press OK.

The basin model and the background-map files are brought into HMS resulting in the following HMS Basin Schematic.



The subbasin and routing elements parameters are then input via HMS editors. That information may be available from previous studies and/or a new regional analysis calibrating the parameters to gaged storms and physical characteristics.

APPENDIX A

References

Hydrologic Engineering Center (1994). *HEC-DSS User's Guide and Utility Manuals: User's Manual*. U.S. Army Corps of Engineers, Davis, CA.

Hydrologic Engineering Center (1998). *HEC-1 Flood Hydrograph Package: User's Manual*. U.S. Army Corps of Engineers, Davis, CA.

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Hydrologic Engineering Center (2000). *Hydrologic Modeling System (HEC-HMS): Technical Reference Manual*. U.S. Army Corps of Engineers, Davis, CA.

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Kull, D.W. and A.D. Feldman (1998). "Evolution of Clark's unit graph method to spatially distributed runoff". *J. Hydrologic Engineerin*g, 3(1), 9-19.

Peters, J.C. and D.J.Easton (1996). "Runoff simulation using radar rainfall data". *J.AWRA*, 32(4), 753-760.

APPENDIX B

Background-Map File Format

Watershed boundaries and stream lines can be displayed as a background for hydrologic elements on the *Basin Model* screen. The use of a background map is optional and not required for any calculations. This appendix describes the background-map file format. The file can be produced using available geographic information system (GIS) tools.

File Definition

Watershed boundary and stream line features are both defined in the same file, which is in plain ASCII format. Each feature type is contained in a separate section of the file; it is not important which section is first in the file. Each section begins with the keyword "MapGeo" followed by a colon and either "BoundaryMap" or "RiverMap" (Figure B-1).

A map segment defines a list of map coordinates that are connected by a line. A closed segment defines a polygon and an open segment defines a line. Closed segments are used for watershed boundaries and open segments are used for stream lines. Each segment begins with the keyword "MapSegment" followed by a colon and either "Closed" or "Open." The last coordinate in a closed segment is automatically connected to the first coordinate.

Segment coordinates are defined with x-y pairs. Map features are automatically scaled in the *Basin Model* screen. Coordinates are therefore independent of projection, units, and offset. All segments must be in the same coordinate system.

```
MapGeo:  BoundaryMap
MapSegment:  closed
   582242.875000, 4174922.500000
   582220.875000, 4174961.500000
   582205.625000, 4175013.750000
   581981.000000, 4174672.750000
   582025.812500, 4174696.250000
   582068.812500, 4174711.000000
MapSegment:  closed
   582810.125000, 4174024.500000
   582874.687500, 4173973.750000
   582950.687500, 4173902.750000
   582554.000000, 4174000.250000
   582667.687500, 4174003.750000
   582810.125000, 4174024.500000
MapGeo:  RiverMap
MapSegment:  open
   582750.187500, 4176706.000000
   582687.000000, 4176594.000000
   582657.375000, 4176468.500000
   582613.125000, 4176359.500000
```

Figure B-1.   Sample background map file.

APPENDIX C

Grid-Cell Parameter File Format

The ModClark transform method requires a grid-cell file. The file defines cells for each subbasin. Parameters for each cell are also included in the grid-cell file. This appendix describes the grid-cell file format. The file can be produced using available geographic information system (GIS) tools.

File Definition

The grid-cell file begins with the keyword "Parameter Order" followed by a colon and parameter keywords indicating the order for reading parameters from the file (Figure C-1). The keyword "End" must be on a line by itself after the "Parameter Order" line. Valid parameter keywords are shown in Table C-1. Parameter keywords are not case sensitive and are separated by spaces. If the parameter order is not defined, it is assumed to be: Xcoord Ycoord TravelLength Area. The coordinate system of Xcoord and Ycoord used in the file must match the coordinate system used in the gridded DSS precipitation records. Typically the coordinate system will be either Hydrologic Rainfall Analysis Project (HRAP) or Standard Hydrologic Grid (SHG).

The data for a subbasin begins with the keyword "Subbasin" followed by a colon and the subbasin identifier. One line beginning with the keyword "Grid Cell" follows for each cell in the subbasin. Data for the subbasin ends with the keyword "End". Keywords are not case sensitive and may contain spaces. Blank lines can be included and lines beginning with "#" are ignored as comments. The same grid-cell file can be referenced by more than one subbasin, allowing data for many subbasins to be stored in the same file. The identifier for a subbasin must be exactly the same in the grid-cell file as it is in the basin model.

Table C-1. Parameter keyword definitions.

