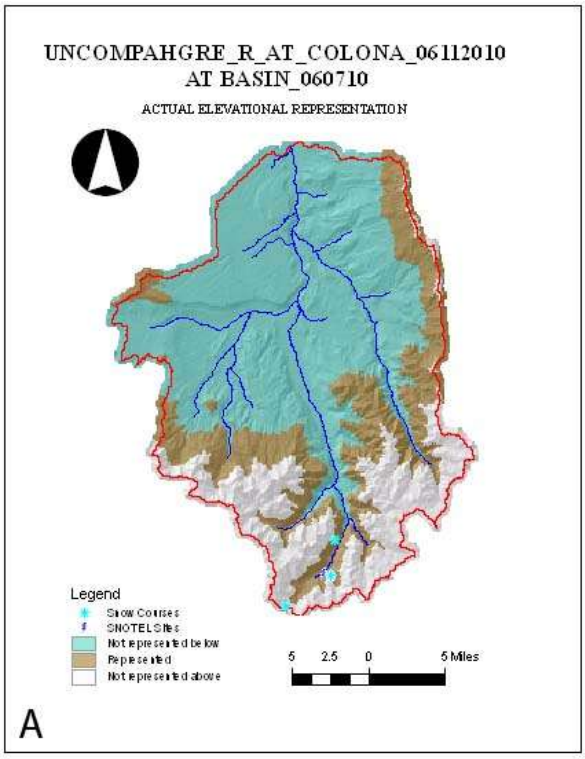
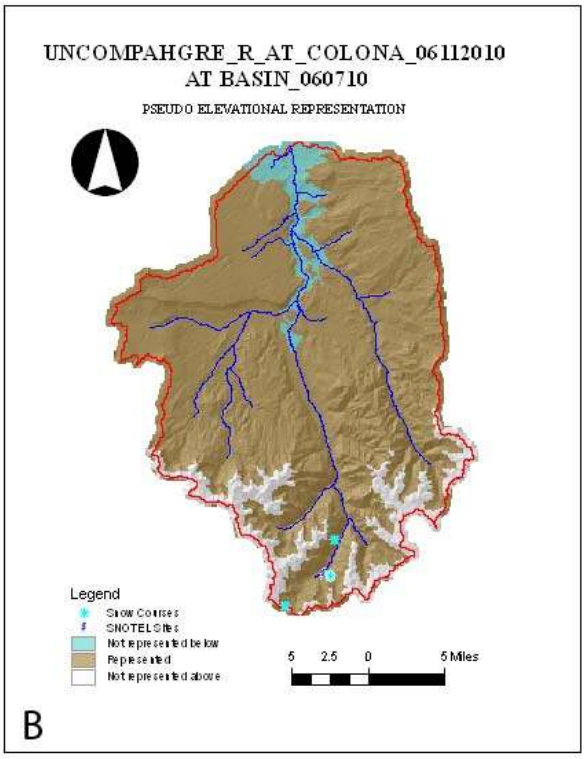
2010

BAGIS User's Manual (Ver 1)





Portland State UNIVERSITY

Jiunn-Der Duh

Center for Spatial Analysis & Research

Geography, Portland State University

12/31/2010

Contact Information:

The Center for Spatial Analysis & Research
Geography, Portland State University
Cramer Hall Rm.424
1721 SW Broadway
Portland, OR 97201
Tel: 503-725-3916
1-800-547-8887
Fax: 503-725-3166

Natural Resources Conservation Service
National Water and Climate Center
1201 NE Lloyd Blvd., Suite 802
Portland, Oregon 97232-1274
Tel: 503-414-3047

To Mary Greene

This project is not possible without her vision and leadership.

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Geoffrey Duh
Portland, Oregon

BASIN ANALYSIS GIS (BAGIS) DISCLAIMERS

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Basin Analysis GIS (BAGIS) User's Manual
(Version 1 July 4, 2010)

1. Introduction

Basin Analysis Geographic Information System (BAGIS) was developed by the Center for Spatial Analysis and Research (CSAR) at Portland State University and the National Water and Climate Center (NWCC) at USDA, Natural Resources Conservation Service (USDA-NRCS). BAGIS provides a set of GIS tools for organizing watershed analysis input and output data, streamlining basin analysis process, and creating an easy-to-use interface for producing analysis maps and tables. It is the latest addition to the state-of-the-art information systems for supporting hydrological analysis and water forecast modeling.

BAGIS was tailor-made for the NWCC forecasters and water resources managers in USDA to perform four major functions:

1. **Basin Preparation:** This function extracts the DEM to a basin folder and generates derived surfaces of the DEM, including a filled DEM, slope, aspect, hillshade, flow-direction, and flow-accumulation layers.
2. **Area of Interest (AOI) Delineation:** An AOI is the unit for a basin analysis. The data used in a basin analysis are stored in an AOI folder. This AOI delineation function allows NWCC water forecasters to identify a watershed pour-point location and use the location to delineate a watershed (or catchment) boundary.
3. **Basin Analysis:** This function generates diagrams and tables (in the form of excel spreadsheets) indicating the geographic representation of SNOTEL and snow course sites with respect to elevation and precipitation distributions. The information is used to identify new SNOTEL sites that could improve the accuracy of water forecast in AOIs.
4. **Map Compilation:** This function produces a set of maps used in basin analysis reports.

Users of BAGIS should have basic operational knowledge of ESRI ArcMap GIS software.

2. Background

Water forecast is one of the major tasks performed at the USDA-NRCS National Water and Climate Center. The task generates essential information for water resource managers to make effective water usage plans. Water forecast requires the integration of accurate geo-spatial data and rigorous hydrological models. There are five major steps in performing water forecast: 1) Delineating area of interest (AOI), 2) Collecting precipitation data (via SNOTEL or snow course sites), 3) Delineating hydrological response units (HRU), 4) Summarizing HRU

parameters, 5) Modeling hydrographs (Figure 2.1). The scope of this project is focused on development of GIS tool to support steps 1 and 2 (indicated by the red rectangle on Figure 2.1).

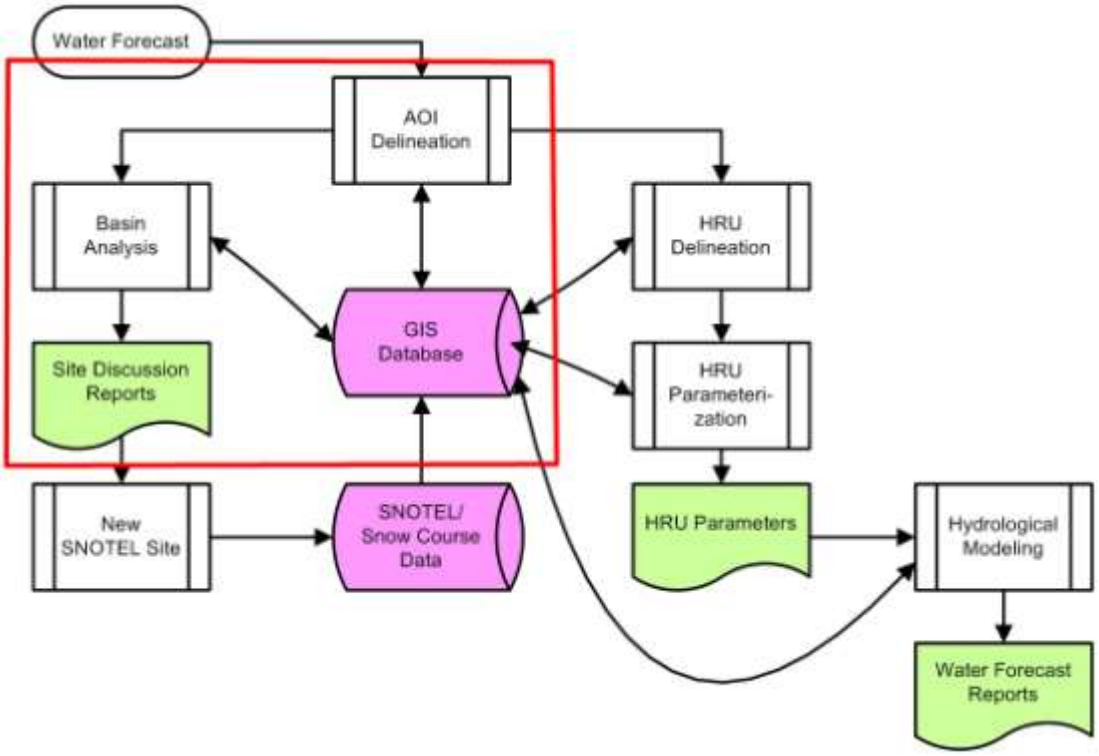


Figure 2.1. Water forecast locations and AOIs created from them.

The specific tasks completed include 1) Basin Analysis GIS Model Building, 2) GIS data compilation, 3) GIS Basin Analysis Model execution. In addition, a pilot examination of GIS Dynamic spatial web interface was conducted.

The project team, including personnel from both NWCC and PSU CSAR, met regularly throughout the project period to design, refine, and test the Basin Analysis GIS (BAGIS) model. The full functions of BAGIS are described in this document. The main computer programming task of developing BAGIS was done between November 2009 and July 2010, including a three months beta-testing period (April to June 2010). BAGIS version 1 was initially released in July 2010 and deployed to NWCC for intensive testing. The latest version (BAGIS_Ver1F) was released on December 31, 2010. CSAR continues to provide maintenance and technical support through additional agreements.

The project team has completed the collection and compilation of 22 GIS data layers. All collected data layers were projected to the NAD 83 Albers Equal Area Conic USGS projection. The key data layers include USGS 10 meters and 30 meters DEMs, PRISM precipitation data created by the PRISM Climate Group led by Oregon State University. The compilation of these datasets had to deal with files with enormous file sizes, making it a time-consuming process. For example, the PRISM precipitation dataset contains 17 layers (12 monthly, 4 quarterly, and 1 annual precipitation data layers) with a total file size of 1.43 GB. The USGS 30 meters DEM

requires 35 GB of disk space. The dataset also reaches the upper file size limit for ArcGIS to process the dataset efficiently. As a result, the 10 meters DEM is separated into several image mosaics with a total size over 300 GB. The project has provided a detail documentation of the data compilation process and the meta-data of the GIS layers. Please refer to Appendix A for the data catalog and data dictionary of the data layers.

The project team has met and defined a protocol for collaborative efforts in basin analysis. The protocol has 7 major steps involving the production, reviewing, and verification of Basin and AOI data. The steps and their specific tasks are listed in Table 2.1.

Table 2.1. Collaborative AOI delineation procedures.

Step	***Tasks***
1. Basic Layers Compilation	NWCC provides SNOTEL, active snow course sites, and forecast point locations as ESRI shapefiles.
2. Identification of Supplemental Layers	NWCC specifies the supplemental layers to be incorporated in the basin analysis. The layers identified include: Forest service road shapefile; NLCD Land cover raster grid (2001); Forest canopy density; Forest density; Forest/land cover type; Federal land; Indian land; Wilderness land; PRISM precipitation layers; USFS service roads; National atlas waterbodies; National atlas streams; National atlas roads.
3. BASIN List Compilation	NWCC provides a list of "large watersheds" for the preparation of BAGIS BASINs. The watersheds are identified using the ID and name of the forecast points. The average size of the basins is around 5000 square miles.
4. BASIN Creation	PSU creates BAGIS BASINs by delineating rectangular boundaries that encompass the complete watersheds of the identified forecast points. A map showing the BASIN boundaries is submitted to NWCC for review.
5. BASIN Verification	NWCC reviews the BASIN boundaries and identifies AOIs in each BASIN. The AOIs are identified using the ID and name of the forecast points. If PSU is not notified by NWCC, AOIs are delineated for all forecast points in a BASIN.
6. AOI Creation	PSU creates the AOIs. The location of the forecast point (i.e., the pour point of the AOI watershed) is determined based on the maps published on the USGS Water-data site information webpage (http://waterdata.usgs.gov/nwis/si). The area of AOI is verified using the area information published on the same webpage. NWCC might provide additional GIS layers showing reference AOI boundaries. When the AOI delineation is completed, PSU submits a map showing the AOI boundaries and a table of the AOI areas to NWCC for review.
7. AOI Verification	NWCC reviews the AOI boundaries. PSU conducts basin analysis for the delineated AOIs.

A total of twelve basins (Step 4 outcomes) and 601 AOIs (Step 6 outcomes) were created. They occupy a disk space of around 700 GB (Table 2.2). The geographic locations of the AOIs, as well as the forecast points used to delineate the AOIs, are shown in Figure 2.2.

Table 2.2. A summary of the AOIs created in BAGIS for water forecast at NWCC.

Region	#AOIs	Disk Size (GB)	Delivered (Approx.)
Great Basin	82	44.37	Dec-10
Humboldt_2	10	19.3	Jan-11
Koot_PO_Spok	48	87.3	Jan-11
Lower Columbia	29	9.16	Dec-10
Middle Columbia	25	9.56	Dec-10
Missouri/Platte	110	209.8	Jan-11
Puget_Sound	14	4.27	Jan-11
Snake River	87	125	Jan-11
South Coast	12	4.90	Dec-10
Upper Colorado	160	167.44	Oct-10
Upper Columbia	23	16.2	Jan-11
Walker Lake (2	1	2.77	Dec-10
Total	**601**	**700.05**	

The complete database for basin analysis for the US western states (input static files only and AOI output files) requires an estimated disk space of around 1 TB (or 1000 GB), including 300 GB of static data and 700GB of AOI data. Though the AOI data must be saved to a logical local drive (e.g., C: drive) or network drive (e.g., the NWCC local file server - S: drive), the static data could be stored ideally on a centralized ArcGIS Server via the Internet. A temporary testing ArcGIS Server was set up in CSAR at PSU for testing GIS web services. The test results indicate that ArcGIS Server approach is a feasible solution for building future GIS Server infrastructure within USDA.

The server was built on a Dell server (PowerEdge T110) running Microsoft Windows Server 2008 R2 64-bit. The server uses Windows Internet Information Services (IIS) to provide web (i.e., http) service that handles requests over the internet. The web service sends GIS server requests to ESRI's ArcGIS Server, which, depending on the types of request, feeds data retrieved from the GIS database to the end users in various formats, such as, raster images or vector features. The ArcGIS Server architecture provides an industrial standard solution to manage and disseminate GIS data on a local area network, as well as over the Internet. The end users could view the data with a web browser or analyze the data in GIS (e.g., ArcMap). A diagram of the ArcGIS Server architecture is shown in Figure 2.3.

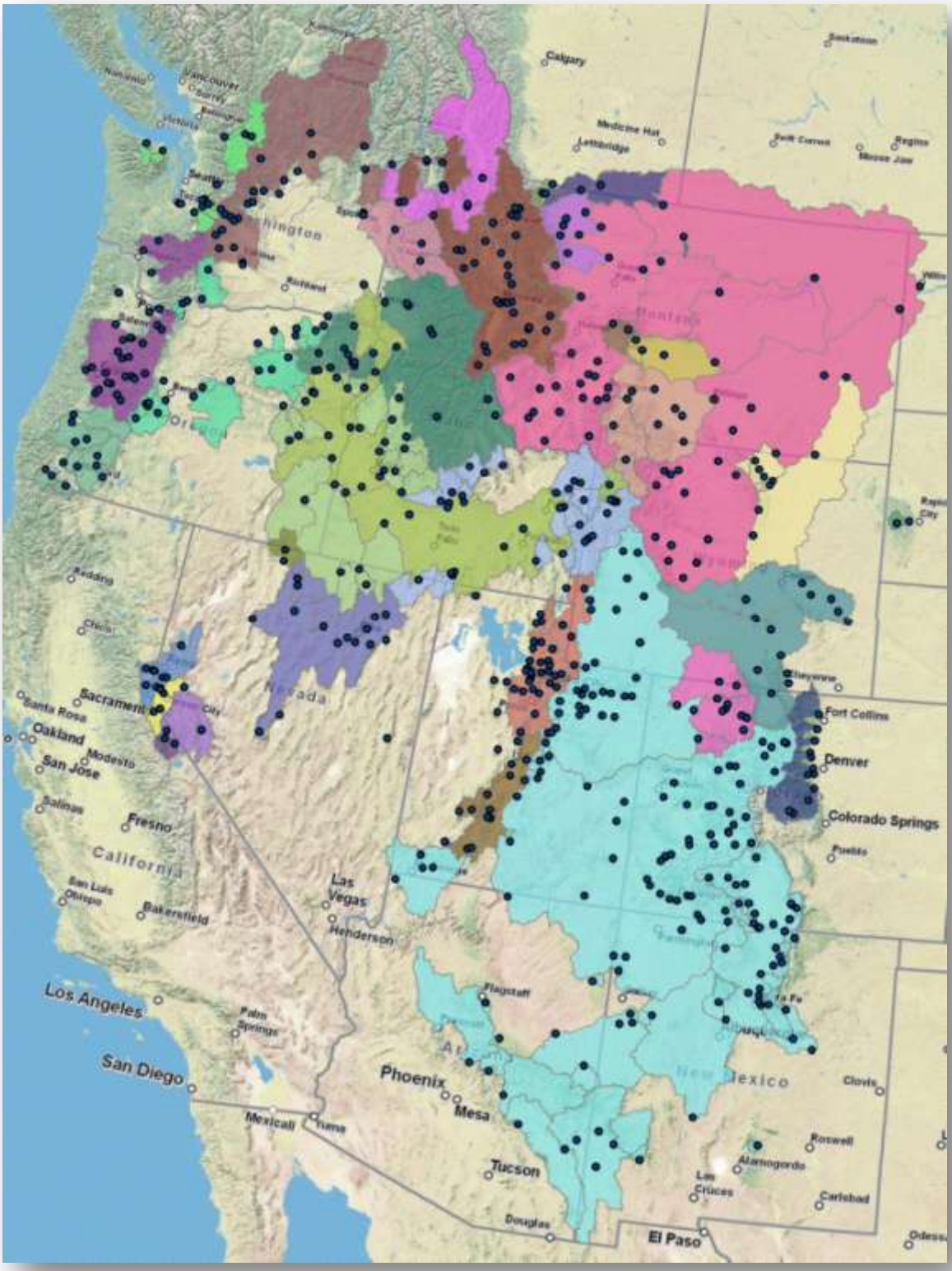


Figure 2.2. Water forecast locations and AOIs created from them.

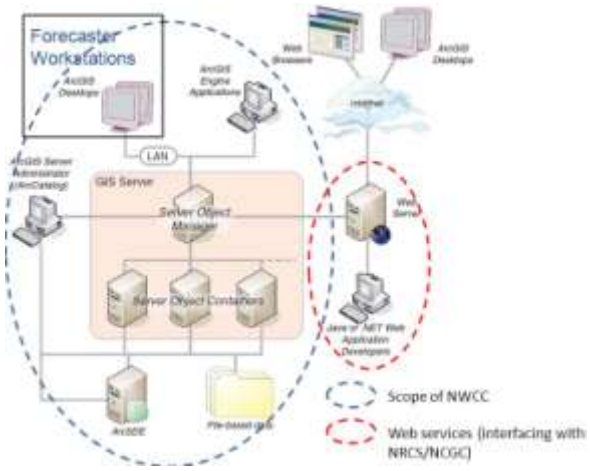


Figure 2.3. ArcGIS Server architecture.

Figure 2.4 illustrates the various image data services currently available on the CSAR test server. These services include DEMs of various spatial resolutions and PRISM precipitation data (shown on the left panel of the figure). The right panel shows a preview of the PRISM 30-year (1971-2000) average January precipitation data.

Once the ArcGIS Server infrastructure is established within NWCC (or NRCS), BAGIS will be customized to have access to the data on the server. The server will also be part of the information system used to disseminate basin analysis and watershed forecast outcomes on the internet.

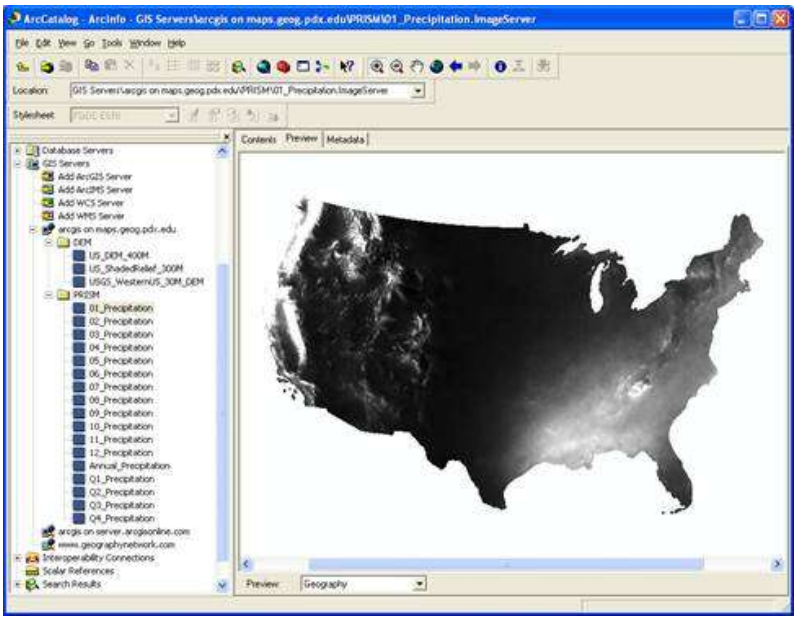


Figure 2.4. An ArcCatalog screen shot of ArcGIS Server Services.

3. System Requirements

BAGIS was developed in the ArcMap Visual Basic for Applications (VBA) environment. VBA allows full access to ArcObjects, the core computational module and building blocks of ArcGIS, and provides a flexible graphic user interface (GUI) customization capability. These aspects of VBA are essential for NWCC's basin analysis, which requires reliable and efficient data processing functions and a streamlined GUI for organizing complex tasks. The current version (Ver 1) was developed and fully tested on ArcGIS versions 9.X and 10. To use BAGIS, the computer system must have the following software packages installed:

- ArcMap 9.X or later with Spatial Analyst extension and VBA capability
- Microsoft Excel 2007 or later

4. Installation, System Setup, and Data Preparation

4.1 Installation

Basin Analysis GIS Tool (BAGIS) was distributed as an ArcMap map template file (BAGIS_VerXX.mxt) for ArcGIS 9.X. Users only need to copy the file to their hard drive and double-click it to start the model. Please refer to Section 8 for instructions on using BAGIS in later ArcGIS version (e.g., ArcGIS 10).

