

The Geomorphic Road Analysis and Inventory Package (GRAIP)

Volume 2: Office Procedures

Addendum for GRAIP 1.0.9

Richard M. Cissel, Thomas A. Black, Kimberly A. T. Schreuders, Ajay Prasad, Charles H. Luce, David G. Tarboton, and Nathan A. Nelson

2014 Update

Combined Stability Index

Inputs

Drain Point Shapefile
C:\WorkSpace\BBS\Scratch\workspace\walloowateest\Control10m\Shapefiles\DrainPoints.shp

Select Drain Point Types
Check drain point types where road drainage should be added to recharge for combined stability index computation.

Broad base dip Stream Crossing
 Diffuse drain Sump
 Ditch relief Water bar
 Lead off
 Non-engineered

Specify Road Width (m)
5

Calibration Parameters Text File
C:\WORKSPACE\BBS\SCRATCH\WORKSPACE\WALLOOWATEEST\CONTROL10M\Gids\workspace ...
View/Edit Calibration Parameter File

Minimum Terrain Recharge (m/hr) 0.0009 Maximum Terrain Recharge (m/hr) 0.00135
Minimum Additional Road Surface Runoff (m/hr) 0.001 Maximum Additional Road Surface Runoff (m/hr) 0.002

Dirt Slope
C:\WORKSPACE\BBS\SCRATCH\WORKSPACE\WALLOOWATEEST\CONTROL10M\Gids\workspace ...

Dirt Specific Catchment Area
C:\WORKSPACE\BBS\SCRATCH\WORKSPACE\WALLOOWATEEST\CONTROL10M\Gids\workspace ...

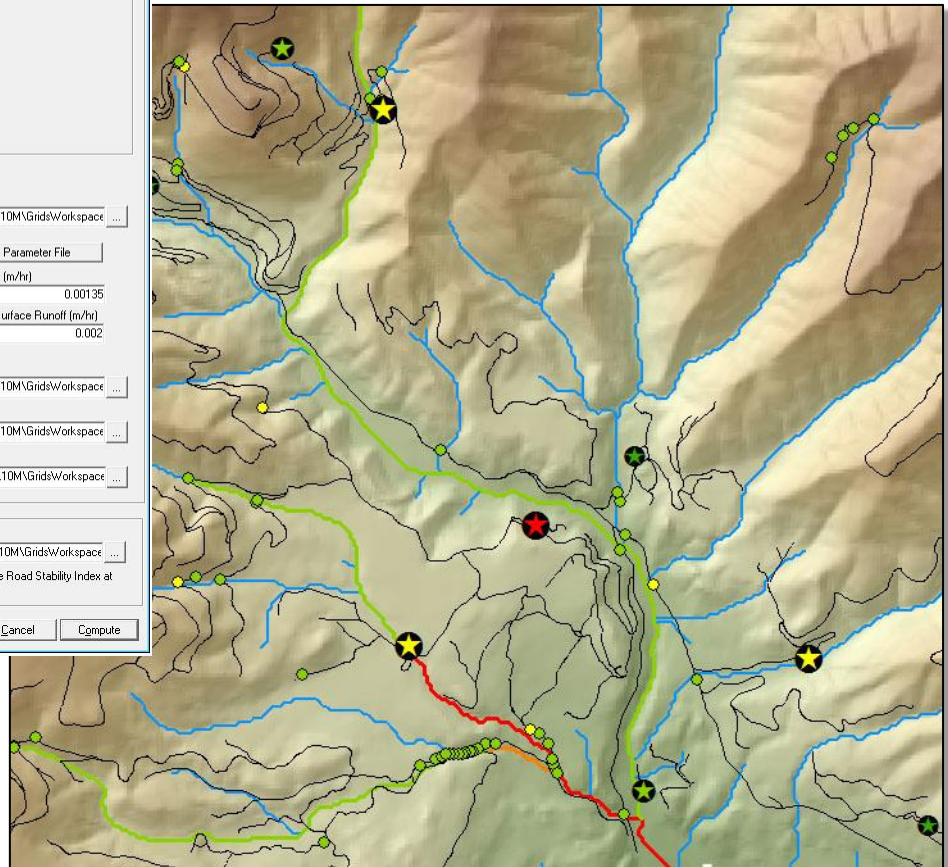
Calibration Grid
C:\WORKSPACE\BBS\SCRATCH\WORKSPACE\WALLOOWATEEST\CONTROL10M\Gids\workspace ...

Outputs
Combined Stability Index Grid
C:\WORKSPACE\BBS\SCRATCH\WORKSPACE\WALLOOWATEEST\CONTROL10M\Gids\workspace ...

The field SIR is appended to the attribute table of the Drain Point shapefile with the Road Stability Index at each drain point estimated from SINMAP output.

Add SI combined grid to the Map

Cancel Compute



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Current as of March 17, 2014
For GRAIP v. 1.0.9 and field data dictionary INVENT 5.0

Support

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Table of Contents

INTRODUCTION	1
SECTION I: ABOUT GRAIP 1.0.9	1
What Has Changed?.....	1
Minor Changes to Processes	2
Changes to the Manual Text and Figures	5
SECTION II: REPLACEMENT INSTRUCTIONS.....	7
Preprocessing Shapefiles	7
Running TauDEM.....	15
Mass Wasting Potential Analysis.....	21
Appendix D: Attribute Table Field Name Explanations.....	35
Release Notes	37
References.....	38

INTRODUCTION

This update to GRAIP 1.0.9 addresses a number of concerns with GRAIP 1.0.8. There were some issues that resulted in slightly inaccurate modeling results or the addition of extra steps to the process. If you are comparing data that you modeled with GRAIP 1.0.8 to newer data that will be modeled with GRAIP 1.0.9, then you should re-run the GRAIP 1.0.8 data with the updated version of GRAIP. Changes made are not expected to significantly affect model results, however, so there may not be a need to update old data that is not being used for comparison with new data.