Keyword	Definition	Units
XCoord	x-coordinate of the southwest corner of the cell	integer value
YCoord	y-coordinate of the southwest corner of the cell	integer value
TravelLength	travel time index from the cell to the subbasin outlet	kilometers
Area	area of cell within the subbasin	square kilometers
ScsCn	SCS curve number of the cell	real value (0.0-100.0)
SmaUnit	Soil moisture accounting unit name	character string

```
Parameter Order: Xcoord YCoord TravelLength Area
End:
Subbasin: 85
Grid Cell:   633   359   88.38    3.76
Grid Cell:   634   359   84.51    0.18
Grid Cell:   633   358   85.55   16.13
Grid Cell:   632   358   82.55   12.76
Grid Cell:   625   348   13.75   12.07
Grid Cell:   626   348   17.12    0.09
Grid Cell:   622   347   21.19    3.26
Grid Cell:   623   347   15.56    9.96
End:
Subbasin: 86
Grid Cell:   637   361   59.13    6.79
Grid Cell:   638   361   59.04    6.95
Grid Cell:   636   361   56.68    1.17
```

Figure C-1. Sample grid-cell parameter file.

APPENDIX D

Standard Hydrologic Grid Specifications

HEC is advocating the use of a standard geographic grid for hydrologic analysis, and has defined a grid for this purpose in the conterminous United States. The proposed Standard Hydrologic Grid has cells of equal area throughout its coverage, and is based on a coordinate system widely used for nationwide mapping of the US. These properties offer significant advantages for hydrologic analysis with distributed watershed models and data development with geographic information systems.

Gridded Hydrology

Many distributed-input models, including HEC's ModClark transform, simulate hydrologic processes on a grid, in effect breaking a watershed into a squares like a checkerboard and treating each square in that board as a separate and uniform (but not necessarily independent) region for hydrologic analysis. Since the squares (or cells) in the checkerboard are much smaller than the watershed, this permits more detailed modeling of hydrologic processes than is possible with lumped parameter methods (like HEC-1) which treat the entire watershed as a uniform region. Each cell in the grid can have unique values for the parameters required by the model, and a unique value for precipitation depth at each time step as the model runs. Using this basic framework, a variety of models can be constructed employing different calculation methods and different assumptions, and requiring different parameters.

Adopting a standard grid framework will enable hydrologists and water managers to exchange data and compare modeling results easily.

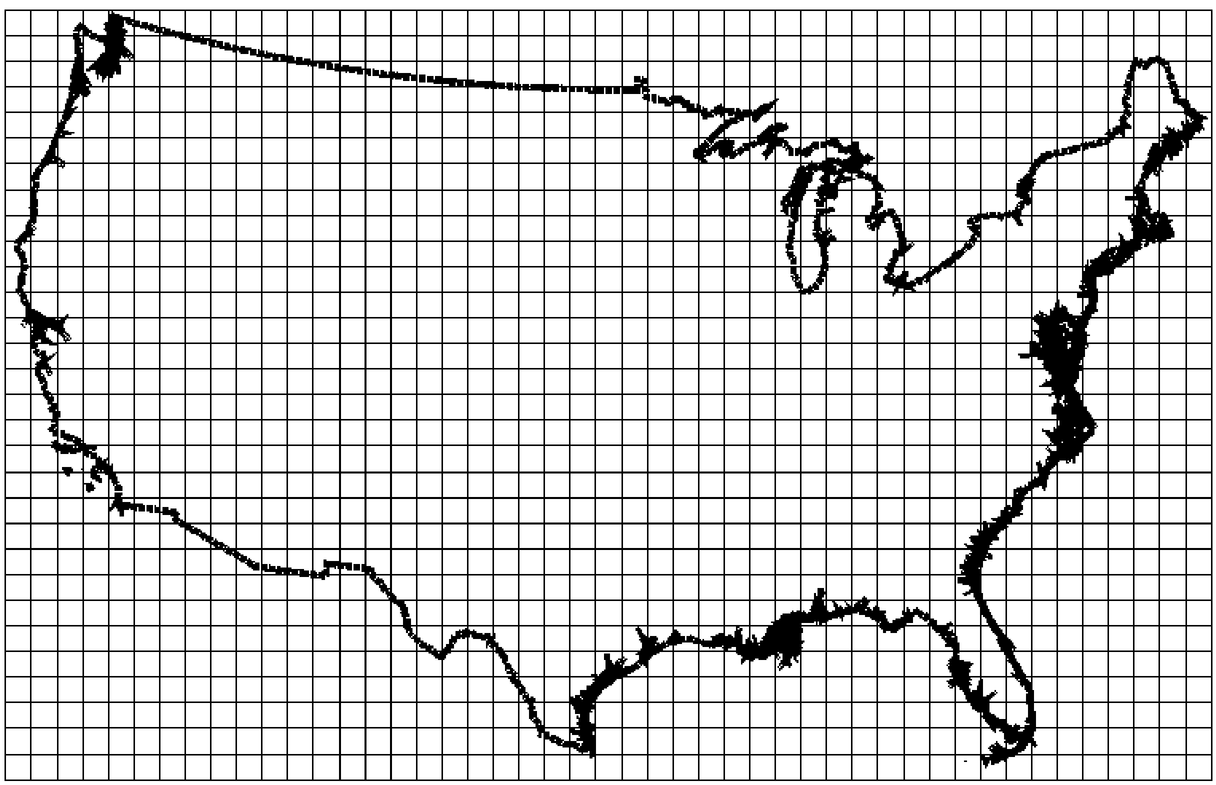
Standard Hydrologic Grid Definition

The proposed SHG grid is a variable-resolution square-celled map grid defined for the conterminous United States. The coordinate system of the grid is based on the Albers equal-area map projection with the following parameters.