4.2. System Setup

The first time you start BAGIS you must specify the model settings data. First, look for the BAGIS Toolbar. If it is not displayed, then go to View / Toolbars on the ArcMap main menu and check the Basin Analyst toolbar. Once the toolbar appears, click the Basin Analyst menu and select Options to set up BAGIS analysis environment. When done, please click the Save Settings button to save the data you just entered. The settings data is saved in an ASCII definition file (basinanalyst.def) stored in a folder specified by an environmental variable. You can see the path of the folder on the caption of the Settings dialog window. The model looks for "BAGIS", "TMP", "TEMP", and "ARCGISHOME" sequentially until finds one variable that is valid. Usually TMP, TEMP, and ARCGISHOME exist on your computer. If you plan to store the definition file in a particular folder, you can create an environmental variable called BAGIS and set its value to a path that you have full access privileges. Please contact your system administrator if you don't know how to create an environmental variable.

4.3 GIS Data Preparation

All GIS layers to be used in BAGIS must be in the same projection. The projection of the BAGIS data is in Albers Equal Area Conic Projection - USGS Version. If the data are in other projections, please use the project or raster project tool in ArcToolbox to reproject the data. See Appendix A for the project parameters of the Albers projection.

There are five major categories of GIS data you need to specify in the Settings window of BAGIS, including:

- Reference maps for locating basins (i.e., watersheds) and Area of Interest (AOI) (i.e., subwatersheds). These maps are pre-symbolized data stored in ArcMap layer files (.lyr). You should create these layer files before you start using BAGIS. The reference maps are labeled as terrain, drainage, and watershed layers, but users can use any layer files available.
- Digital Elevation Model (DEM) and gauge station (or forecast point) location data for AOI delineation and basin analysis. At this point, BAGIS uses only two DEM datasets: 10 meter and 30 meter resolution. Users must verify the elevation (Z) unit (either in meters or feet) of the data and correctly specify the unit in the BAGIS Settings.
- Gauge station location data set, which stored as a point shapefile, is used as a reference for selecting pour points for AOI delineation. The gauge stations (or forecast points) layer must have a text attribute field containing the name of the station. Optionally, the data can have an area field containing the upstream (or catchment) area of the station. The area value is used to verify the AOI area created by BAGIS if the field is specified. In this case, users must also specify the unit of the area values.
- SNOTEL and Snow course point shapefiles. Both data sets must have a numerical attribute field containing the elevation (in feet or meters) of the site locations. Optional, they could have a text field indicating the name of the site location.
- PRISM precipitation based on 30 year averaged data, including annual, quarterly, and monthly data stored as ESRI grid raster format. The folder containing PRISM data must have 17 folders (i.e., Jan, Feb, Mar, Apr, May, Jun, Jul, Aug, Sep, Oct, Nov, Dec, Q1, Q2, Q3, Q4, Annual), each containing a raster grid called “grid”). Figure 4.1 is an ArcCatalog view of the PRISM folder.
- Participating layers - any other layer that might be used in the basin analysis. Some of the commonly used layers are listed in Table 4.1.

Please refer to Section 6.1.5 System Settings Module for detail instructions on preparing the data for BAGIS.

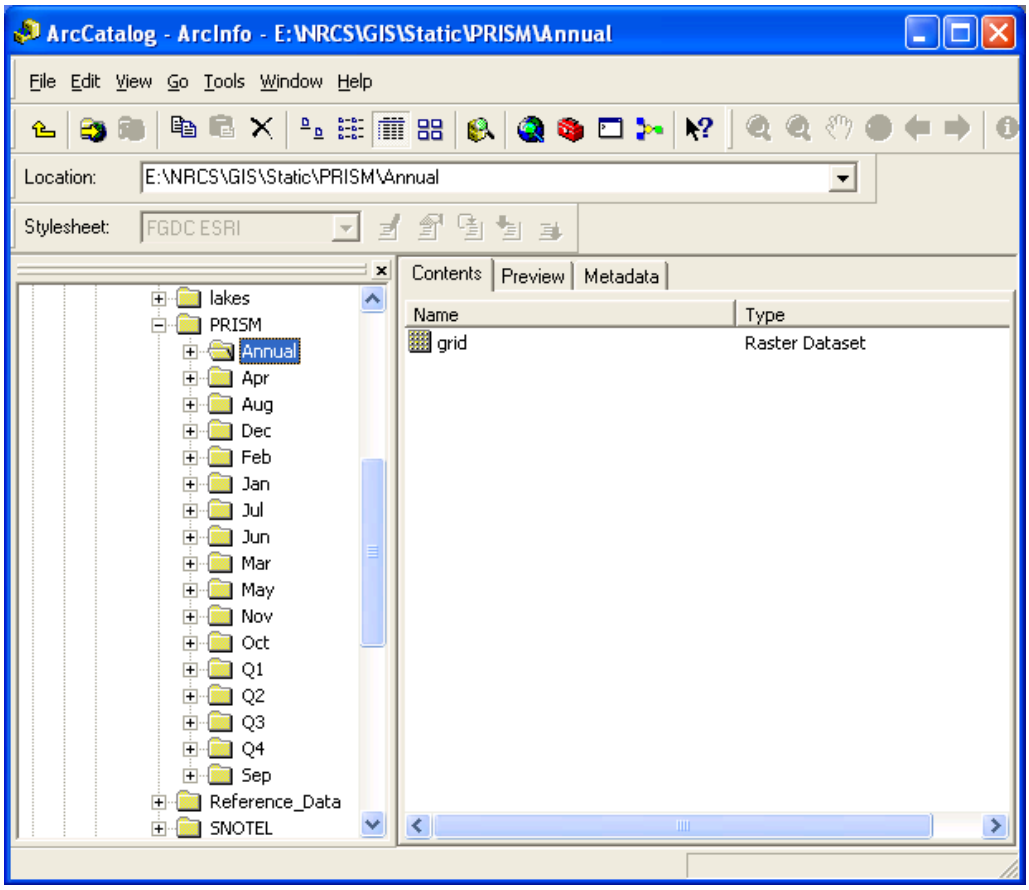


Figure 4.1. An ArcCatalog screenshot of the PRISM precipitation file structure.

Table 4.1. Commonly used data layers in Basin Analysis (see Appendix A for more information).

Layer Name	***Data Type***	***File Format***
Forest density	Raster	ArcInfo grid
Forest/land cover type	Raster	ArcInfo grid
Federal land	Polygon	ESRI Shapefile
Indian land	Polygon	ESRI Shapefile
Wilderness land	Polygon	ESRI Shapefile
PRISM precipitation layers	Raster (17 layers)	ArcInfo grid
USFS service roads	Line	ESRI Shapefile
National atlas waterbodies	Polygon	ESRI Shapefile
National atlas streams	Line	ESRI Shapefile
National atlas roads	Line	ESRI Shapefile
NRCS Soil	Polygon	ESRI Shapefile

5. Workspace File Structures

To facilitate data management and processing, BAGIS adopts the file organization structure used by NWCC and the USGS Weasel GIS tool. The main workspace is on NWCC's network file system (e.g., S: Drive). Under the main GIS folder, there are two subfolders, Basins and Static. Basins stores basin analysis output. Static contains source and supplemental data used in basin analysis. This file structure (Fig 5.1) could be altered by the users if necessary. Under the main basin folder, the model will generate subfolders of basins and areas of interest (AOIs). These folders have predefined structures generated and used by the BAGIS model (Fig 5.2). Users **must not** modify these model's file structures.

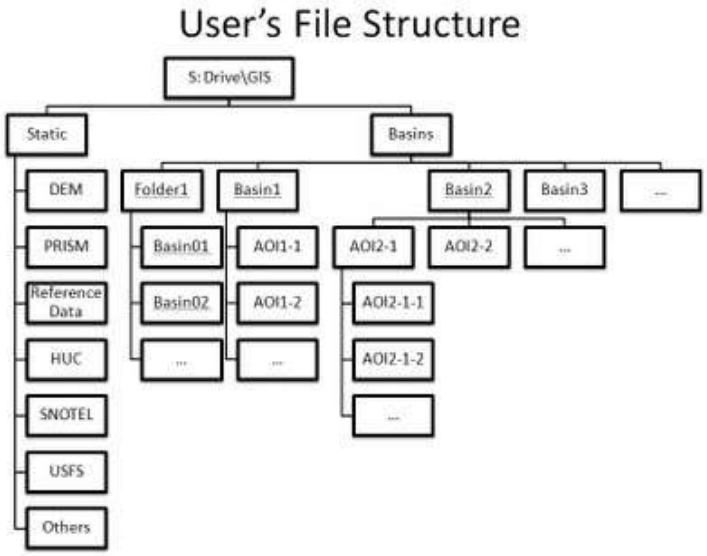


Figure 5.1. Basin analysis main file structure that could be redefined by users.

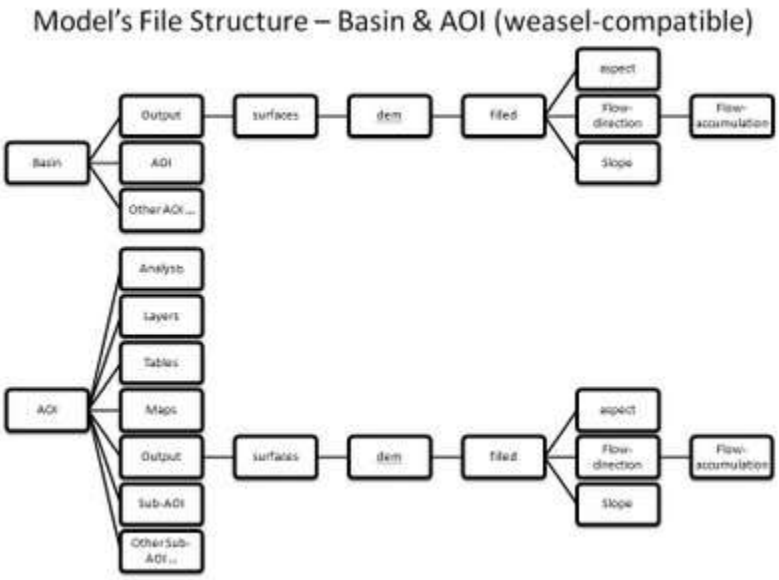


Figure 5.2. File structures of Basin and AOI, defined by the model, not by the users.

A basin folder is a folder containing a filled (i.e., depression-less) DEM and its derived surface layers, including slope, aspect, flow direction, and flow accumulation. Users must select (or create) a basin folder to start the basin analysis process. Once a basin folder is specified, users can then create AOIs based on pour point locations within the geographic boundaries of the basin.

An AOI folder is a folder containing a filled DEM and its derived surface layers (the same as a basin), AOI layers delineating the watershed boundaries of the AOI, and additional participating layers used in basin analysis. Users must select (or create) an AOI folder to do basin analysis. Once a basin folder is specified, users can generate maps showing the geographic representation of SNOTEL and Snow Course sites within the AOI.

Since an AOI folder has an identical DEM file structure as a basin folder, it is possible to create sub-AOIs within existing AOIs.

6. Modules

The model has five major modules: 1. System configuration, 2. Basin Tools, 3. AOI Tools, 4. Basin Analysis Tools, and 5. Mapping Tools. These modules are organized in ArcMap's graphic user interface (GUI) as menus and buttons on a toolbar (Figure 6.1) that guides users through the logical sequence of basin analysis.

Figure 6.1. Basin analysis model toolbar.

Once a user has finished the initial system setup (Module 1), every time he or she uses the model, they must select (or create) a basin (Module 2) and then select (or create) an AOI (Module 3) to continue with basin analysis. Table 6.1 lists the individual functions of BAGIS. Detail descriptions of these functions follow.

Table 6.1. An overview of BAGIS functions.

Groups	Tools
6.1. Basin Analyst menu	6.1.1. Add Reference Layers 6.1.2. Save AOI map document (mxd) 6.1.3. Show basin information 6.1.4. Show AOI information 6.1.5. System settings 6.1.6. About BAGIS
6.2. Basin tools	6.2.1. Select Basin tool 6.2.2. Set basin extent tool 6.2.3. Clip DEM tool

6.3. AOI tools	6.3.1. Select AOI tool 6.3.2. Set pour point tool 6.3.3. Create AOI tool
6.4. Analysis and maps menu	6.4.1. Create AOI stream tool 6.4.2. Generate Maps tool 6.4.3. Elevation distribution map 6.4.4. SNOTEL elevation representation map 6.4.5. Snow course elevation representation map 6.4.6. Precipitation distribution map 6.4.7. Aspect distribution map 6.4.8. Slope distribution map 6.4.9. Elevation scenario tool 6.4.10. Actual representation map 6.4.11. Pseudo representation map 6.4.12. Export map tool

6.1 Basin Analyst Tools Menu

The Basin Analyst Tools menu (Figure 6.2) has six tools: 1. Add Reference Layers, 2. Save AOI MXD, 3. Basin Info, 4. AOI Info, 5. Options, and 6. About. These tools provide general utilities of BAGIS.

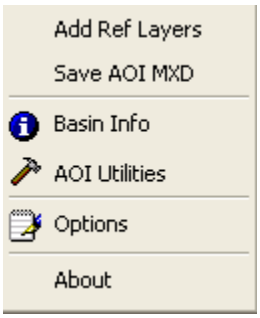


Figure 6.2. Basin Analyst tools menu.

6.1.1 Add Reference Layers

Users can load "Terrain Ref," "Drainage Ref," and "Watershed Ref" layers into ArcMap map frame when selecting this item (Figure 6.3). These reference layers are specified as ArcGIS layer files (.lyr) and used only as a reference for selecting study sites. They are not involved in any analysis. The Terrain Ref layer could be a shaded relief map showing the terrain relief. The Drainage Ref layer could be a line map showing the river network. The Watershed Ref layer could be a polygon map showing the boundaries of major watersheds. The reference layers are specified in the system settings dialog window (see 6.1.5). If no reference layer is specified, the tool does nothing. This tool has identical function as the "Add Ref Layers to Map" button on the system settings dialog window.

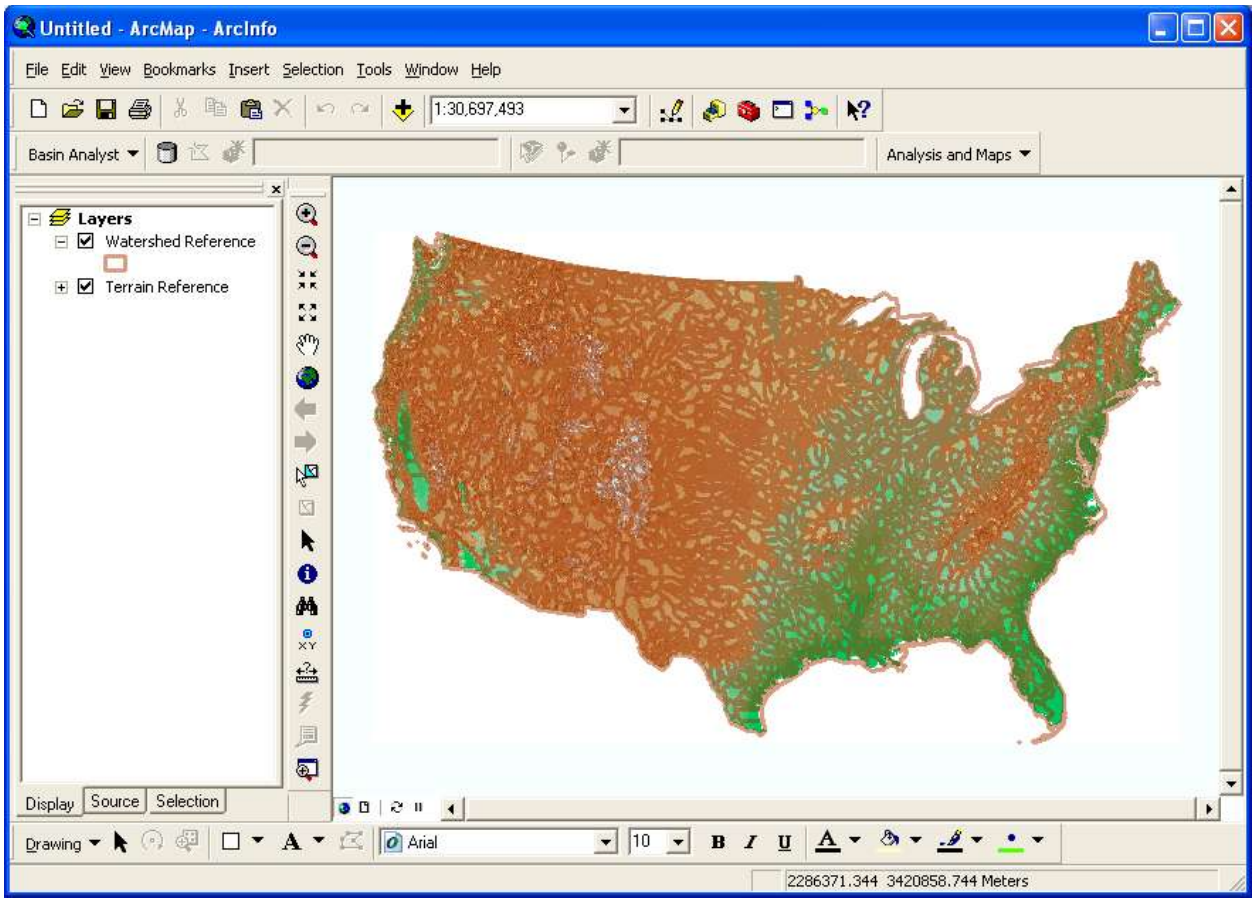


Figure 6.3. A screen shot of the reference layers in ArcMap.

6.1.2 Save AOI MXD

This tool saves the current map document to an ArcMap map document file (mxd). Make sure the file is saved in the intended folder. A mxd file stores the layers and their symbologies.

6.1.3 Basin Info

The tool displays the basic information of a basin (Figure 6.4), including minimum and maximum elevation values in the basin and basin area. Click OK to dismiss the window.

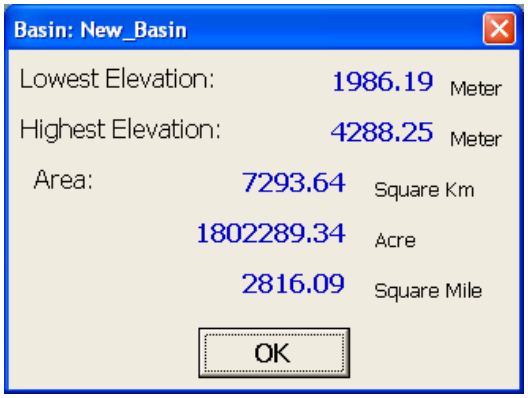


Figure 6.4. Basin information dialog window.

6.1.4 AOI Utilities

The tool displays the basic information of an AOI (Figure 6.5), including minimum and maximum elevation values in the AOI, AOI areas, and existing user-supplied GIS layers of the AOI. The shapearea is calculated from the geometry of the AOI polygon. The reference area is derived from the attribute table of the forecast point (or gauge station) the AOI was based upon. In addition, users can find several useful tools from this dialog window. The descriptions of these tools follow. Click Close to dismiss the window.

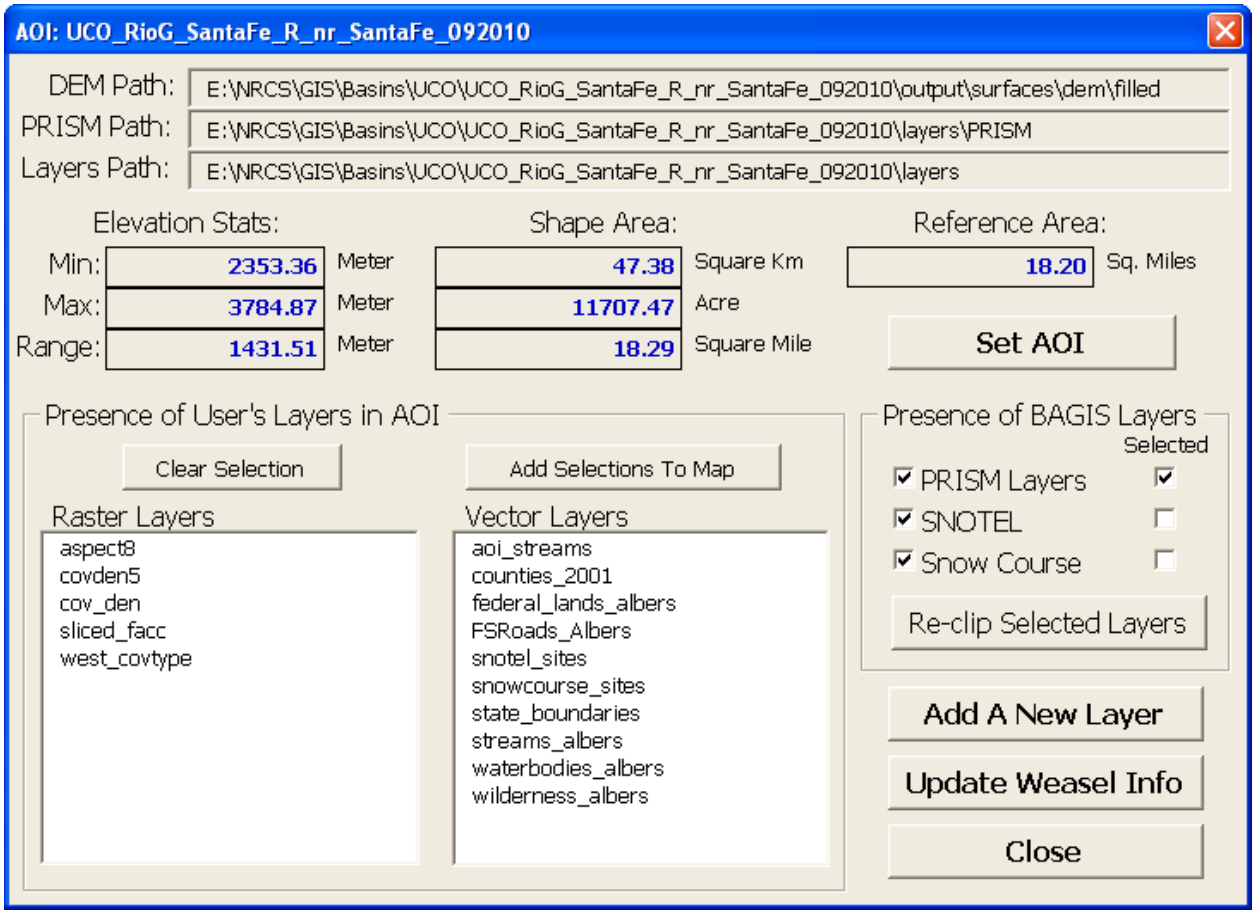


Figure 6.5. AOI information dialog window.

Set AOI Tool

The **Set AOI** tool allows users to select an existing AOI without needing to select a basin first. This tool acts as a short cut to AOIs and allows AOIs to be independent from any basin. Once an AOI is set, users can proceed to do basin analysis (see Section 6.4).

Re-Clip BAGIS Layers Tool

When an AOI was created, several BAGIS internal layers (including PRISM precipitation, SNOTEL points layer, and Snow Course points layer) were clipped to the AOI folder and are ready to be used in basin analysis. If new PRISM, SNOTEL, or snow course data become available, users can use this tool to update the internal BAGIS layers in the selected AOI. Make sure the new layers are correctly specified in the system settings dialog window (see Section

6.15). You need to first select the layer(s) you want to update and click the Re-Clip Selected Layers button to update the selected layer(s) in AOI.

Add a New Layer to AOI Tool

The tool allows users to add new user's layers, one at a time, to the selected AOI. The added layer appears in the Presence of User's Layers in AOI panel. Users can click the layers in the panels and use the Add Selections to Map button to quickly add the selected layers to ArcMap.

Update Weasel Info Tool

If an AOI was moved to a folder different from its original folder, then a user must update the file-dependency definition files in the AOI before the AOI can be used in the GIS Weasel tool. Just select the AOI you want to process and click the Update Weasel Info button. The path information in all file-dependency definition files in the AOI is updated immediately.

6.1.5 System Settings

The System Settings window is used to provide the file path locations for data used in BAGIS. It can be accessed by clicking on the "Basin Analyst" menu bar and selecting "Options" from the dropdown list. This opens the System Settings dialog window (Figure 6.6) which allows users to specify source locations for data by clicking on the "Set" button for each layer and navigating to the file directly. The caption of the dialog window indicates the file name and folder the setting information is stored.

There are three groups of data layer settings. The first data group (yellow box) pertains to the topographic reference data layers that can be used to incorporate location information to the map (Figure 6.6; highlighted in Yellow). These raster layers are optional and will not be used for cartographic or analytical purposes, however they do provide an excellent means of identify basin locations for analytical purposes. Users can load these layers to the map by checking the "Add Ref Layers to Map" button. These layers include "Terrain Ref," "Drainage Ref," and "Watershed Ref" layers. Users can double-click on the text fields to clear the setting.

The second data group (red box) relates to the analytical reference layers that will be used as data sources for BAGIS (Figure 6.6; highlighted in Red). Each of these sources are required as they provide reference to terrain elevations, station locations, and precipitation data. Users are required to identify the preferred DEM resolution (10 or 30 meter), each layer's elevation unit (meters or feet), the gauge station's area unit and field, and the elevation field and name field for each shapefile.

The third group (green box) relates to the participating layers that will be clipped during to AOI boundary generated in the AOI Tools Module (Figure 6.6; highlighted in Green). These layers are optional to add and must be in either shapefile or raster format (does not support triangulated irregular networks or coverages). There are several commands associated with managing these files in the System Configuration Module. A user can add an entry with the "Add" button, remove an entry with the "Remove" button, and clear all entries in the list box using the "Clear All" button.

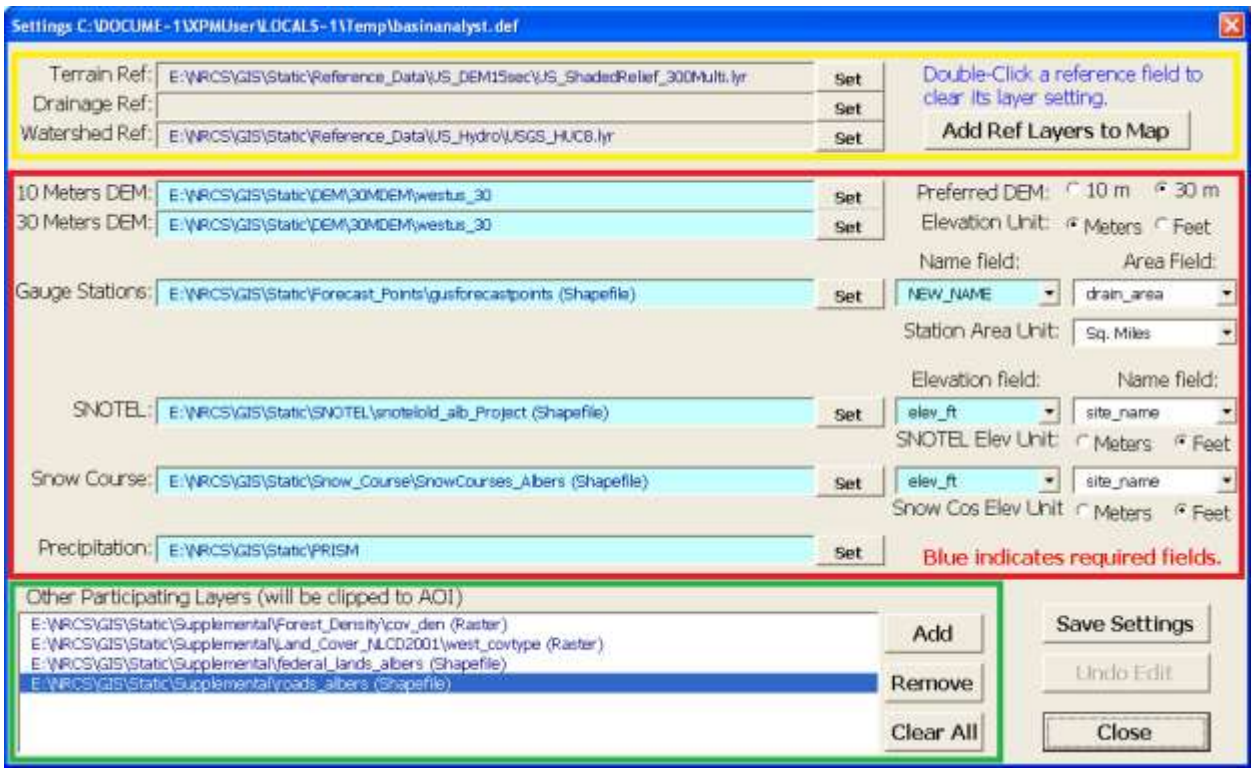


Figure 6.6. The System Settings interface (topographic reference data highlighted in Yellow, analytical reference highlighted in Red, and participating highlighted in Green).

Once all of the data sources have been set in the System Configuration Module, the user must click on the "Save Settings" button in order to save their settings data. This writes a definition file in a temporary folder that BAGIS will read every time it is started. An "Undo Edit" button was added to the System Configuration Module interface to allow the user to undo any modifications they make with the System Configuration Module.

6.1.6 About

This menu item displays the BAGIS development information in a dialog window (Figure 6.7). Click any when in the dialog window or the upper-right cross to close the window.

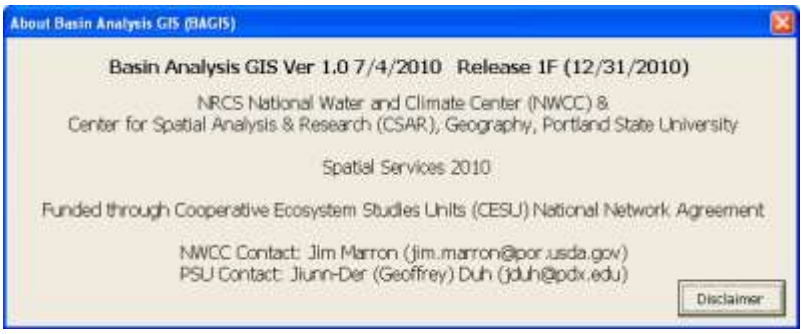


Figure 6.7. Basic BAGIS development information.

6.2 Basin Tools Module

The Basin Tools module (Figure 6.8) has three major tools: 1. Basin Tool, 2. Set DEM Extent, and 3. Clip DEM. These tools are used to (1) designate a parent folder to save the data, (2) locate an area of interest containing the target basin boundaries, and (3) generate, clip, and save supporting data layers.

Figure 6.8. Location of Basin Tools (outlined in red) within basin analysis model toolbar.

6.2.1 Basin Tool

The Basin Tool menu bar item ( ) is used to designate the location of the basin's parent folder. It opens up the Basin Tool dialog window (Figure 6.9). Users can locate a folder to store basin data by clicking on the "Open" button within the Basin Tool's dialog window and navigate to a desired folder's directory (Figure 6.10). User can create a new folder and rename it with this folder selection dialog window. If a new name is given, make sure to reselect the folder with the new name to continue.

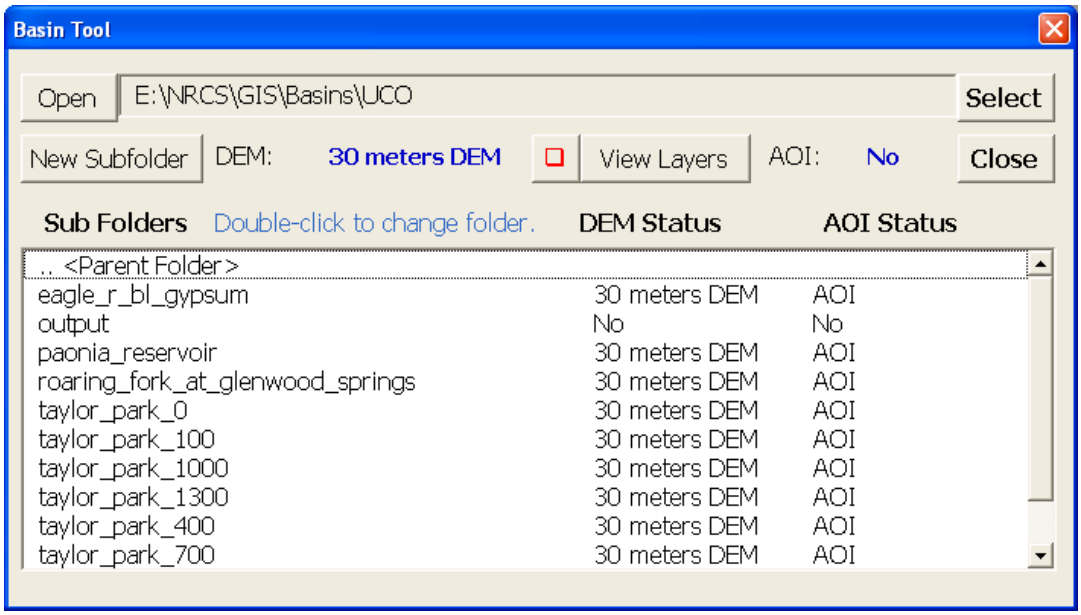


Figure 6.9. The Basin Tool dialog window.

Once a parent folder is selected, all subfolders located within this folder will be visible in the "List Box." Subfolders can be selected as the new parent folder by double clicking on them. This will change the "Path Directory" and repopulate the "List Box" with the folders that are contained within that subfolder. Users can create a new subfolder within the parent directory by clicking on the "New Subfolder" button. If a user wishes to return to the previous parent folder they can do so by double clicking on the "..<Parent Folder>" item in the "List Box."

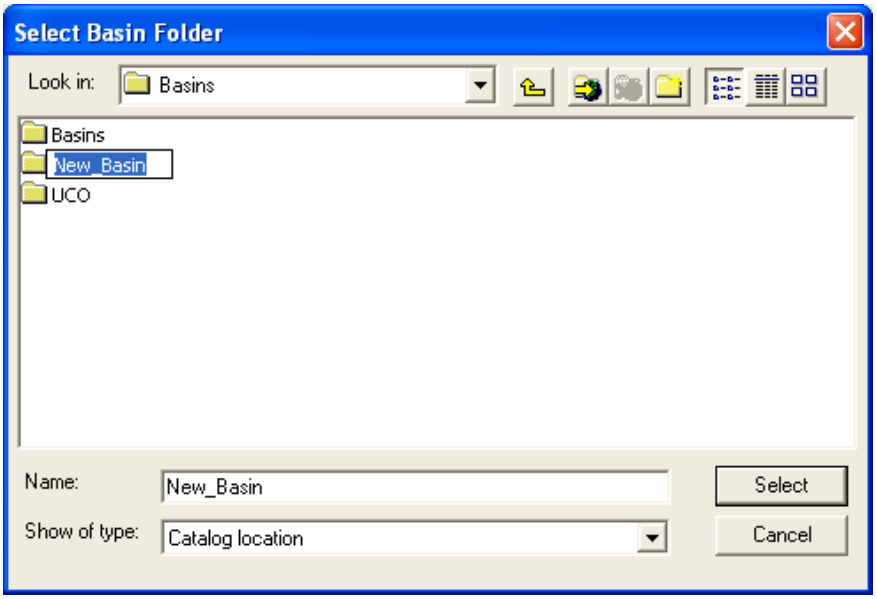


Figure 6.10. Folder selector for selecting a basin folder.

The Basin Tool window (Figure 6.9) indicates if the parent folder contains either DEM or AOI data below the "Path Directory." This information is replicated for the subfolders in the "DEM Status" and "AOI Status" columns of the "List Box." A parent folder may be selected for use by clicking on the "Select" button. If a parent folder contains DEM data, a dialog box (Figure 6.11) will open after selecting the folder prompting the user to decide whether they will use the current DEM data for this analysis. If a user chooses "Yes" the AOI Tools will become available as the remaining Basin Tools stay inactive; if the user chooses "No" then **all existing basin DEM data are deleted** and the user must proceed to the Set DEM Extent tool (see 6.2.2) in order to regenerate the data. After the user selects the basin folder, the folder's name is then placed in the Selected Basin text box.

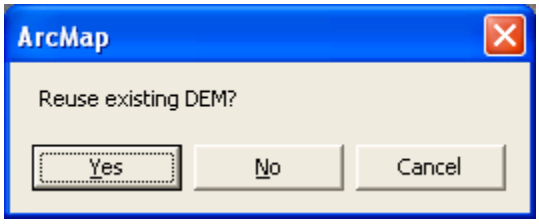


Figure 6.11. A message box confirming if the user wants to reuse the existing DEM of a basin.

The "View Layers" button will become active after a user selects a folder that contains DEM data. Selecting this button opens a list of layers that are generated by the Basin Tool module, and allows the user to preview these data in the active map (Figure 6.12). The user can then either the check specific layers, or all layers (with the "All" button), that they wish to preview. A "None" button has been installed that will prompt the clearing of all selected layers in this list.

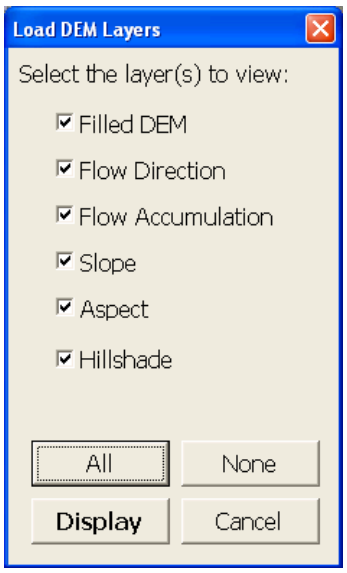


Figure 6.12. The image displays the View Layers dialog window.

6.2.2 Set DEM Extent:

The Set DEM Extent ( ) tool allows the user to generate a rectangular graphic around the extent of a basin (Figure 6.13). The boundaries of this basin may be cited by reference maps selected and applied in the System Configuration Module. After creating the extent, the Clip DEM tool will then become active.

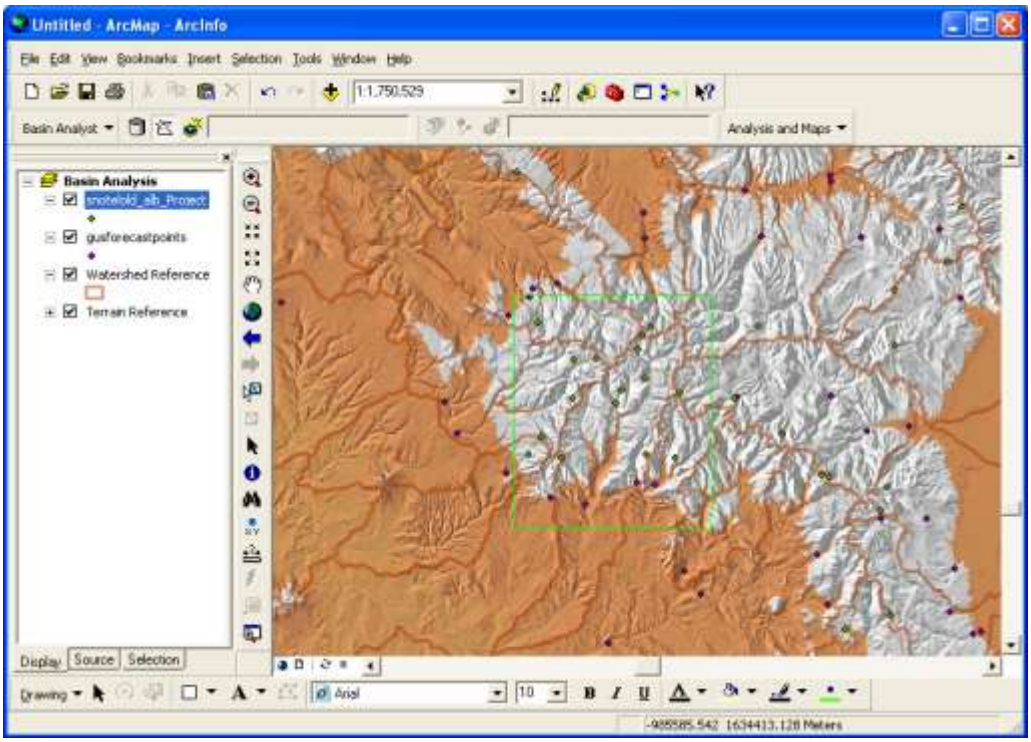


Figure 6.13. Image portraits the rectangular graphic extent generated by the Set DEM Extent tool.

6.2.3 Clip DEM Tool

The purpose of the Clip DEM Tool ( ) is to reduce the processing time of analytical operations by reducing the extent of the data properties, and providing a data library for AOI automation. The Clip DEM Tool dialog window (Figure 6.14) allows the user to specify the resolution of the DEM input ("Source DEM") before clipping it to the rectangular graphic extent generated by the Set DEM Extent tool. This clipped DEM will then be used to generate a series of "Output Layers" that can be viewed upon the completion of the clipping process. Users can select specific or all layers (with the "All" button) to view before initiating the clipping procedures via the "Clip" button. The Hillshade Z factor parameter allows users to adjust the elevation exaggeration effects on the output hillshade layer. A value of 1 is suitable for mountainous terrain; a value of 5 for flat terrain. Depending on the size of the basin, the "Clipping" process could take minutes to hours to complete. BAGIS shows a message window to inform the progress of the process (Figure 6.15). Figure 6.16 shows an example of the output basin.

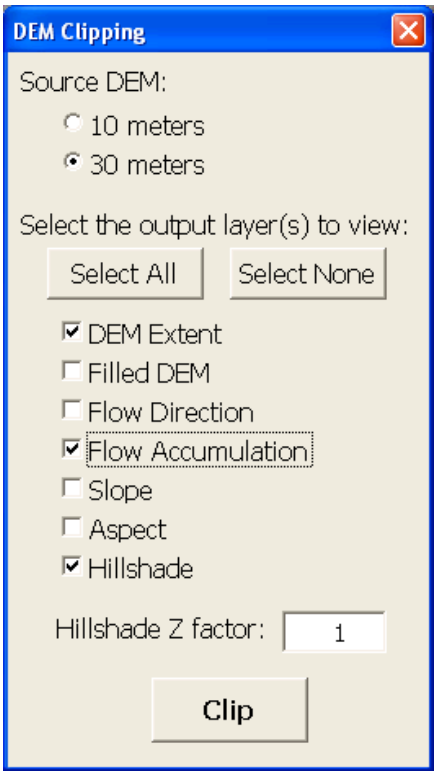


Figure 6.14. The Clip DEM Tool interface.

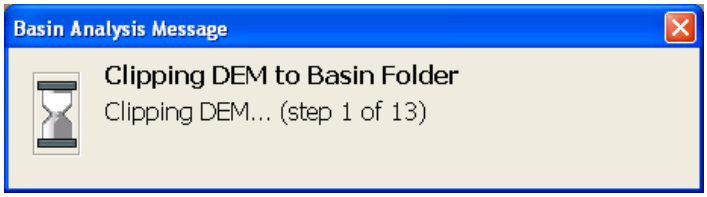


Figure 6.15. A message window showing the progress of basin preparation process.

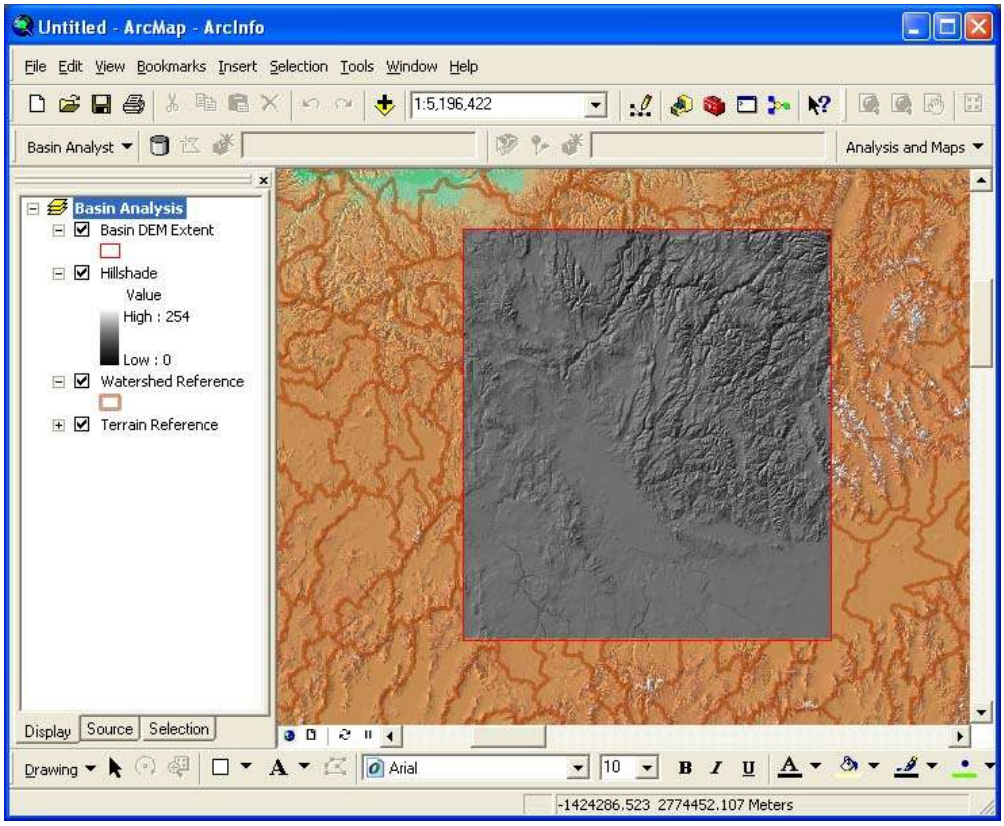


Figure 6.16. The hillshade layer of a BAGIS basin.