Units:	Meters
Datum:	North American Datum, 1983 (NAD83)
1st Standard Parallel:	29 degrees 30 minutes 0 seconds North
2nd Standard Parallel:	45 degrees 30 minutes 0 seconds North

Central Meridian:	96 degrees 0 minutes 0 seconds West
Latitude of Origin:	23 degrees 0 minutes 0 seconds North
False Easting:	0.0
False Northing:	0.0

Users of the grid can select a resolution suitable for the scale and scope of the study for which it is being used. For general-purpose hydrologic modeling with NexRad radar precipitation data, HEC recommends 2000 m cells, and HEC computer programs that use the SHG for calculation will select this cell size as a default. HEC will also support the following grid resolutions: 10,000 m, 5,000 m, 1,000 m, 500 m, 200 m, 100 m, 50 m, 20 m, 10 m. The grids resulting from the different resolutions will be referred to as SHG-2km, SHG-1km, SHG-500m and so on. The accompanying illustration shows cells in this map projection superimposed on the outline of the conterminous US (note that, for purposes of illustration, the cells are larger than the 10 km maximum SHG cell).



For identification, each cell in the grid has a pair of integer indices (i, j) indicating the position, by cell count, of its southwest (lower left, or minimum-x, minimum-y) corner, relative to the grid's origin at 96 W 23 N. For example he southwest corner of cell (121, 346) in the SHG-2km grid is located at an easting of 242000 m and a northing of 692000 m. To find the indices of the cell in which a point is located, find the point's easting and northing in the projected coordinate system defined above, and calculate the indices with the following formulas.

$$i = floor(\frac{easting}{cellsize}) \qquad j = floor(\frac{northing}{cellsize})$$

Where floor(x) is the largest integer less than or equal to x.

Advantages

Using the specified Albers equal-area projection as the basis for the Standard Hydrologic Grid offers significant benefits.

The equal-area property of the projection means that one inch of precipitation in any SHG-2km cell produces 82 acre-feet of water. The National Weather Service HRAP grid, in contrast, is based on a conformal map projection, and cells sizes range from 3.5 km to 4.5 km in the US (and the volume on one inch of precipitation varys from 252 to 417 acre-feet).

The Albers equal-area projection is probably the most common equal-area projection, and is supported by nearly all GIS packages. State Plane and universal transverse mercator (UTM) projections are somewhat more widespread, but do not have the equal-area property, and cannot provide a uniform coordinate system over as large an area as the Albers.

The USGS and other federal agencies use the same Albers projection for a number of national mapping products including the national atlas, and the STATSGO soil database (produced by the Natural Resource Conservation Commission). Since the coordinates in these data sets can be converted directly to the Standard Hydrologic Grid, data sampling for model parameter development is relatively simple.

Examples

As examples of cell identification in the SHG system, indices of cells containing points in the western US and the eastern US will be identified in the 1 km, 2 km, and 500 m SHG grids.

Western US: The location 121 degrees 45 minutes west, 38 degrees 35 minutes north (near Davis, California) projects to -2185019 m easting, 2063359 m northing, in the specified Albers projection. In the SHG-2km system the indices of the cell containing this point are

$$i = floor(-\frac{2185019}{2000}) = floor(-1092.5) = -1093$$

$$j = floor(\frac{2063359}{2000}) = floor(1031.7) = 1031$$

In the SHG-1 km grid the indices are (-2186, 2063), and in SHG-500 m they are (-4371, 4126)

Eastern US: The location 76 degrees 30 minutes west, 42 degrees 25 minutes north (near Ithaca, New York) projects to 1583506 m easting, 2320477 m northing, in the specified Albers projection. In the SHG-2km system the indices of the cell containing this point are

$$i = floor(\frac{1583509}{2000}) = floor(791.8) = 791$$

$$j = floor(\frac{2320477}{2000}) = floor(1160.2) = 1160$$

In the SHG-1 km grid the indices are (1583, 2320), and in SHG-500 m they are (3167, 4640)

APPENDIX E

Program License Agreement

Use of the program is governed by a license agreement. The program can not be used unless the user accepts the terms of the agreement. This appendix gives the full text of the program license agreement.

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