6.3 AOI Tools Module

The AOI (Area of Interest) Tools Module (Figure 6.17) has three major components: 1. AOI Tool, 2. Set Pour Point tool, and 3. Create AOI tool. These components are used to (1) select a Gauge Station of interest, (2) set the pour point of that Gauge Station location, and (3) generate an AOI based on the Gauge Station's watershed.

Figure 6.17. Location of AOI Tools (outlined in red) within basin analysis model toolbar.

6.3.1 AOI Tool

The AOI Tool ( ) uses an interface that manages the AOIs located within a basin (Figure 6.18). A user has the ability to generate a new AOI with the "New" button, or if AOIs exist in this basin they can select a previously generated AOI with the "Select" button, view its components with the "Layers" button, or delete it with the "Delete" button.

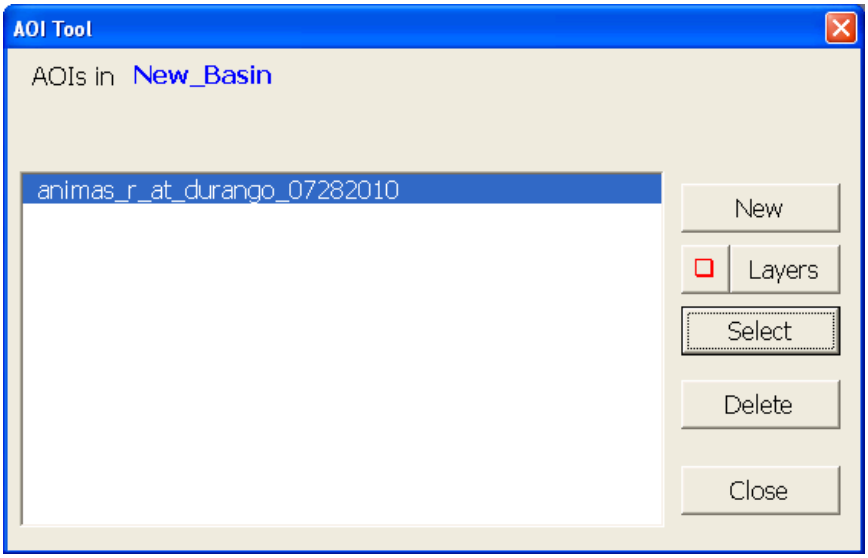


Figure 6.18. AOI Tool dialog window.

When a user chooses to generate a new AOI, the AOI Tool dialog window will close and a new interface will open (Figure 6.19). This new window is designed to allow the user to view and select a Gauge Station that will act as the AOI's pour point based on either its location or Station ID (the name field designated in the System Configuration Module settings).

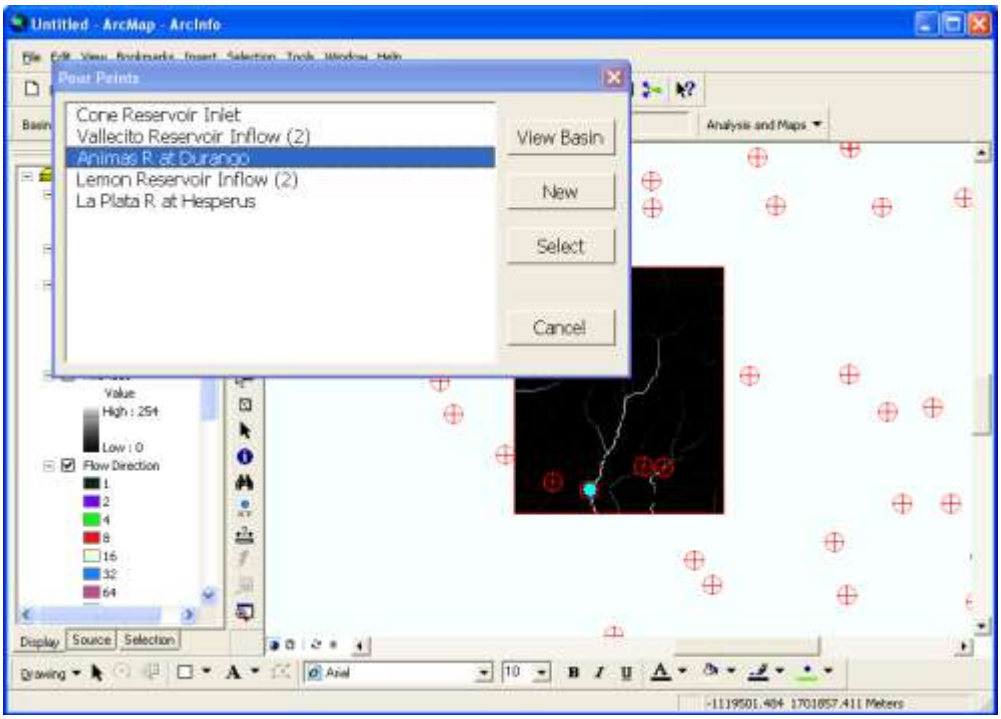


Figure 6.19. Pour point selection dialog window.

After selecting the Gauge Station, a message box will open that will allow the user to rename the AOI folder (Figure 6.20). The default folder name will be the station name followed by the date of creation.

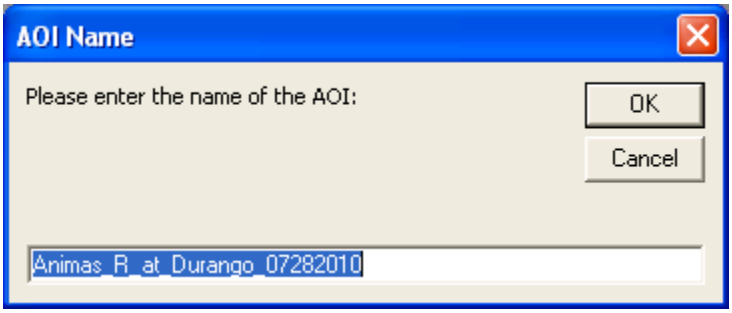


Figure 6.20. Message box used to rename AOI folder.

6.3.2 Set Pour Point

The Set Pour Point tool ( ) is used to correct any spatial inaccuracies associated with the Gauge Station shapefile by allowing the user to manually set the pour point location of an AOI (Figure 6.21). The pour point then is used to delineate the boundaries of the AOI. The location of the pour point has to be on the "stream" channel characterized by the flow accumulation layer to generate correct AOI. Users should zoom closely to the gauge station to get a precise placement of the pour point (See Figure 6.22).

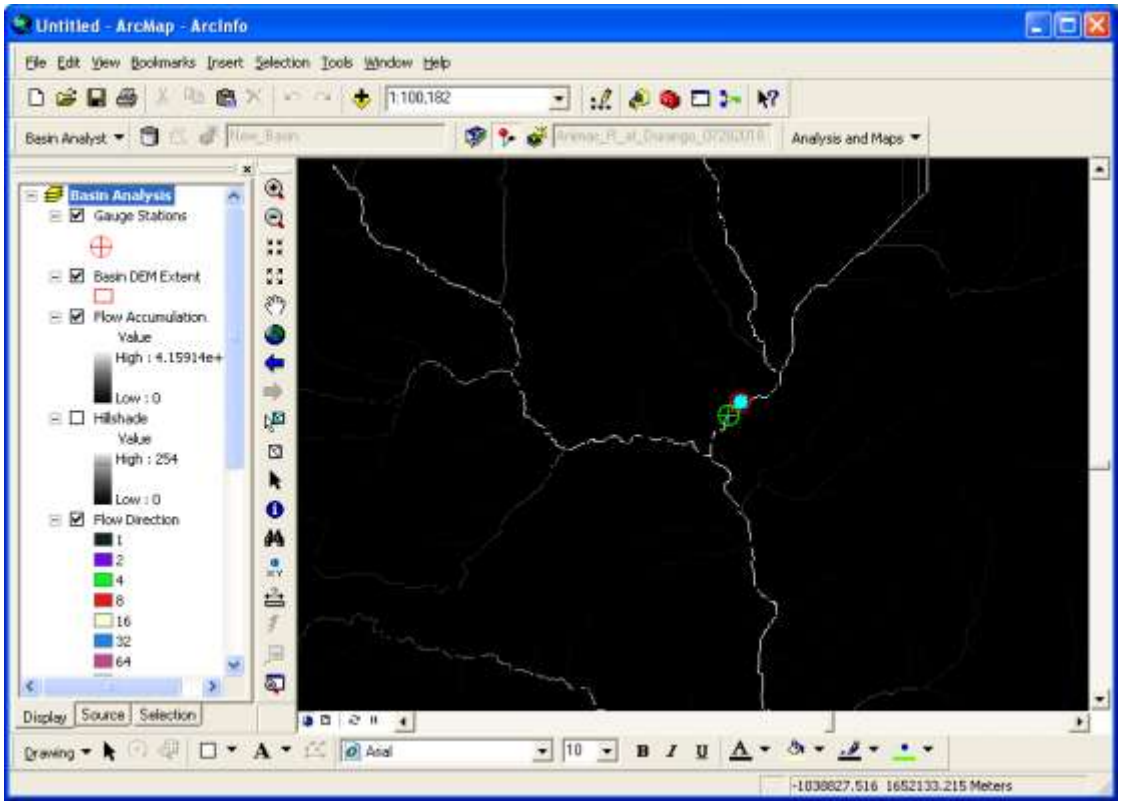


Figure 6.21. Image portraits a dot graphic generated by the Set Pour Point tool (in Green) and pour point (in Red).

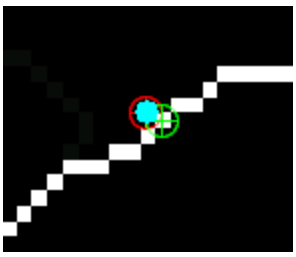


Figure 6.22. A close-up view of the selected pour-point location, indicated by a green cross-hair marker. The white pixels are locations with high flow accumulation values. Pour points should be set on these locations.

6.3.3 Create AOI Tool

The Create AOI Tool () is used to generate an AOI boundary that will be used to clip out supporting data layers to the AOI folder. The tool has two functions that can be applied within its initial dialog window (Figure 6.23). The first function allows the user to automatically snap the pour point to the area with the highest flow accumulation within a given distance. Users can deactivate this function by either setting the "Snap Distance" to zero or by deselecting the "Automatically snap pour point" option. The second function determines if, and at what distance, the AOI should be buffered before initiating the clipping sequences. Users can deactivate this function by either setting the "Buffer Distance" to zero or by deselecting the "Buffer AOI to clip layers" option. Please note that the PRISM precipitation layers are clipped to the AOI with a 1000 meter (1 Km) buffer to prevent missing data in the later analysis. After customizing these functions, the AOI layer mask can then be created by clicking on the "Generate AOI" button.

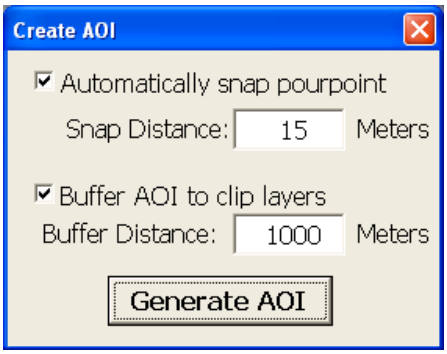


Figure 6.23. The Create AOI Tool interface.

After the AOI's mask has been created it is displayed on the map (Figure 6.24) and a message box is activated prompting the user to either verify or reject AOI boundaries (Figure 6.25). Area values for both the AOI mask are projected in this message box along with a referenced area value captured from the Gauge Station layer. If rejected the tool reverts back to Set Pour Point tool, otherwise it proceeds to clip all layer associated with that AOI. BAGIS shows a message window to inform the progress of the process (Figure 6.26). Figure 6.27 show an AOI and its associated layers created by the Create AOI tool.

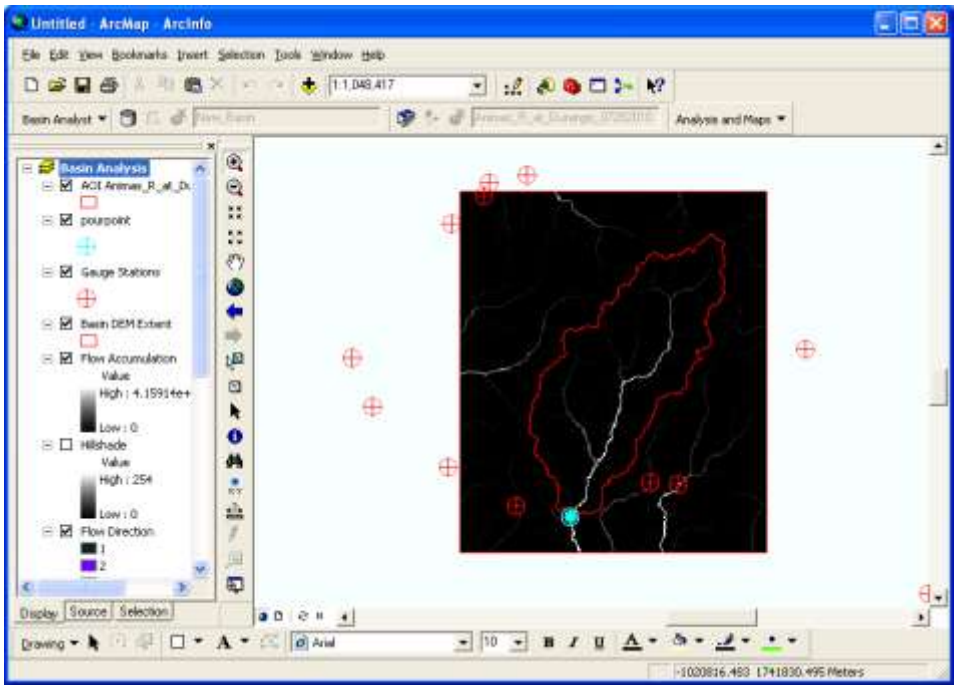


Figure 6.24. AOI boundaries delineated by BAGIS.

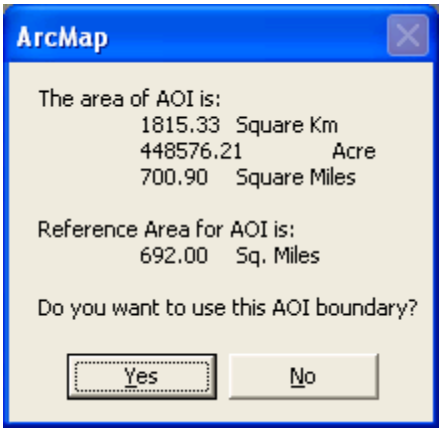


Figure 6.25. Image displays the message box prompting the user to verify or reject the AOI's mask.

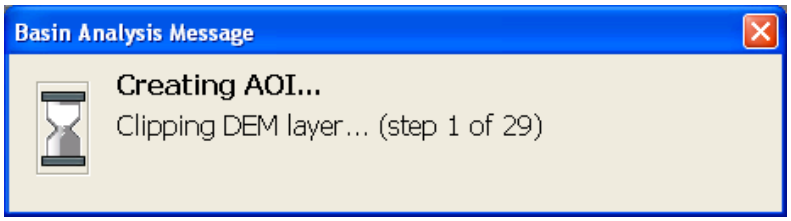


Figure 6.26. A message window showing the progress of AOI preparation process.

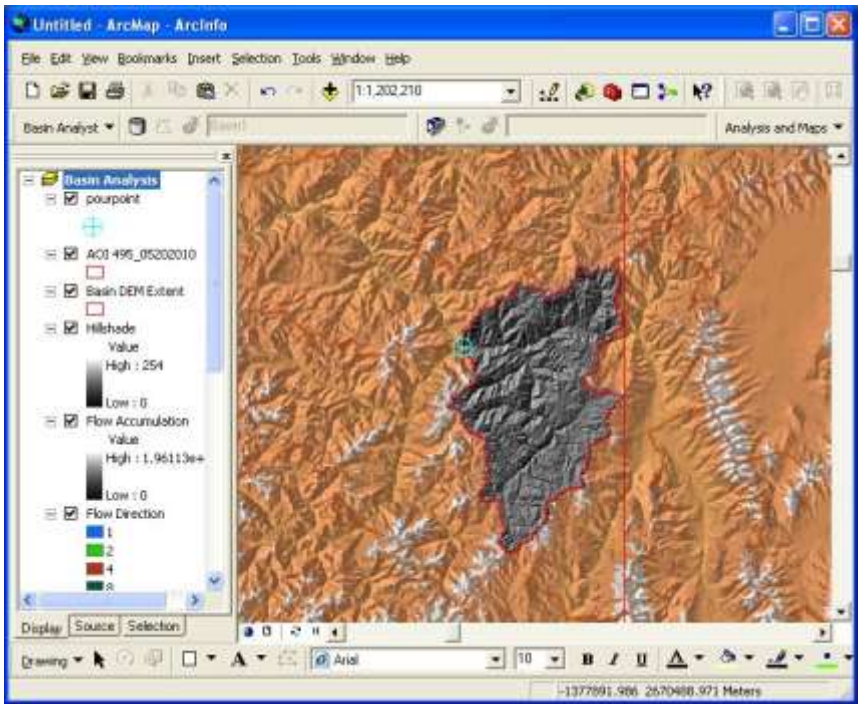


Figure 6.27. The boundaries and hillshade layers of an AOI watershed created with the "Create AOI Tool."

6.4 Basin Analysis and Maps Tools

The Basin Analysis and Maps tool menu include the Create AOI Streams, Elevation Scenario, map export, and several map display tools (Figure 6.28). These tools are designed to provide further analysis AOI data layers.

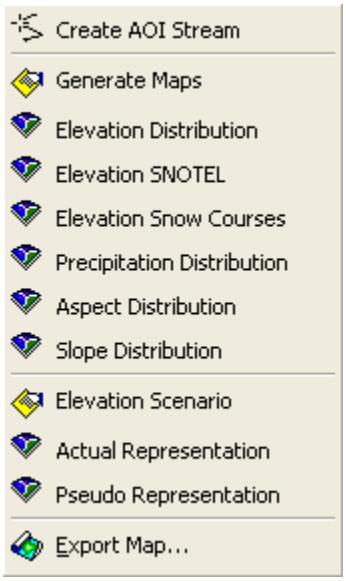


Figure 6.28. Basin Analysis and Maps tools menu.

6.4.1 Create AOI Streams

The Create AOI Streams tool converts the flow accumulation raster layer into a streams vector layer using the standard deviation of flow accumulation value (Figure 6.29). The interface reports the "Max Flow Accumulation Value" and "Standard Deviation of Flow Accumulation" value to the user upon initialization. After being generated, the layer is saved in the "*\AOI\Layers" folder and added to the map (Figure 6.30). A smaller value creates a more detail stream layer.

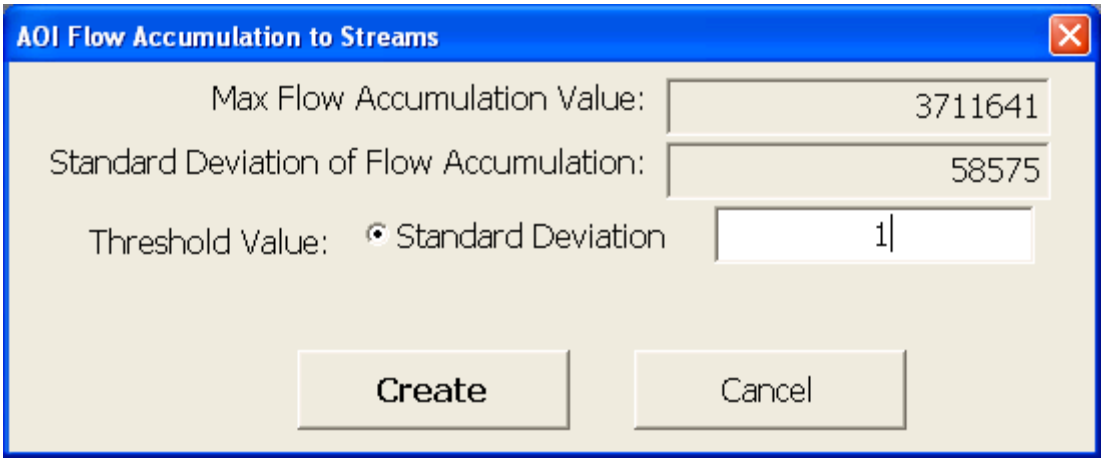
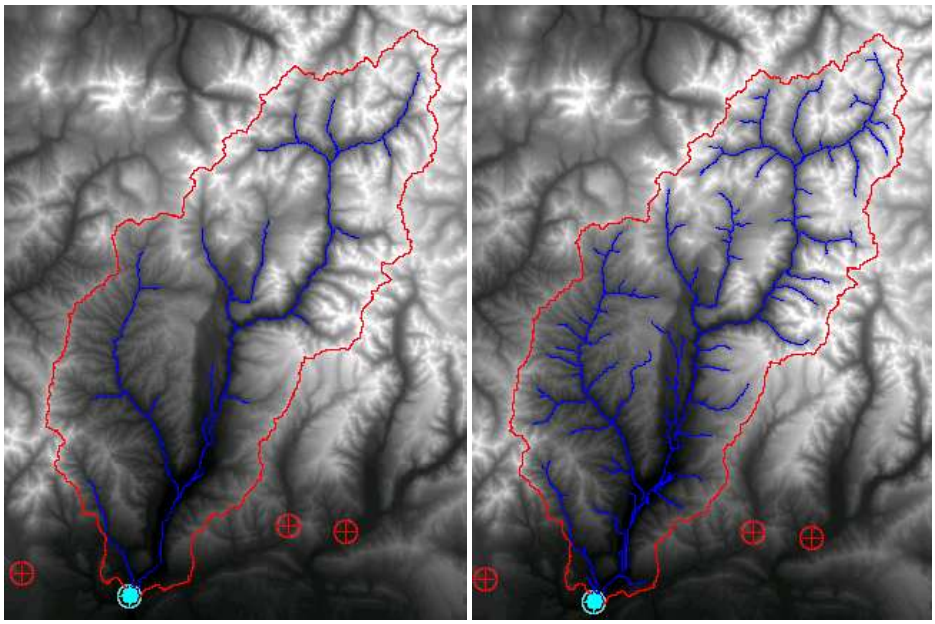


Figure 6.29. The Create AOI Streams dialog window.



(A) (B)

Figure 6.30. The stream layer of an AOI created with the "Create AOI Streams" tool. The stream lines were derived from the flow accumulation layer of the AOI. Map A used a threshold value of 1 standard deviation. Map B is 0.2 standard deviation.

6.4.2 Generate Maps

The purpose of the Generate Maps tool is to reclassify the DEM data into zones of interest (precipitation classes, SNOTEL and Snow Course site locations), and project their analysis through a series of maps, tables, and charts. In order to accomplish this, the Generate Maps tool is devised in five different functions that address these objectives (Figure 6.31).

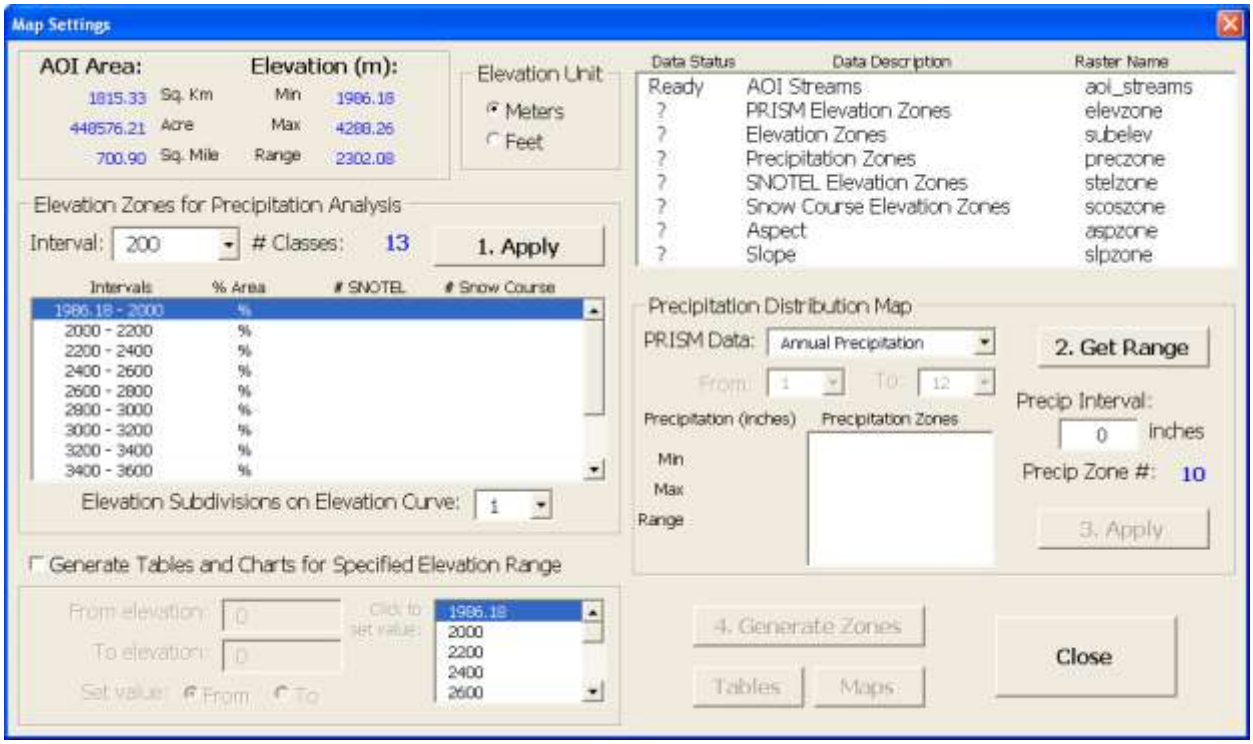


Figure 6.31. Generate Maps tool dialog window.

Upon opening the Generate Maps tool, information pertaining to AOI's area and elevation will be provided in the "AOI Information" data frame (upper left corner). The availability of various data layers used in making tables and charts is reported in the Data Status data frame (upper right corner). After verifying this data the user can proceed to the "Elevation Zones foe Precipitation Analysis" data frame (mid-left of the dialog window) where they can select the elevation interval that they wish to classify the DEM into. This can be done by clicking on the dropdown list next to the "Interval" tab and then clicking "1.Apply." The list box below will then become populated providing the percent of the DEM's area and number of SNOTEL and Snow Course sites for each elevation interval range. The elevation subdivision on elevation curve parameter allows the user to create a detail elevation curve on the charts. The subdivided intervals are not used in analysis.

A second reclassification is made to the precipitation data in the "Precipitation Distribution Map" data frame (mid-right of the window). This function allows the user to choose a predetermined or custom interval scheme from the dropdown list next to the "PRISM Data" tab. If a user chooses a custom interval scheme then the dropdown lists entitled "From" and "To" will become active allowing the user to custom pick target months. After the

precipitation data has been selected, the user must then click the “2. Get Range” button to get the summary statistics of the compiled PRISM precipitation data. The user can then provide an interval in the “Precip Zone Interval (Inches)” text box. This interval will be used to reclassify the PRISM data into precipitation zones. The precipitation zones will then be populated to the “Precipitation Zones” list box after the user clicks on the “3.Apply” button.

Once the elevation and precipitation zones have been created, the user can then click on the “4.Generate Zones” button to generate new raster files with these reclassified zones. These raster files will be saved in the “Analysis” folder of the AOI directory.

Optionally, a user can conduct a basin analysis on a user-specified elevation range. The Generate Tables and Charts for Specified Elevation Range data frame (lower left corner of the window) enables the selection of a “from” elevation value and a “to” elevation value from the elevation list box to the right. The user can toggle the set value from and to option buttons and click on an item in the list box to set the from and to elevation values.

After the elevation and precipitation data has been reclassified, the user can then generate tables and charts that display the zonal statistics of each reclassification. These tables (see Figure 6.32 for example) and charts (see Figure 6.33 for an example) will be placed in an Excel file when the process is completed. Tables 6.2 and 6.3 summary the Excel spreadsheets created by the Generate Maps tool. A list of the charts generated is shown in Table 6.4. Please refer to Appendix B for a detail description of the columns in these spreadsheets and Appendix C for the example of different types of charts.

	A	B	C	D	E	F	G	H	I	J	K
1	VALUE	COUNT	AREA	MIN	MAX	RANGE	MEAN	STD	SUM	%_AREA	Label
2	2272.87									0	
3	2367.2	1	874885.5	22.002985	22.002985	0	22.002985	0	22.002985	1.449275362	2313.5 - 2367.2
4	2421	1	874885.5	21.93291092	21.93291092	0	21.93291092	0	21.93291092	1.449275362	2367.3 - 2421
5	2474.8	1	874885.5	22.30121231	22.30121231	0	22.30121231	0	22.30121231	1.449275362	2421.1 - 2474.8
6	2528.6	14	12248397	22.76148415	24.65841293	1.896928787	23.51454544	0.532292604	329.2036133	20.28985507	2474.9 - 2528.6
7	2582.4	18	15747939	23.51667976	25.63058281	2.113903046	24.29165459	0.617766321	437.2497864	26.08695652	2528.7 - 2582.4
8	2636.2	13	11373512	23.74157524	27.04781532	3.306240082	25.11686897	0.865966797	326.5192871	18.84057971	2582.5 - 2636.2
9	2690	9	7873969.5	23.75693512	27.32259941	3.565664291	25.15503502	1.098495126	226.3953094	13.04347826	2636.3 - 2690
10	2743.8	3	2624656.5	26.39895058	27.86654472	1.467594147	27.36620712	0.68408972	82.09861755	4.347826087	2690.1 - 2743.8
11	2797.6	2	1749771	28.42652321	29.16862488	0.742101669	28.79757309	0.371050835	57.59514618	2.898550725	2743.9 - 2797.6
12	2851.4	2	1749771	29.8323288	29.97971153	0.147382736	29.90602112	0.073691368	59.81204224	2.898550725	2797.7 - 2851.4
13	2905.2	1	874885.5	30.08638763	30.08638763	0	30.08638763	0	30.08638763	1.449275362	2851.5 - 2905.2
14	2959	1	874885.5	31.20816612	31.20816612	0	31.20816612	0	31.20816612	1.449275362	2905.3 - 2959
15	3012.8	2	1749771	32.04771042	33.20067978	1.15296936	32.6241951	0.57648468	65.2483902	2.898550725	2959.1 - 3012.8
16	3228	1	874885.5	34.9924736	34.9924736	0	34.9924736	0	34.9924736	1.449275362	3174.3 - 3228

Figure 6.32. A screenshot of an Excel spreadsheet generated in BAGIS.

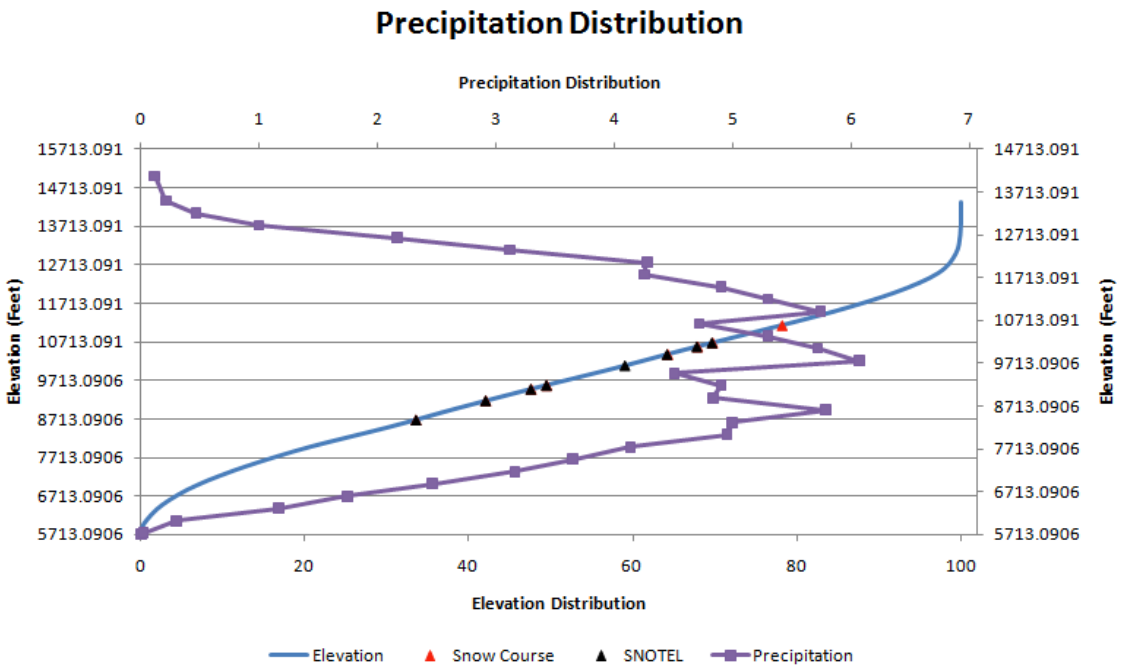


Figure 6.33. An example of the precipitation distribution chart of an AOI.

Table 6.2. Excel spreadsheets created in basin analysis (full elevation range in AOI)

Spreadsheet Name	Description	Associated Chart(s)
Charts	Charts of the data spreadsheet (see Table 5.4)	N/A
Area Elevations	Area distribution of elevation zones	N/A
PRISM	Precipitation distribution of elevation zones	Precipitation Distribution and Precipitation Distribution (combined with SNOTEL and Snow Course)
Slope	Slope distribution of AOI	Slope Distribution
Aspect	Aspect distribution of AOI	Aspect Distribution
Snow Course	Area distribution between Snow Course sites at different elevations	Snow Course and Precipitation Distribution (combined with SNOTEL and Snow Course)
SNOTEL	Area distribution between SNOTEL sites at different elevations	SNOTEL and Precipitation Distribution (combined with SNOTEL and Snow Course)
Elevation Curve	Area distribution of subdivided elevation zones	All charts, except Slope and Aspect distributions

Table 6.3. Excel spreadsheets created in elevation range analysis (within user-specified elevation range).

Spreadsheet Name	Description	Associated Chart(s)
Range Charts	Charts of the range data spreadsheet (see Table 5.4)	N/A
Elevation Range	Area distribution of elevation zones within user-specified elevation range	N/A
PRISM Range	Precipitation distribution of elevation zones within user-specified elevation range	Precipitation Distribution and Precipitation Distribution (combined with SNOTEL and Snow Course)
SNOTEL Range	Area distribution between SNOTEL sites at different elevations within user-specified elevation range	SNOTEL and Precipitation Distribution (combined with SNOTEL and Snow Course)
Snow Course Range	Area distribution between Snow Course sites at different elevations within user-specified elevation range	Snow Course and Precipitation Distribution (combined with SNOTEL and Snow Course)

Table 6.4. Excel charts created in basin analysis and elevation range analysis

Chart Name	Type	Description
Area Elevation	Scatter plot	Cumulative % area against elevation
Precipitation Distribution	Scatter plot	% precipitation volume against elevation, superimposed by Area Elevation Chart
Precipitation Distribution (combined with SNOTEL and Snow Course)	Scatter plot	% precipitation volume against elevation, superimposed by Area Elevation, SNOTEL, and Snow Course Charts
SNOTEL	Scatter plot	Cumulative % area against elevation of SNOTEL, superimposed by Area Elevation Chart
Snow Course	Scatter plot	Cumulative % area against elevation of Snow Course, superimposed by Area Elevation Chart
Slope Distribution	Histogram	% area of each slope interval
Aspect Distribution	Histogram	% area of each aspect direction

The last function allows the user to generate maps after each reclassification by clicking on the “Maps” button. Once the process is completed, premade mapping templates can be found in the “Analysis and Maps” menu bar. Each map represents its own theme and is equipped with a legend, scale bar, north arrow, title, and appropriate layers. Users are allowed to modify these map elements freely using ArcMap’s built-in functions. See Sections 6.4.3 through 6.4.8 for samples of maps generated by BAGIS.

6.4.3. Elevation distribution map

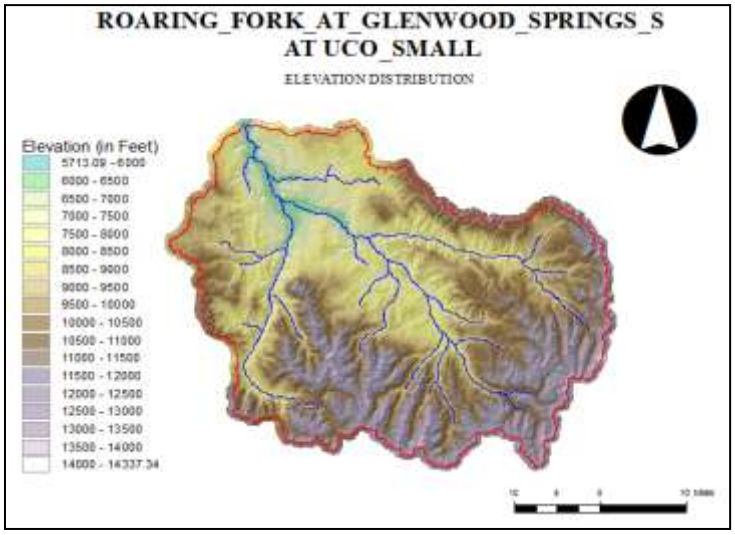


Figure 6.34. Elevation distribution map in a selected AOI.

6.4.4. SNOTEL elevation representation map

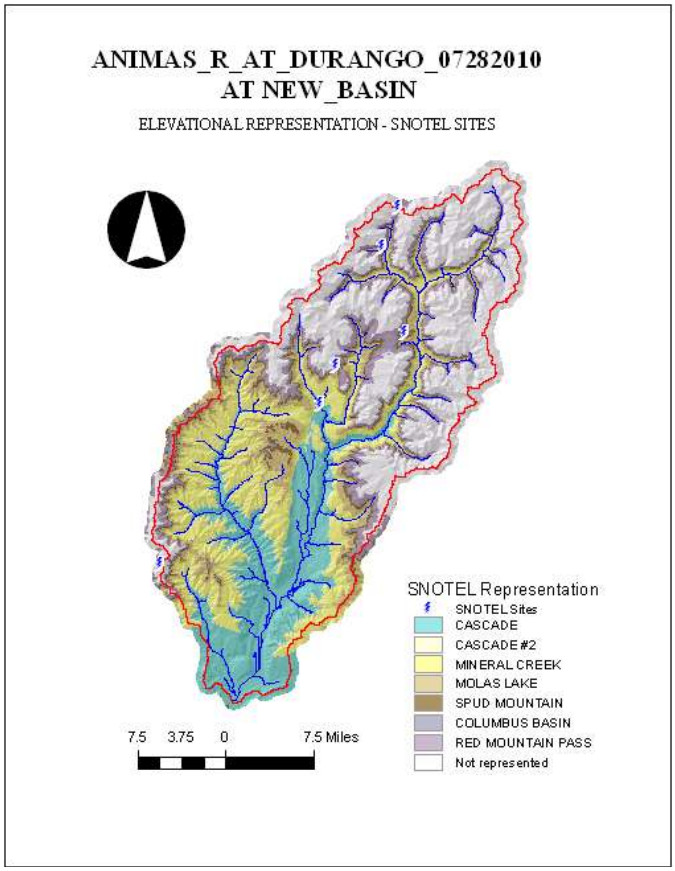


Figure 6.35. SNOTEL elevation representation map in a selected AOI.

6.4.5. Snow course elevation representation map

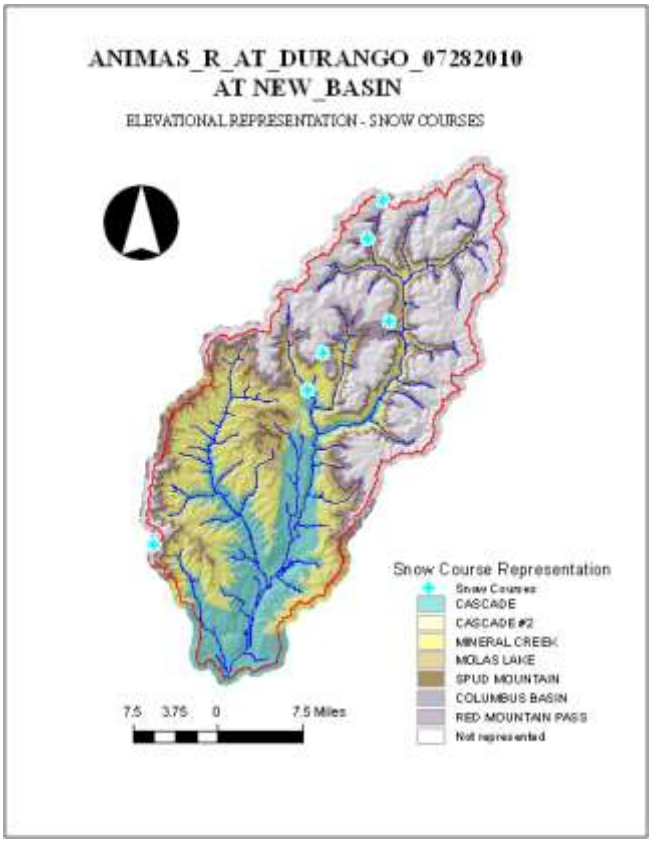


Figure 6.36. Snow Course elevation representation map in a selected AOI.

6.4.6. Precipitation distribution map

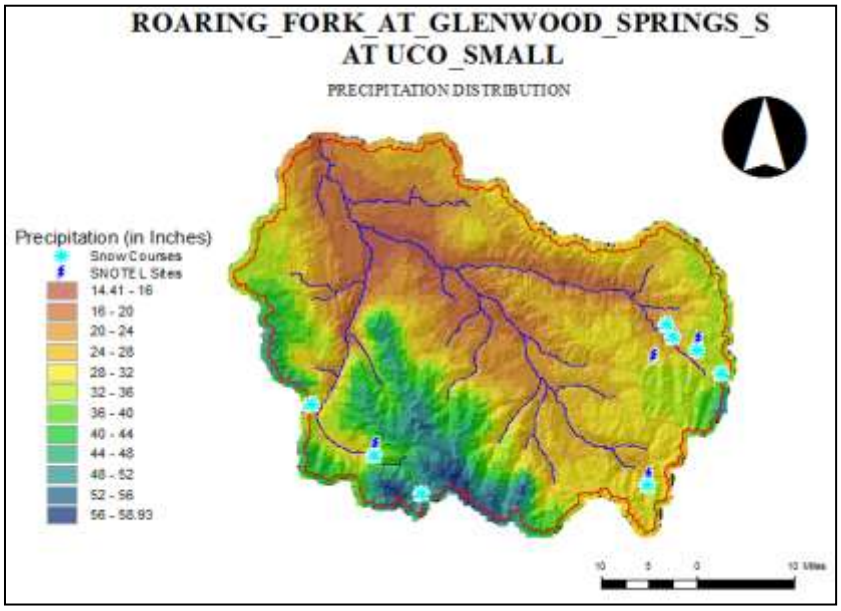


Figure 6.37. Precipitation distribution map in a selected AOI.

6.4.7. Aspect distribution map

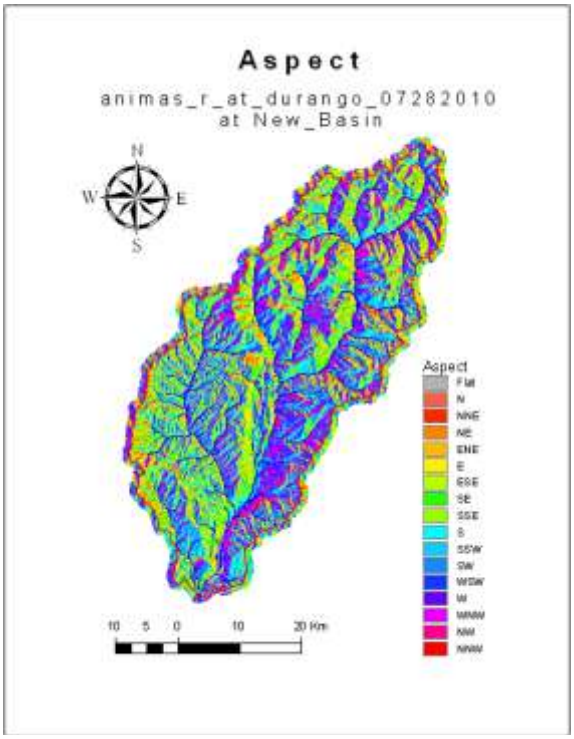


Figure 6.38. Aspect distribution map in a selected AOI.

6.4.8. Slope distribution map

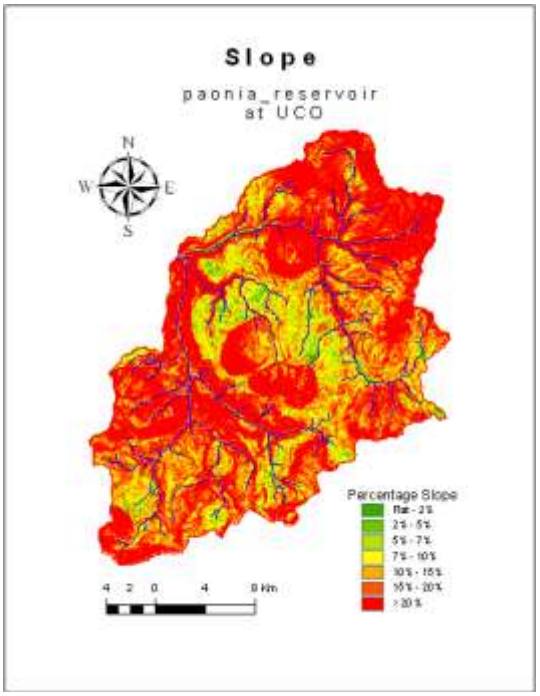


Figure 6.39. Slope distribution map in a selected AOI.

6.4.9 Elevation Scenario

This tool allows the user to estimate the area in an AOI not represented by existing SNOTEL or snow course sites. The tool calculates the actual non-represented areas and pseudo non-represented areas using elevation data entered by the user. Areas with an elevation higher than the highest site(s) or lower than a user-specified elevation range below the lowest site(s) are deemed non-represented by the monitoring sites. After the calculation, the areas, shown in acres or hectares, and percentages of non-presented areas are displayed on the dialog window (Figure 6.40) and in the map layout window (Figure 6.41).

Figure 6.40. The Create AOI Streams interface.

5.4.10. Actual representation map & 5.4.11. Pseudo representation map

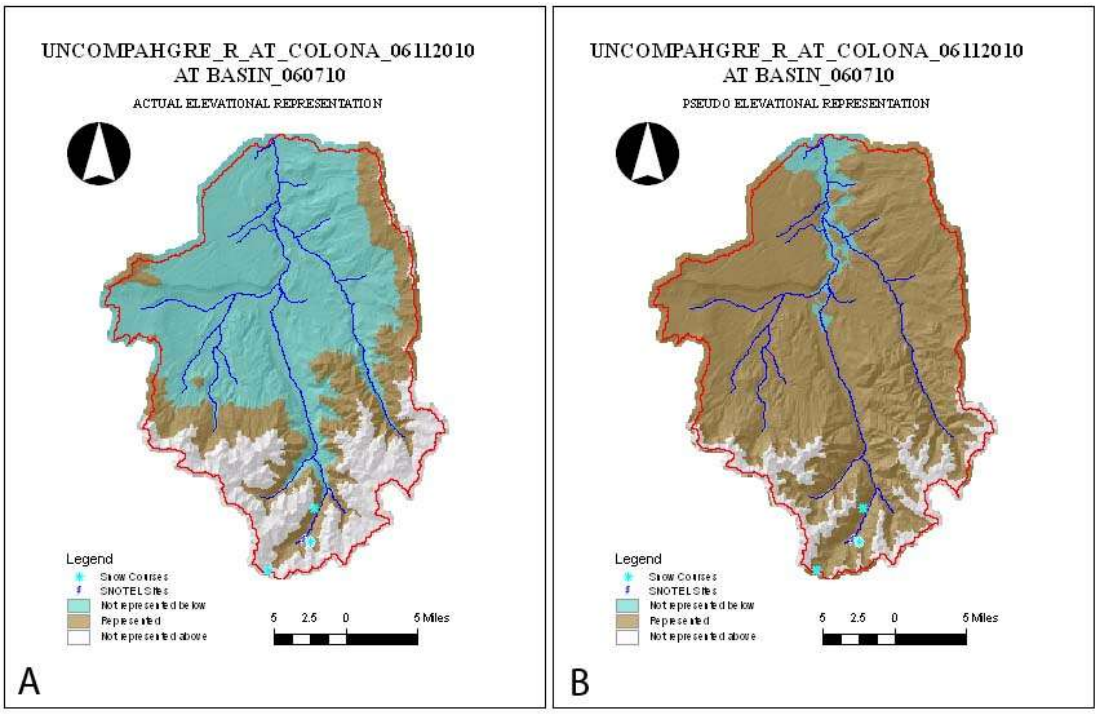


Figure 6.41. Elevational representations of SNOTEL and snow course sites: A) actual sites, B) pseudo sites.

6.4.12 Export Maps

Users can export the current map by selecting the "Export Maps" tool found in the "Analysis and Maps" menu bar. This opens an export interface that allows the user to name the map, decide where to save it, the appropriate format to export in, and the image quality (Figure 6.42).

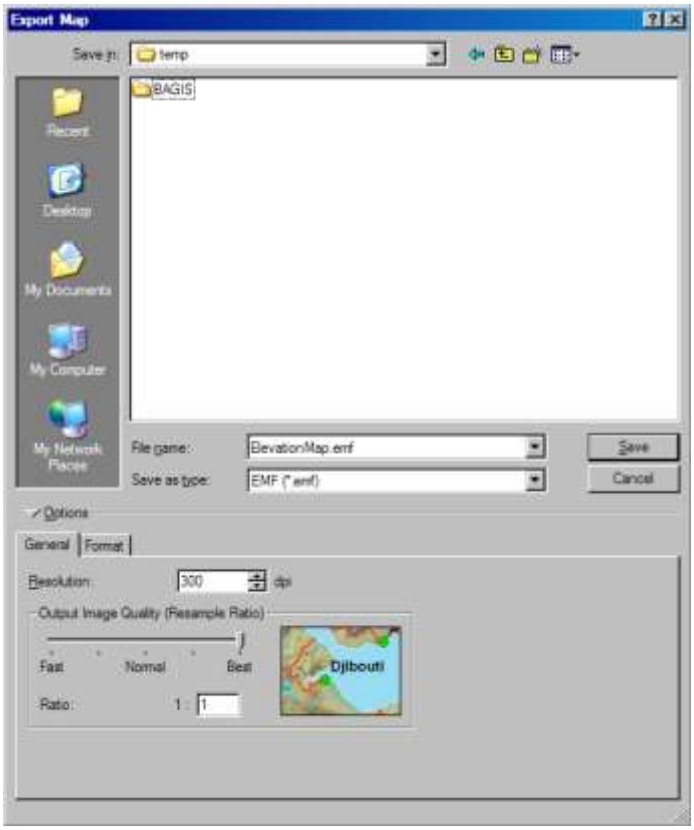


Figure 6.42. Export Map interface.

7. Working with GIS Weasel

BAGIS uses the same file structure as what is defined in GIS Weasel to store the DEM and its derived surfaces of an AOI. See Section 5 for a description of the workspace and file structure of BAGIS. Users can use GIS Weasel to process the AOIs created in BAGIS. The GIS Weasel tool was partially developed in ArcInfo AML. ESRI's ArcInfo Workstation product must be installed on the computer to use the Weasel tool. Please use the instructions below to bring BAGIS AOIs into GIS Weasel.

1) In BAGIS, select the AOI Utilities tool (see Section 6.1.4) and set the AOI you want to process as the target AOI.
2) Use (Click on) the Update Weasel Info tool to update Weasel's file-dependency information of the AOI. Make sure you file path is within the length limit of Weasel. If

the length exceeds the limit, a warning message appears. ArcInfo (i.e., GIS Weasel) does not allow the name of any folder to exceed 80 characters and the path of a workspace to exceed 115 characters.

3) Open The GIS Weasel Tool by double-clicking the tool icon on the desktop.
4) Navigate to the basin folder and select (click on) the AOI folder. Check the "Use Input DEM previously associated with current Write Directory." (Figure 7.1) and select the grid layer appeared in the "Input Elevation Grid" panel. Click Apply to continue.

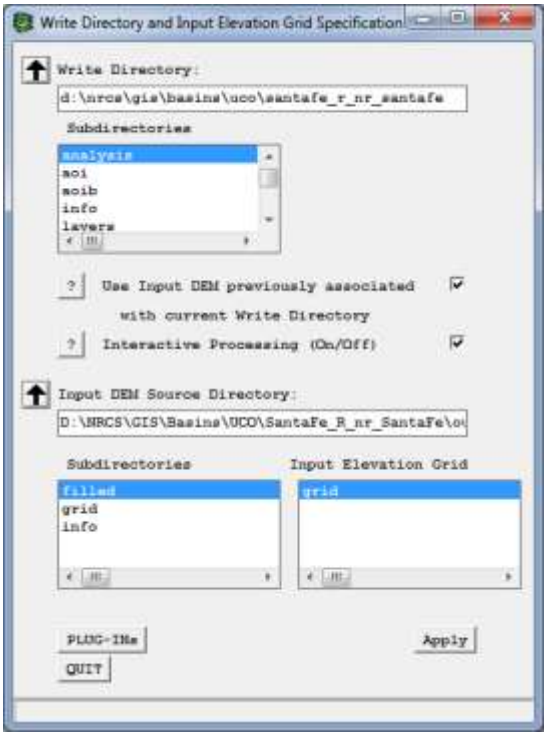


Figure 7.1. GIS Weasel main dialog window for selecting an AOI.

5) Set the elevation (Z) unit of the DEM grid.
6) Follow the prompt to reuse the layers created in BAGIS.
7) When the AOI Delineation dialog appears, set "Raster" as the externally established AOI. Click "Use externally established AOI" (Figure 7.2).

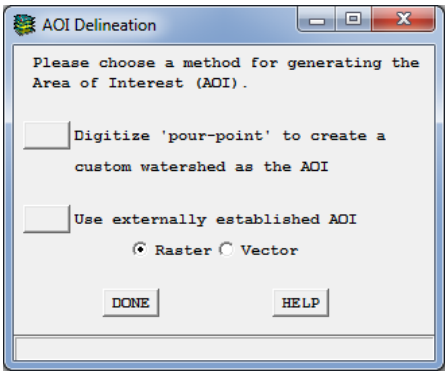


Figure 7.2. GIS Weasel dialog window for choosing AOI boundaries layer.

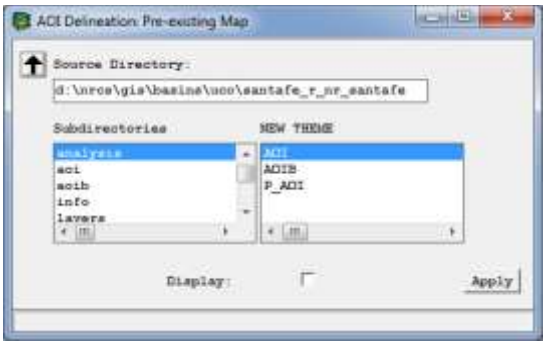


Figure 7.3. Selecting a pre-existing AOI boundary in GIS Weasel.

8) Select the "AOI" raster layer and click Apply to continue (Figure 7.3). The AOI Delineation dialog reappears. Click "Done" to continue.
9) Follow the prompt to reuse the layers created in BAGIS.
10) GIS Weasel now has successfully opened the AOI created in BAGIS for subsequent analysis.

8. Using BAGIS in ArcGIS 10

BAGIS tool has two different versions for ArcGIS 9.x and ArcGIS 10. This is because ArcGIS 10 uses a different framework for managing map template files than ArcGIS 9.x. The source code of BAGIS is stored in a map template. ArcGIS 10 no longer use a map template file (.mxt) to set a user-defined map template. Instead, it uses a regular version 10 map document (.mxd). You should use the matching version of BAGIS. Both versions of BAGIS have identical functions and VBA codes.

When using the version in ArcGIS 10, you can either double-clicking the mxd file to start the model or copy the mxd to user's ArcGIS 10 template folder and use the new document option to select the BAGIS template. The ArcGIS 10 template folder usually is at:

C:\Users\account_name\AppData\Roaming\ESRI\Desktop10.0\ArcMap\Templates

You can find the path to the template folder on your computer by selecting "New" from the File menu in ArcMap and clicking on the blank map. The path should appear toward the bottom of the dialog window.

9. Creating AOIs for Endorheic (Closed) Watersheds

An endorheic (or closed) watershed is a drainage basin from which there is no outflow of water. Such watersheds are usually surrounded by terrain barriers that keep water in enclosed hydrological systems. When delineating the AOI of a closed watershed, users must use

the lowest point in the watershed as the "pour point" and the lowest point on the DEM must contain a "NODATA" value. When selecting the pour point in BAGIS, users must click on the DEM grid cell that is NODATA and disable the snap option when generating the AOI boundaries.

If the DEM has not be "preconditioned", then you need to find the lowest points in endorheic watersheds and set the DEM cell values on these locations to "NODATA." The ArcGIS software interprets the NODATA cells as watershed outlets so that these endorheic basins are not labeled as "sinks" of the terrain and get "filled" when the software tries to maintain the proper hydrological properties of the terrain by filling the sinks. On a regular DEM that is not preconditioned to location the terminals of the endorheic drainage systems, the endorheic watersheds are filled and merged with their neighboring watersheds, resulting in an erroneous delineation of the AOIs. Users can follow the instructions below to precondition the DEM. Users are expected to know ArcMap well enough to implement the procedures. Please contact your IT staff if you have any question on using ArcMap.

1) Create a new point shapefile in ArcCatalog using the same coordinate system as the DEM. You use the shapefile to keep track the lowest locations of all closed basins in your forecast areas.
2) Locate the lowest points of closed basins and create a point for each basin. You might want to add attribute to differentiate the lowest points of different closed basins.
3) Activate the Spatial Analyst extension in ArcMap and use the "Feature to Raster" tool in ArcToolbox to convert the shapefile to a raster grid. Set the output raster to have the same spatial extent and cell size as the DEM.
4) The output raster contains some cells with values and all other cells with a NODATA value. The next step is to use the "CON" (conditional) and ISNULL tools to change the NODATA value to 0 (zero) and other values to 1. If you use ArcGIS raster calculator, you should use the following syntax to generate the output.
   ```
   CON( ISNULL("pointgrid"), 0, 1)
   ```
5) Now you can use the SETNULL tool again to set the elevation on the DEM to NODATA at the lowest points of the closed basin. Assume the output of Step 4 is called "lowestp", the syntax is:
   ```
   SETNULL("lowestp" == 1, "dem")
   ```
6) You should verify the DEM is correctly conditioned. Add both the point shapefile and the DEM to ArcMap and zoom in to a selected point on the shapefile. Verify the value on that location is NODATA. After the verification, the DEM is ready for creating AOIs of these closed basins. Make sure you update the settings value in BAGIS and disable the snap feature when creating AOIs of closed watersheds.

Appendix A. Basin Analysis GIS (BAGIS) Input Data Dictionary

All GIS data collected and compiled for BAGIS are in the Albers Equal Area Conic Projection. The specific projection parameters are:

USA_Contiguous_Albers_Equal_Area_Conic_USGS_version

Projection: Albers
False_Easting: 0.000000
False_Northing: 0.000000
Central_Meridian: -96.000000
Standard_Parallel_1: 29.500000
Standard_Parallel_2: 45.500000
Latitude_Of_Origin: 23.000000
Linear Unit: Meter (1.000000)

Geographic Coordinate System: GCS_North_American_1983
Angular Unit: Degree (0.0174532925199433299)
Prime Meridian: Greenwich (0.000000000000000000)
Datum: D_North_American_1983
Spheroid: GRS_1980
Semimajor Axis: 6378137.000000000000000000
Semiminor Axis: 6356752.314140356100000000
Inverse Flattening: 298.257222101000020000

BAGIS Data Catalog

Data Name	Description	Data Type	Sources
Active COOP Sites	COOP Climate Stations	GIS Point	NWCC
Active/Inactive Snow Courses	Existing Snow Courses	GIS Point	NWCC
DEM 10 meters – Western US	USGS The National Elevation Dataset (NED) - 1/3 arc-second	GIS Grid/Raster	The National Map Seamless Server
DEM 30 meters - Alaska	ASTER Global Digital Elevation Map	GIS Grid/Raster	ASTER GDEM
DEM 30 meters - Canada	ASTER Global Digital Elevation Map	GIS Grid/Raster	ASTER GDEM
DEM 30 meters - Western US	USGS The National Elevation Dataset (NED) - 1 arc-second	GIS Grid/Raster	The National Map Seamless Server
Forest Density	Forest Density - From USGS Weasel	GIS Grid/Raster	NWCC
Forest Type / Land Cover	Forest Type - from USGS Weasel	GIS Grid/Raster	NWCC
HUC Basin Boundary	Hydrologic Unit Code Boundary	GIS Polygon	
Land Management: Federal	Federal lands/areas	GIS Polygon	The National Map Seamless Server
Land Management: Indian	Indian lands/areas	GIS Polygon	The National Map Seamless Server
Land Management: Wilderness	Wilderness lands/areas	GIS Polygon	The National Map Seamless Server
National Atlas - Roads	National Atlas Roads	GIS Line	The National Map Seamless Server
National Atlas - Streams	National Atlas Streams	GIS Polygon	The National Map Seamless Server
National Atlas - Waterbodies	National Atlas Waterbodies	GIS Polygon	The National Map Seamless Server
PRISM annual prcp & monthly prcp	800 meter precipitation data	GIS Grid/Raster	
SNOTEL sites - existing	Existing SNOTEL sites	GIS Point	NWCC
SNOTEL sites - Proposed	Proposed SNOTEL Sites	GIS Point	NWCC
Soil	Soil Data - from USGS Weasel	GIS Polygon	
USFS Service Roads	Service roads in National Forests	GIS Line	http://svinetfc4.fs.fed.us/vectorgateway/index.html
USGS Gauges (Forecast points)	USGS stream gauges	GIS Point	NWCC

Data Name: **DEM 10 Meters – Western US**
File Names: mtwy_10p, ndsd_10p, orwa_10p, se_10p, sw_10p (5 separate raster files)
File Folder: GIS\Static\10_meter
File Type: ESRI GRID
Geometry: Raster
Data Source: The National Map Seamless Server
Download URL: http://seamless.usgs.gov/index.php
Metadata URL: http://seamless.usgs.gov/index.php

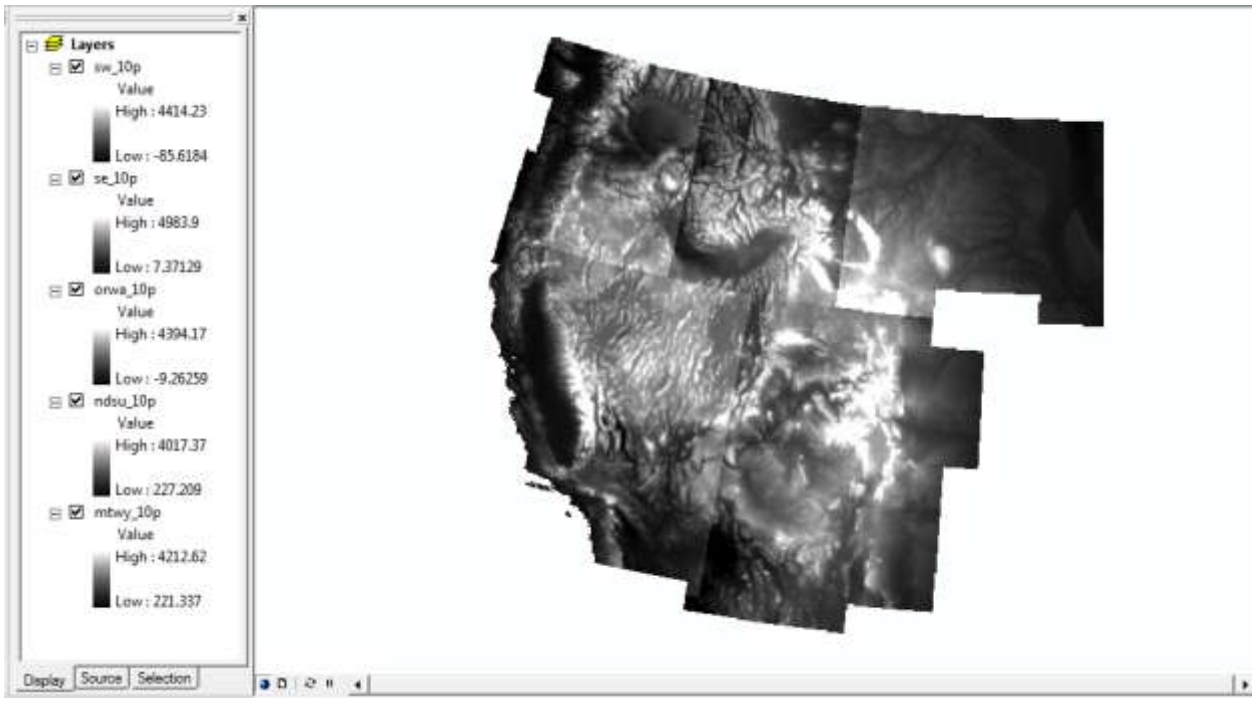
Processes:

1. Rasters downloaded by Lat Long from URL (1° x 1/2°)
2. Mosaicked into overlapping large raster datasets
3. Reprojected to USA_Contiguous_Albers_Equal_Area_Conic_USGS_version

Attributes:

This raster does not have an attribute table.

Thumbnail image:



Data Name: **DEM 30 meters – Alaska**
File Name: ak30_albers
File Folder: \Projects\NWCC\GIS\Static\AK_30_albers
File Type: ESRI GRID file
Geometry: Raster
Data Source: ASTER Global Digital Elevation Model (GDEM). ASTER GDEM is a product of METI and NASA.
Download URL: http://www.gdem.aster.ersdac.or.jp/search.jsp
Metadata URL: https://lpdaac.usgs.gov/lpdaac/products/aster_overview

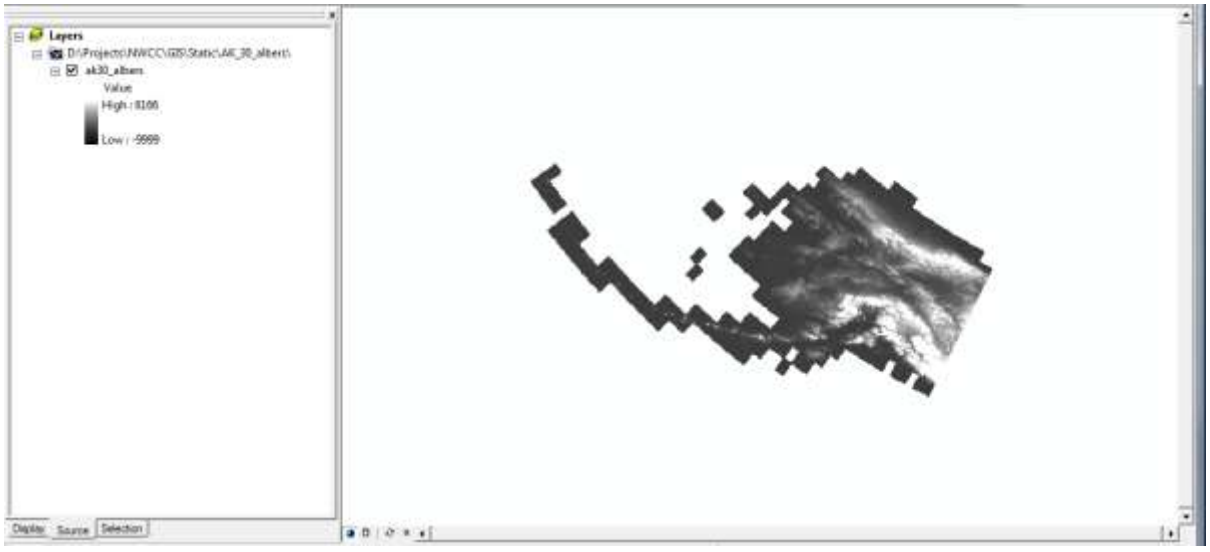
Processes:

1. Shapefiles downloaded from URL by LatLong tiles
2. GeoTIFF files unpacked using 7-Zip
3. GeoTIFF files transformed to .img format
4. GeoTIFF files mosaicked to single .img file
5. .img file transformed to GRID format
6. Reprojected to USA_Contiguous_Albers_Equal_Area_Conic_USGS_version

Attributes:

This raster does not have an attribute table.

Thumbnail image:



Data Name: **DEM 30 meters – Canada**
File Name: cdndem30_alb
File Folder: \Projects\NWCC\GIS\Static\CDNDEM_30_albers
File Type: ESRI GRID file
Geometry: Raster
Data Source: ASTER Global Digital Elevation Model (GDEM) - ASTER GDEM is a product of METI and NASA.
Download URL: http://www.gdem.aster.ersdac.or.jp/search.jsp
Metadata URL: https://lpdaac.usgs.gov/lpdaac/products/aster_overview

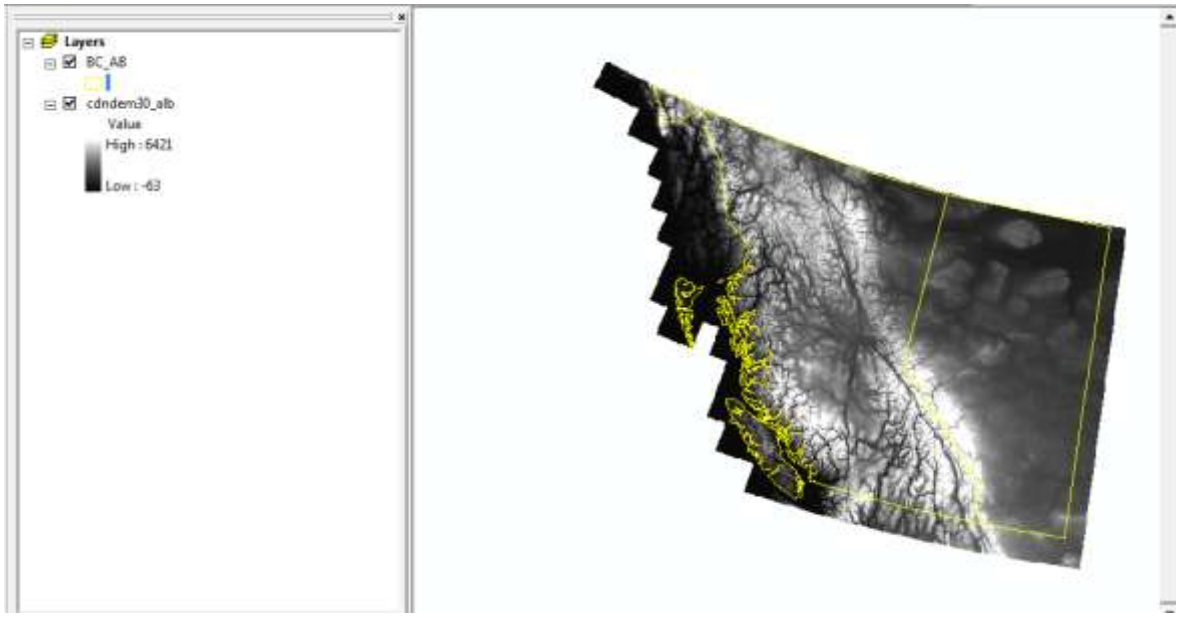
Processes:

1. Shapefiles downloaded from URL by LatLong tiles
2. GeoTIFF files unpacked using 7-Zip
3. GeoTIFF files transformed to .img format
4. GeoTIFF files mosaicked to single .img file
5. .img file transformed to GRID format
6. Reprojected to USA_Contiguous_Albers_Equal_Area_Conic_USGS_version

Attributes:

This raster does not have an attribute table.

Thumbnail image:



Data Name: **DEM 30 Meters – Western US**
File Names: westus_30
File Folder: GIS\Static\DEM\30MDEM\
File Type: ESRI GRID
Geometry: Raster
Data Source: The National Map Seamless Server
Download URL: http://seamless.usgs.gov/index.php
Metadata URL: http://seamless.usgs.gov/index.php

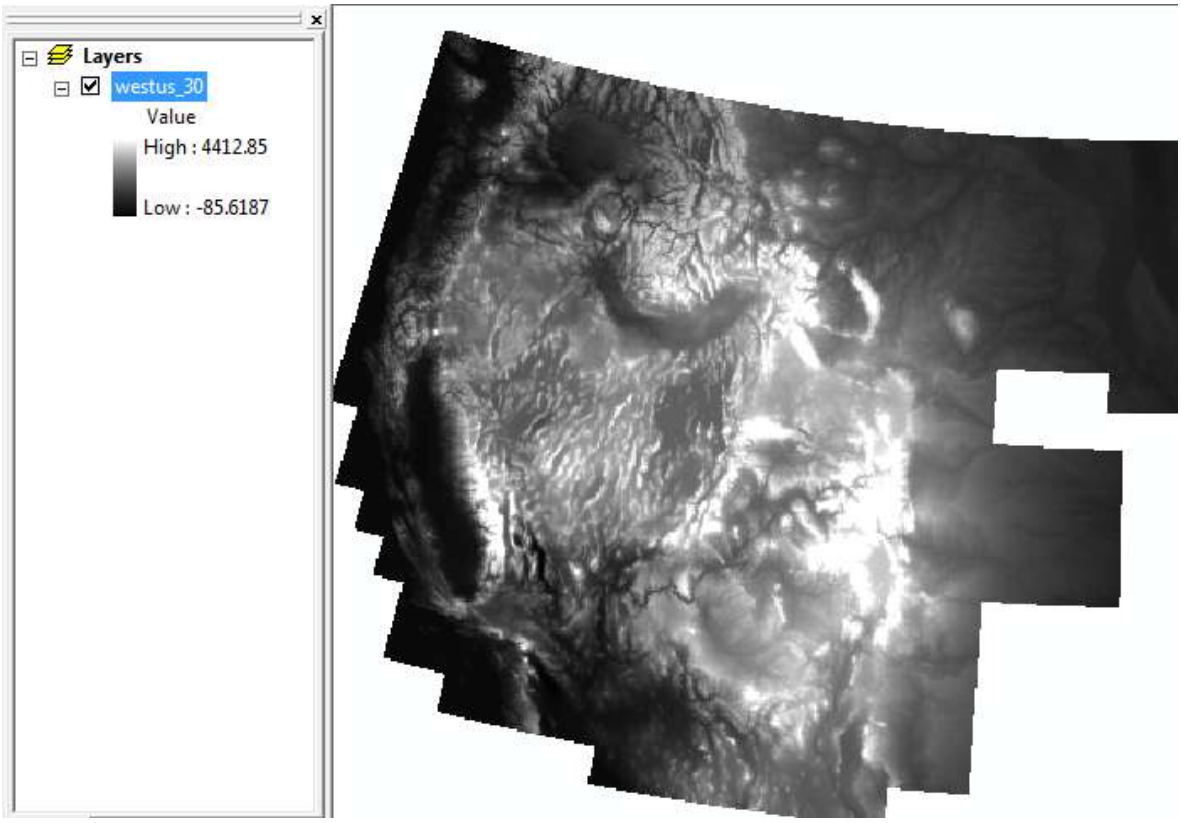
Processes:

1. Small rasters downloaded by Lat Long from URL
2. Mosaicked into single large raster dataset
3. Reprojected to USA_Contiguous_Albers_Equal_Area_Conic_USGS_version

Attributes:

This raster does not have an attribute table.

Thumbnail image:



Data Name: **Land Management - Federal Lands**
File Name: federal_lands_albers.shp
File Folder: \Projects\NWCC\GIS\Static\Supplemental
File Type: ESRI Shapefile
Geometry: Polygon
Data Source: The National Map Seamless Server
Download URL: http://seamless.usgs.gov/index.php
Metadata URL: http://seamless.usgs.gov/index.php

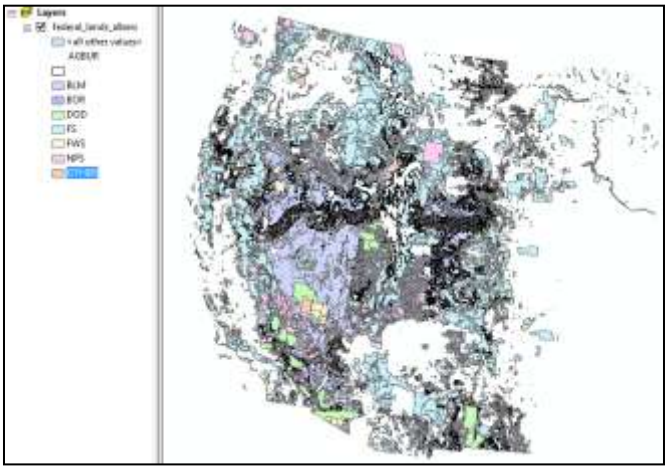
Processes:

1. Overlapping shapefiles downloaded from the URL
2. Merged downloaded shapefiles
3. Clipped to Western States Boundary
4. Reprojected to USA_Contiguous_Albers_Equal_Area_Conic_USGS_version

Attributes:

Field Name	Data Type (width)	Definition
FID	OID	Internal feature number
Shape	Geometry	Feature geometry
FEDLANP020	Number (9)	Internal feature number
FEATURE1	String (80)	**Primary or only type of Federal land and the owning agency**
FEATURE2	String (80)	Secondary type of Federal land and the owning agency
FEATURE3	String (80)	Tertiary type of Federal land and the owning agency
AGBUR	String (7)	Code for the owning or administering agency
URL	String (150)	Uniform Resource Locator
NAME1	String (80)	Name associated with Feature1
NAME2	String (80)	Name associated with Feature2
NAME3	String (80)	Name associated with Feature3
STATE	String (14)	Two-character State code
STATE_FIPS	String (14)	Two-character State code

Thumbnail image:



Data Name: **Land Management - Indian Lands**
File Name: indian_lands_albers.shp
File Folder: \Projects\NWCC\GIS\Static\Supplemental
File Type: ESRI Shapefile
Geometry: Polygon
Data Source: The National Map Seamless Server
Download URL: http://seamless.usgs.gov/index.php
Metadata URL: http://seamless.usgs.gov/index.php

Processes:

1. Overlapping shapefiles downloaded from the URL
2. Merged downloaded shapefiles
3. Clipped to Western States Boundary
4. Reprojected to USA_Contiguous_Albers_Equal_Area_Conic_USGS_version

Attributes:

Field Name	Data Type (width)	Definition
FID	OID	Internal feature number
Shape	Geometry	Feature geometry
INDLANP020	Number (9)	Internal feature number
FEATURE	String (80)	**Type of feature in the dataset**
ADMINISTRAT	String (5)	
NAME	String (80)	Name of the Indian reservation
STATE	String (14)	Two-character State code
STATE_FIPS	String (14)	Two-character State code

Thumbnail image:

Data Name: **Land Management - Wilderness**
File Name: wilderness_albers.shp
File Folder: \Projects\NWCC\GIS\Static\Supplemental
File Type: ESRI Shapefile
Geometry: Polygon
Data Source: The National Map Seamless Server
Download URL: http://seamless.usgs.gov/index.php
Metadata URL: http://seamless.usgs.gov/index.php

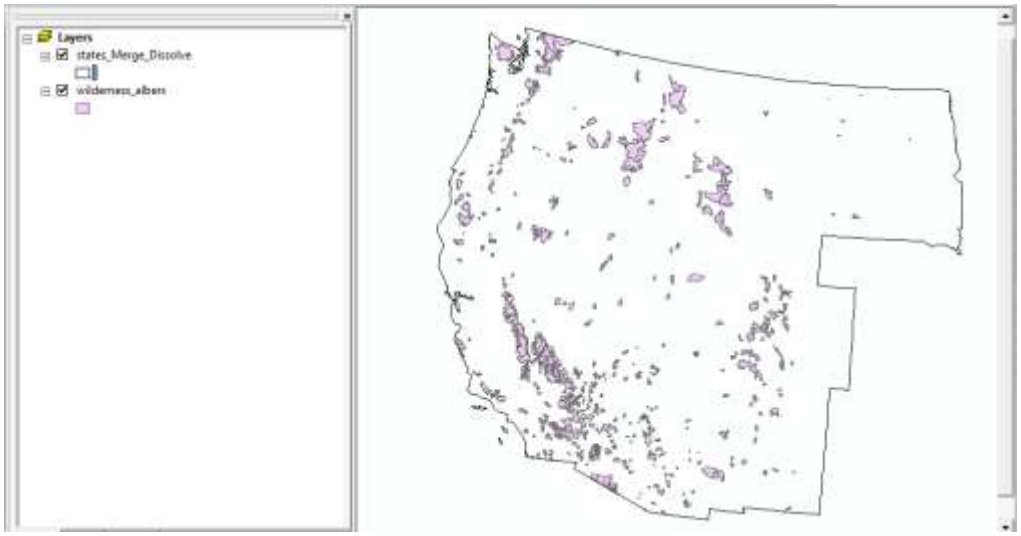
Processes:

1. Overlapping shapefiles downloaded from the URL
2. Merged downloaded shapefiles
3. Clipped to Western States Boundary
4. Reprojected to USA_Contiguous_Albers_Equal_Area_Conic_USGS_version

Attributes:

Field Name	Data Type (width)	Definition
FID	OID (4)	Internal feature number
Shape	Geometry	Representation of entry in the data
WILDRNP020	Number (9)	Internal feature number
FEATURE1	String (80)	Indication of primary feature type
FEATURE2	String (80)	Indication of secondary feature type
AGBUR	String (7)	Code for owning or administering agency
URL	String (150)	Uniform Resource Locator
NAME	String (80)	Name of the wilderness area
STATE	String (14)	Two-character state code
STATE_FIPS	String (14)	Two-character FIPS state code

Thumbnail image:



Data Name: **National Atlas - Roads**
File Name: roads_albers.shp
File Folder: \Projects\NWCC\GIS\Static\Supplemental
File Type: ESRI Shapefile
Geometry: Polyline
Data Source: The National Map Seamless Server
Download URL: http://seamless.usgs.gov/index.php
Metadata URL: http://seamless.usgs.gov/index.php

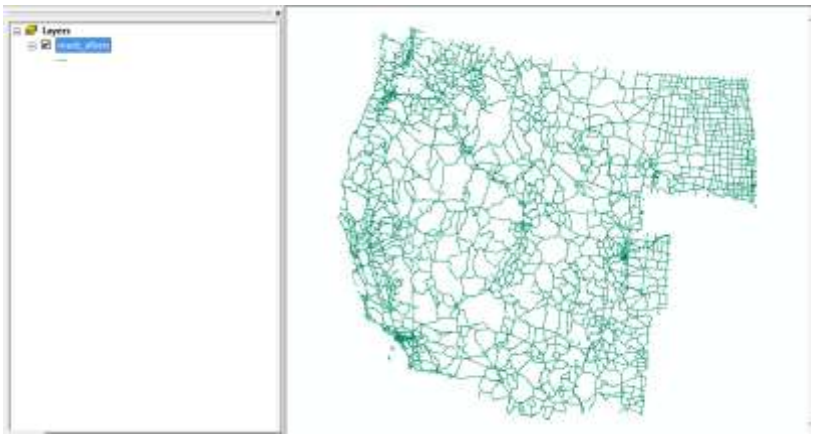
Processes:

1. Overlapping shapefiles downloaded from the URL
2. Merged downloaded shapefiles
3. Clipped to Western States Boundary
4. Reprojected to USA_Contiguous_Albers_Equal_Area_Conic_USGS_version

Attributes:

Field Name	Data Type (width)	Definition
FID	OID (4)	Internal feature number
Shape	Geometry	Feature geometry
FNODE_	Number (11)	Internal number of the from-node
TNODE_	Number (11)	Internal number of the to-node
LPOLY_	Number (11)	**Internal number of the polygon to the left of the arc**
RPOLY_	Number (11)	**Internal number of the polygon to the right of the arc**
LENGTH	Number (18)	**length of the arc in coverage units**
ROADTRL020	Number (11)	Internal feature number
FEATURE	String (80)	**Type of road**
NAME	String (120)	Name of the road
STATE	String (2)	Two-character FIPS state code
STATE_FIPS	String (2)	Two-character FIPS state code

Thumbnail image:



Data Name: **National Atlas - Streams**
File Name: streams_albers.shp
File Folder: \Projects\NWCC\GIS\Static\Supplemental
File Type: ESRI Shapefile
Geometry: Polyline
Data Source: The National Map Seamless Server
Download URL: http://seamless.usgs.gov/index.php
Metadata URL: http://seamless.usgs.gov/index.php

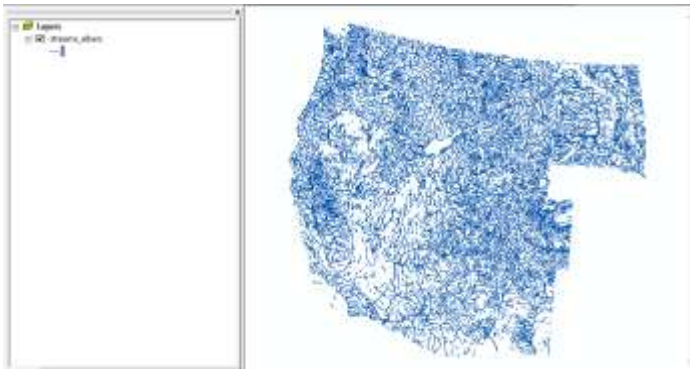
Processes:

1. Overlapping shapefiles downloaded from the URL
2. Merged downloaded shapefiles
3. Clipped to Western States Boundary
4. Reprojected to USA_Contiguous_Albers_Equal_Area_Conic_USGS_version

Attributes:

Field Name	Data Type (width)	Definition
FID	OID (4)	Internal feature number
Shape	Geometry	Feature geometry
FNODE_	Number (9)	Internal number of the from-node
TNODE_	Number (9)	Internal number of the to-node
LPOLY_	Number (9)	**Internal number of the polygon to the left of the arc**
RPOLY_	Number (9)	**Internal number of the polygon to the right of the arc**
LENGTH	Number (19)	**length of the arc in coverage units**
HYDROGM020	Number (9)	Internal feature number
FEATURE	String (80)	**Type of stream**
F_CODE	Number (2)	Feature code for type of stream
NAME	String (80)	Name of the water feature
STATE	String (5)	Two-character state code
STATE_FIPS	String (5)	Two-character FIPS state code
NAME_UC	String (80)	Upper-case name of the water feature

Thumbnail image:



Data Name: **National Atlas - Water Bodies**
File Name: waterbodies_albers.shp
File Folder: \Projects\NWCC\GIS\Static\Supplemental
File Type: ESRI Shapefile
Geometry: Polygon
Data Source: The National Map Seamless Server
Download URL: http://seamless.usgs.gov/index.php
Metadata URL: http://seamless.usgs.gov/index.php

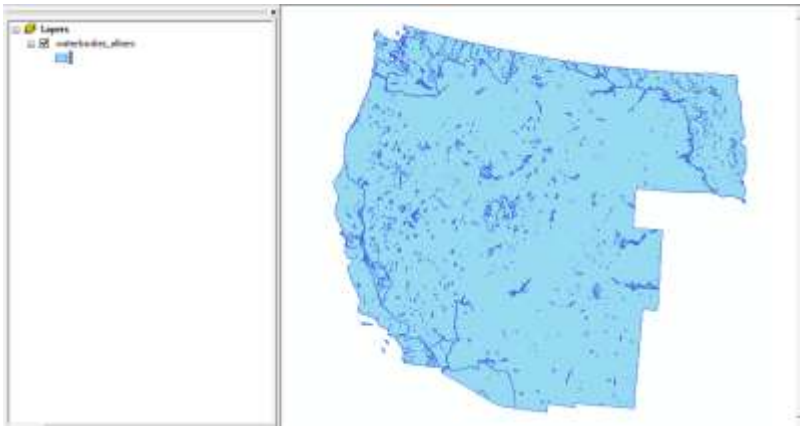
Processes:

1. Overlapping shapefiles downloaded from the URL
2. Merged downloaded shapefiles
3. Clipped to Western States Boundary
4. Reprojected to USA_Contiguous_Albers_Equal_Area_Conic_USGS_version

Attributes:

Field Name	Data Type (width)	Definition
FID	OID (4)	Internal feature number
Shape	Geometry	Representation of entry in the data
HYDROGM020	Number (9)	Internal feature number
FEATURE	String (80)	**Type of water body**
F_CODE	Number (2)	Feature code for type of water body
NAME	String (80)	Name of the water feature
STATE	String (20)	Two-character state code
STATE_FIPS	String (20)	Two-character FIPS state code
NAME_UC	String (80)	Upper-case name of the water feature
WILDRNP020	Number (9)	Internal feature number
FEATURE1	String (80)	Indication of primary feature type
FEATURE2	String (80)	Indication of secondary feature type
AGBUR	String (7)	Code for owning or administering agency
URL	String (150)	Uniform Resource Locator

Thumbnail image:



Data Name: **USFS Service Roads**

File Name: FSRoads_Albers.shp
File Folder: Projects\NWCC\GIS\Static\Supplemental\FSRoads
File Type: ESRI shape file
Geometry: Lines
Data Source: FSGeodata Clearinghouse
Download URL: http://svinetfc4.fs.fed.us/vectorgateway/index.html
Metadata URL: http://svinetfc4.fs.fed.us/metadatagateway/explorer.jsp

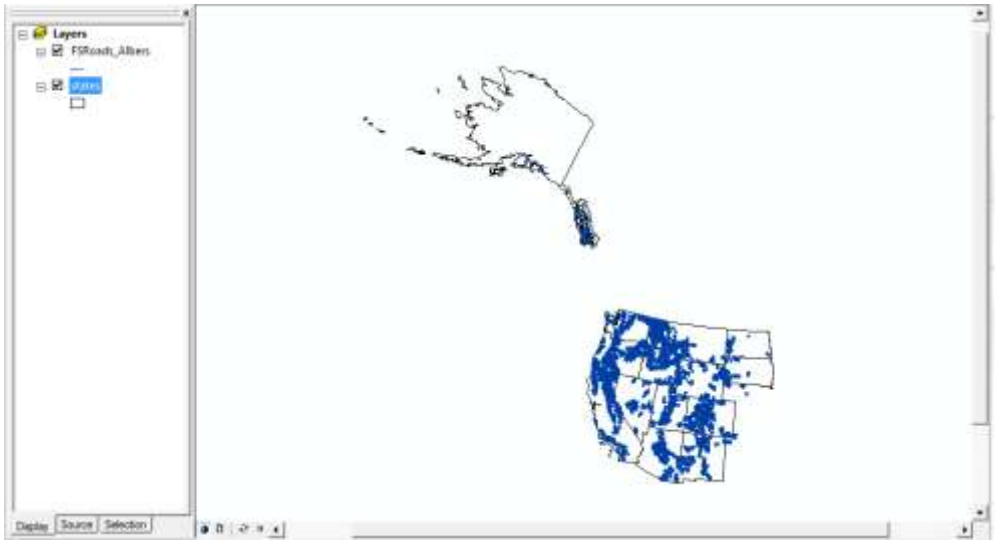
Processes:

1. Overlapping shapefiles downloaded from URL by manually selected extent
2. Shapefiles unpacked using 7-Zip
3. Merged individual shapefiles into single shapefile
4. Reprojected to USA_Contiguous_Albers_Equal_Area_Conic_USGS_version with a geographic transformation from NAD_1927_CGQ77 to NAD_1983_2

Attributes:

Field Name	Data Type (width)	Definition
FID	OID (4)	Object ID
Shape	Geometry	
CFF1 ~ CFF10	Numeric (9)	Feature Description
SECOORD	Numeric (9)	
CFF_ID	Numeric (9)	
CFF_ID_1	Numeric (19)	
CFF	Numeric (4)	Cartographic Feature File

Thumbnail image:



Appendix B. Table columns in Excel spreadsheets generated in Basin Analysis

Spreadsheet Name: **Aspect**

Field Name	Data Type	Description
DIRECTION	Number	Aspect direction code (corresponding to the DIRECTION text)
DIRECTION	Text	Text of 16 aspect directions and Flat
COUNT	Number	Number of raster cells within each aspect direction
AREA	Number	Area (square meters) within each aspect direction
MIN	Number	Minimum aspect (degree – 0 for due north)
MAX	Number	Maximum aspect (degree – 0 for due north)
RANGE	Number	Range of aspect (degree – 0 for due north)
MEAN	Number	Average aspect (degree – 0 for due north)
STD	Number	Standard deviation of aspect (degree – 0 for due north)
SUM	Number	Sum of aspect of all the cells in the interval (degree)
%_AREA	%	Percentage of area of aspect directions

Spreadsheet Name: **Area Elevations**

Field Name	Data Type	Description
VALUE	Number	Upper bound of elevation intervals in feet or meters
COUNT	Number	Number of raster cells within each elevation interval
AREA	Number	Area (square meters) within each elevation interval
MIN	Number	Minimum elevation (feet or meters)
MAX	Number	Maximum elevation (feet or meters)
RANGE	Number	Range of elevation (feet or meters)
MEAN	Number	Average elevation (feet or meters)
STD	Number	Standard deviation
SUM	Number	Total elevation of all the cells in the interval
%_AREA	%	Percentage of area of the interval in AOI
%_AREA_ELV	%	Cumulative percentage of area
LABEL	Text	Label of the elevation interval

Spreadsheet Name: **Elevation Curve**

See **Area Elevations**.

Spreadsheet Name: **Elevation Range**

Field Name	Data Type	Description
VALUE	Number	Upper bound of elevation intervals in feet or meters
COUNT	Number	Number of raster cells within each elevation interval
AREA	Number	Area (square meters) within each elevation interval
MIN	Number	Minimum elevation (feet or meters)
MAX	Number	Maximum elevation (feet or meters)
RANGE	Number	Range of elevation (feet or meters)
MEAN	Number	Average elevation (feet or meters)
STD	Number	Standard deviation
SUM	Number	Total elevation of all the cells in the interval
%_AREA	%	Percentage of area of the interval in AOI
C%_AREA	%	Cumulative percentage of area
LABEL	Text	Label of the elevation interval

Spreadsheet Name: **PRISM**

Field Name	Data Type	Description
VALUE	Number	Upper bound of elevation interval in feet or meters
COUNT	Number	Number of raster cells within each elevation interval
AREA	Number	Area (square meters) within each elevation interval
MIN	Number	Minimum precipitation (inches)
MAX	Number	Maximum precipitation (inches)
RANGE	Number	Range of precipitation (inches)
MEAN	Number	Average precipitation (inches)
STD	Number	Standard deviation of precipitation (inches)
SUM	Number	Total precipitation of all the cells in the interval (inches)
%_AREA	%	Percentage of area of the interval
LABEL	Text	Label of the elevation interval (feet or meters)
AREA_DEM	Number	Area (square meters) within each elevation interval derived from the elevation raster (instead of the PRISM raster)
%_AREA_DEM	%	Percentage of area of the interval based on AREA_DEM
VOL_ACRE_FT	Number	Precipitation volume (Acre-feet) in elevation interval
%_VOL	%	Percentage of precipitation volume

Spreadsheet Name: **PRISM Range**

Field Name	Data Type	Description
VALUE	Number	Upper bound of elevation interval in feet or meters
COUNT	Number	Number of raster cells within each elevation interval
AREA	Number	Area (square meters) within each elevation interval
MIN	Number	Minimum precipitation (inches)
MAX	Number	Maximum precipitation (inches)
RANGE	Number	Range of precipitation (inches)
MEAN	Number	Average precipitation (inches)
STD	Number	Standard deviation of precipitation (inches)
SUM	Number	Total precipitation of all the cells in the interval (inches)
%_AREA	%	Percentage of area of the interval
LABEL	Text	Label of the elevation interval (feet or meters)
AREA_DEM	Number	Area (square meters) within each elevation interval derived from the elevation raster (instead of the PRISM raster)
%_AREA_DEM	%	Percentage of area of the interval based on AREA_DEM
VOL_ACRE_FT	Number	Precipitation volume (Acre-feet) in elevation interval
%_VOL	%	Percentage of precipitation volume

Spreadsheet Name: **Slope**

Field Name	Data Type	Description
SLOPE	Text	Text of percentage slope intervals
COUNT	Number	Number of raster cells within each slope interval
AREA	Number	Area (square meters) within each slope interval
MIN	Number	Minimum slope (%)
MAX	Number	Maximum slope (%)
RANGE	Number	Range of slope (%)
MEAN	Number	Average slope (%)
STD	Number	Standard deviation of slope (%)
SUM	Number	Sum of slope of all the cells in the interval (%)
%_AREA	%	Percentage of area of the interval

Spreadsheet Name: **SNOTEL**

Field Name	Data Type	Description
VALUE	Number	elevation of sites
COUNT	Number	Number of raster cells between the site(s) and its next lower site(s) (unit in feet of meters)
AREA	Number	Area (square meters)
MIN	Number	Next lower elevation of the site(s) (feet or meters)
MAX	Number	Elevation of the site(s) (feet or meters)
RANGE	Number	Elevation difference between the site(s) and the next lower site(s) (feet or meters)
MEAN	Number	Average elevation (feet or meters)
STD	Number	Standard deviation (feet or meters)
SUM	Number	Total elevation of all the cells
%_AREA	%	Percentage of area covered the site(s) and the next lower site(s)
%_AREA_ELV	%	Cumulative percentage of area
LABEL	Text	Label of site name(s)

Spreadsheet Name: **SNOTEL Range**

See **SNOTEL**.

Spreadsheet Name: **Snow Course**

See **SNOTEL**.

Spreadsheet Name: **Snow Course Range**

See **SNOTEL**.

Appendix C. Excel Charts Generated in BAGIS.

Chart Name	*Type*	*Description*
Area Elevation	Scatter plot	Cumulative % area against elevation

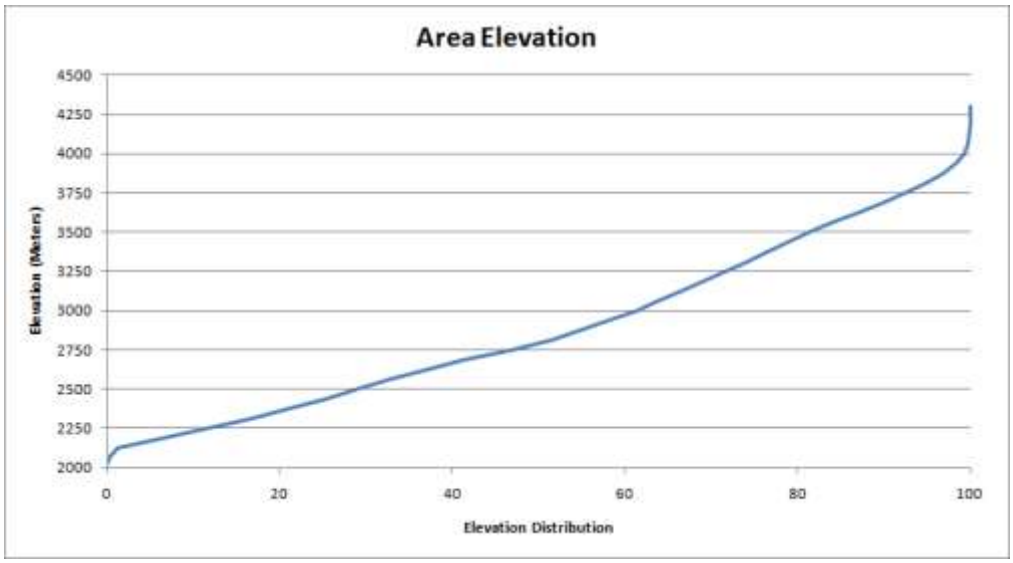


Chart Name	*Type*	*Description*
Precipitation Distribution	Scatter plot	% precipitation volume against elevation, superimposed by Area Elevation Chart

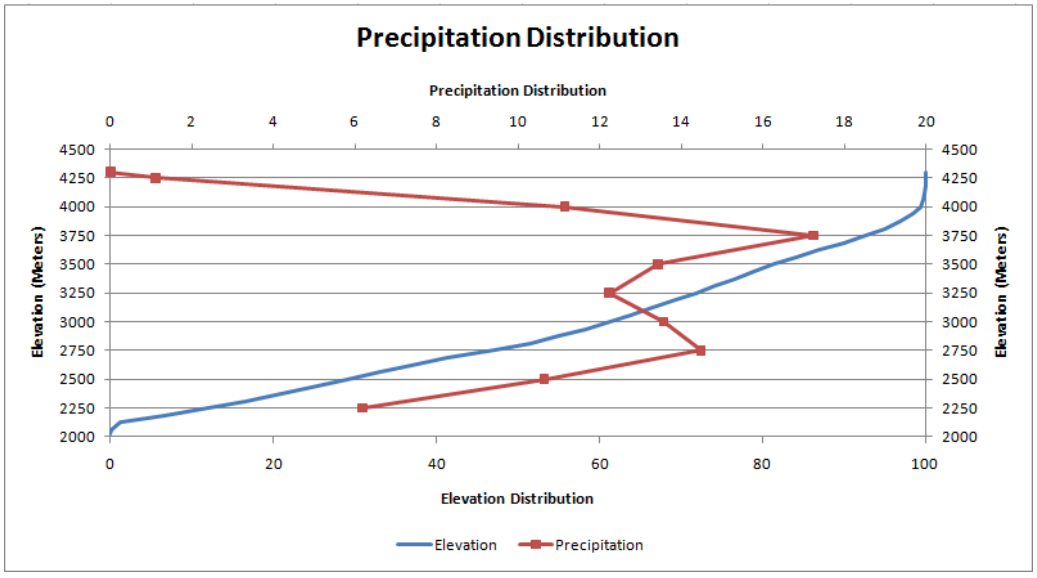


Chart Name	*Type*	*Description*
Precipitation Distribution (combined with SNOTEL and Snow Course)	Scatter plot	% precipitation volume against elevation, superimposed by Area Elevation, SNOTEL, and Snow Course Charts

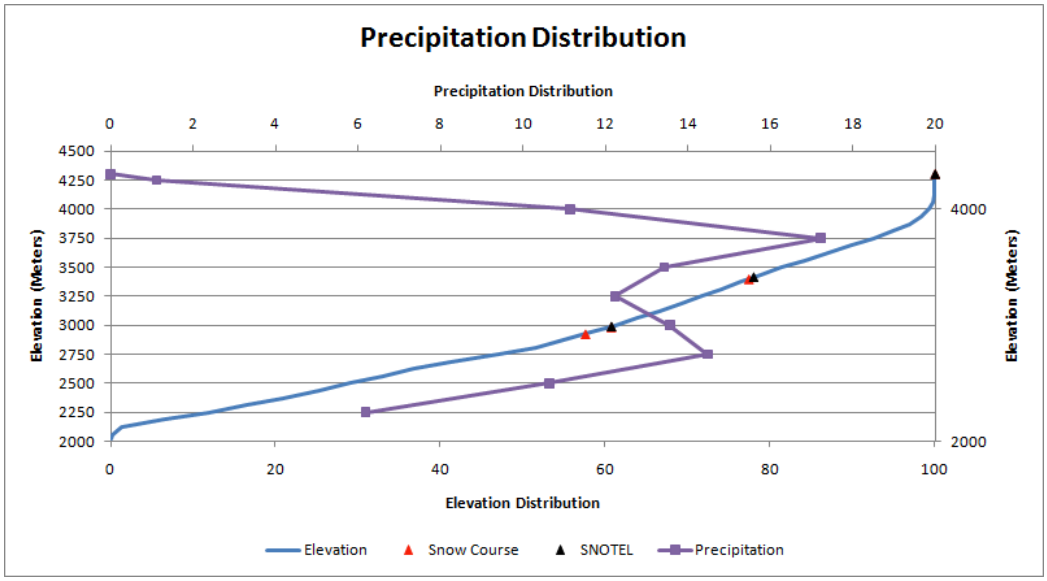


Chart Name	*Type*	*Description*
SNOTEL	Scatter plot	Cumulative % area against elevation of SNOTEL, superimposed by Area Elevation Chart

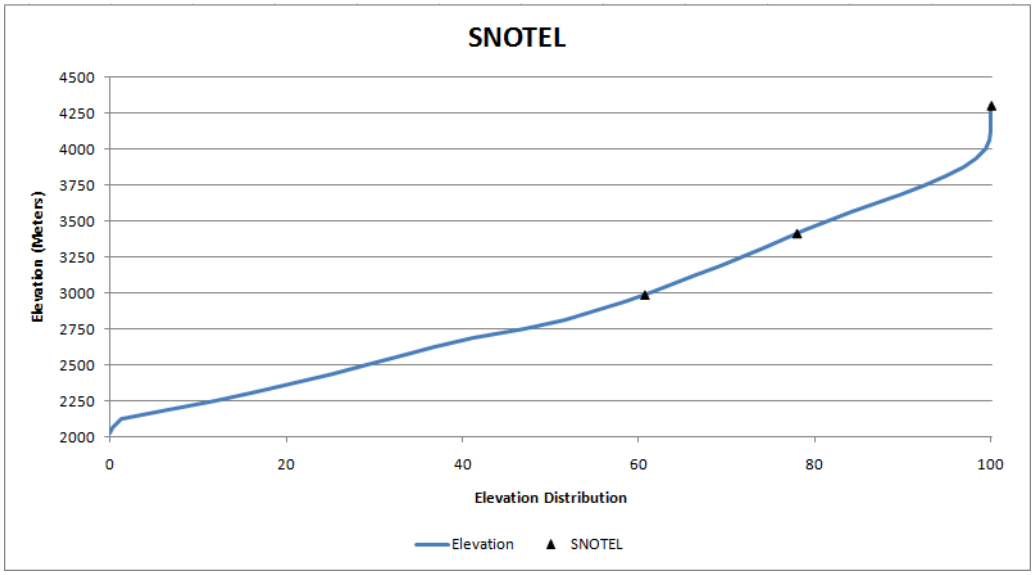


Chart Name	*Type*	*Description*
Snow Course	Scatter plot	Cumulative % area against elevation of Snow Course, superimposed by Area Elevation Chart

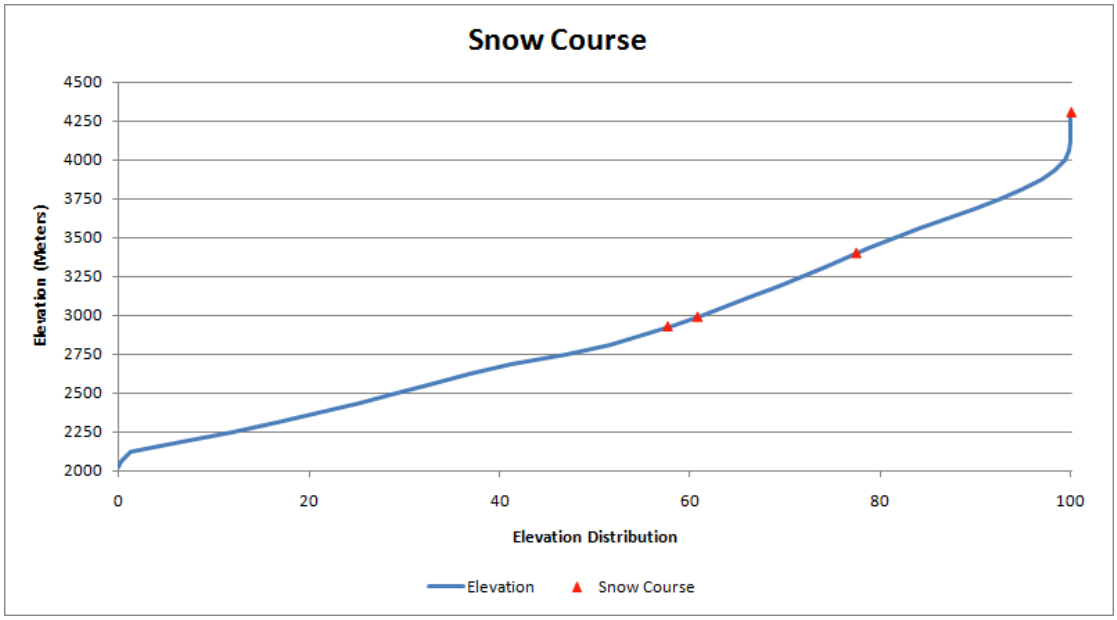


Chart Name	*Type*	*Description*
Slope Distribution	Histogram	% area of each slope interval

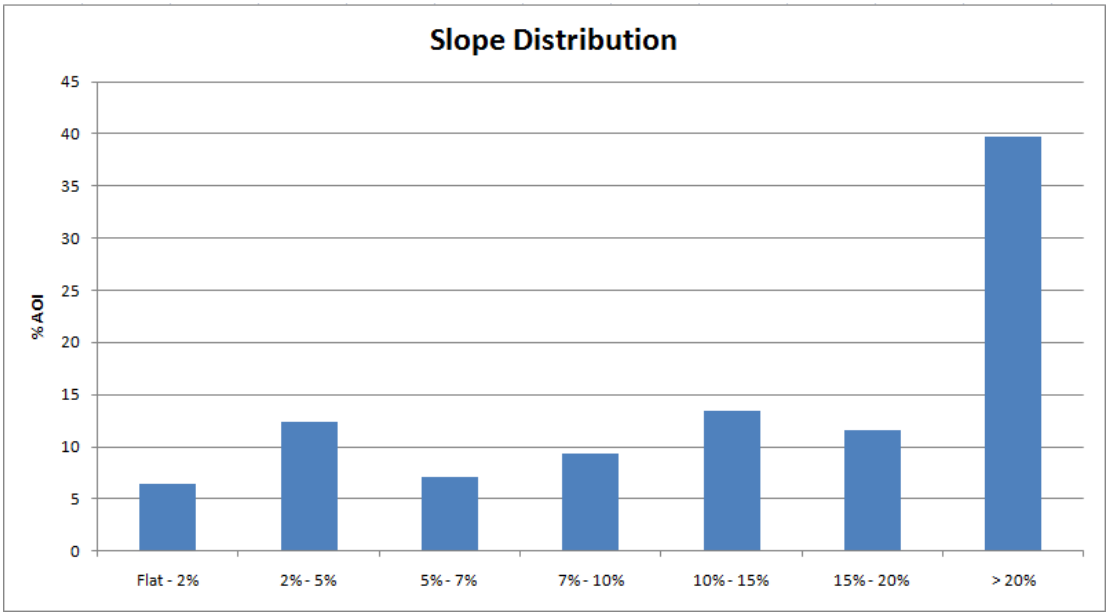


Chart Name	*Type*	*Description*
Aspect Distribution	Histogram	% area of each aspect direction