GRAIP 1.0.9 is compatible with Windows 7, as well as previous versions at least as old as Windows XP. However, it is not compatible with ArcGIS 10, and requires ArcGIS 9 (9.3.1 is the most recent). GRAIP is written in the Visual Basic language, which is not compatible with ArcGIS 10. In order to update GRAIP to run in the current version of ArcGIS, the program will need to be re-written in another programming language; this update is expected to be available late in 2014 or in 2015.

The purpose of this Addendum is to address and explain these changes (Section I: About GRAIP 1.0.9), and to update the GRAIP office manual (Cissel et al. 2012) where there are new processes or significant changes to old processes (Section II: Replacement Instructions). In addition to a detailed explanation of the changes made, Section I covers some other minor updates to processes and additional information not covered in the GRAIP office manual. The instructions in Section II should be used in place of those in the office manual.

SECTION I: ABOUT GRAIP 1.0.9

This section discusses the changes made to GRAIP in detail, presents a brief how-to for avoiding the use of Hawth's Tools, which is defunct, discusses DEMs in more detail than is present in the office manual, and addresses how to integrate this information with that available in the office manual.

What Has Changed?

There were a number of changes made with the update to GRAIP 1.0.9, both to increase usability and to correct some program errors. Perhaps the most substantial, the way in which the range of a road line is calculated (that is, *length × slope*), which is used in the calculation of sediment production for each road segment, has been changed so that it is more accurate. Previously, this function referred to ArcGIS Zonal Statistics to find the range, which uses the minimum and maximum elevation values along the road. The change was made so that GRAIP now calculates the range based on the DEM cell value at the end points of each road line segment, independently of Zonal Statistics. This results in a more realistic range for the road lines. There are no changes to the procedure that result from this.

The next major change is to the method in which the *Combined Stability Index* function works. Previously, this function included water that drained to stream crossings and diffuse points when it modeled the risk of shallow landslides due to roads. Since these drain points do not behave in the same way as the others when it comes to landslides, there was a complicated set of steps that had to be performed to remove the water that drained to those points from consideration. The *Combined Stability Index* function has been modified so that the user can choose which drain points to include, and stream crossings (regular and excavated) and diffuse points are excluded by default. This saves a lot of time, and the simplified process is included in this Addendum (Section II).

The other changes to the model were:

- A modification to the sediment routing in streams to fix the error where sediment may have been routed upstream on some flat slope stream segments.
- A change to the *Stream Blocking Index* (SBI) function so that only culverts (steel, aluminum, plastic, cement, etc.) are now included in the calculation of SBI, and bridges, fords, and log culverts are excluded.
- The specific sediment (*SpecSed* in the stream network shapefile) is now calculated correctly, using sediment accumulation (*SedAccum*) converted to Mg and downstream contributing area (*DS_Cont_Ar*) converted to km².
- An improvement to the resampling method used in the *Resample DEM* step so that it now uses the cubic convolution method instead of the nearest neighbor method.
- The addition of the discharge location to the DrainPoints shapefile (the *DischargeT* field).

Each of these do not require any change to the procedure. Finally, an overland flow distance from the drain point to the closest stream field has been added to the DrainPoints shapefile (in m; *DistToStre*). This requires an extra step be taken when TauDEM is run, and that section has been updated and included in Section II.

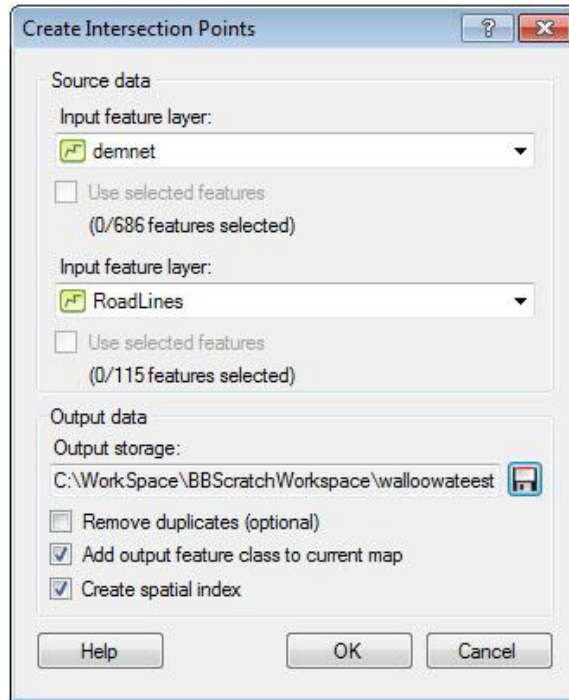
Minor Changes to Processes

Previously, GRAIP has depended on Hawth's Tools to generate outlet points at road-stream intersections in order to split the stream lines at the intersections so that sediment is not routed upstream of the road. Hawth's has been out of date for a number of years, and its replacement does not have the same functionality. There are two methods that can be used to generate the Outlets shapefile. These instructions apply to the *Preprocessing* section of the office manual, starting on p.89.

First, you can use XTools Pro, which has a license available for Forest Service computers, but otherwise is not free, and has a function that will do this in one step.

1. In the XTools toolbar, click the *XTools Pro* drop-down -> *Layer Operations*-> *Create Intersection Points*

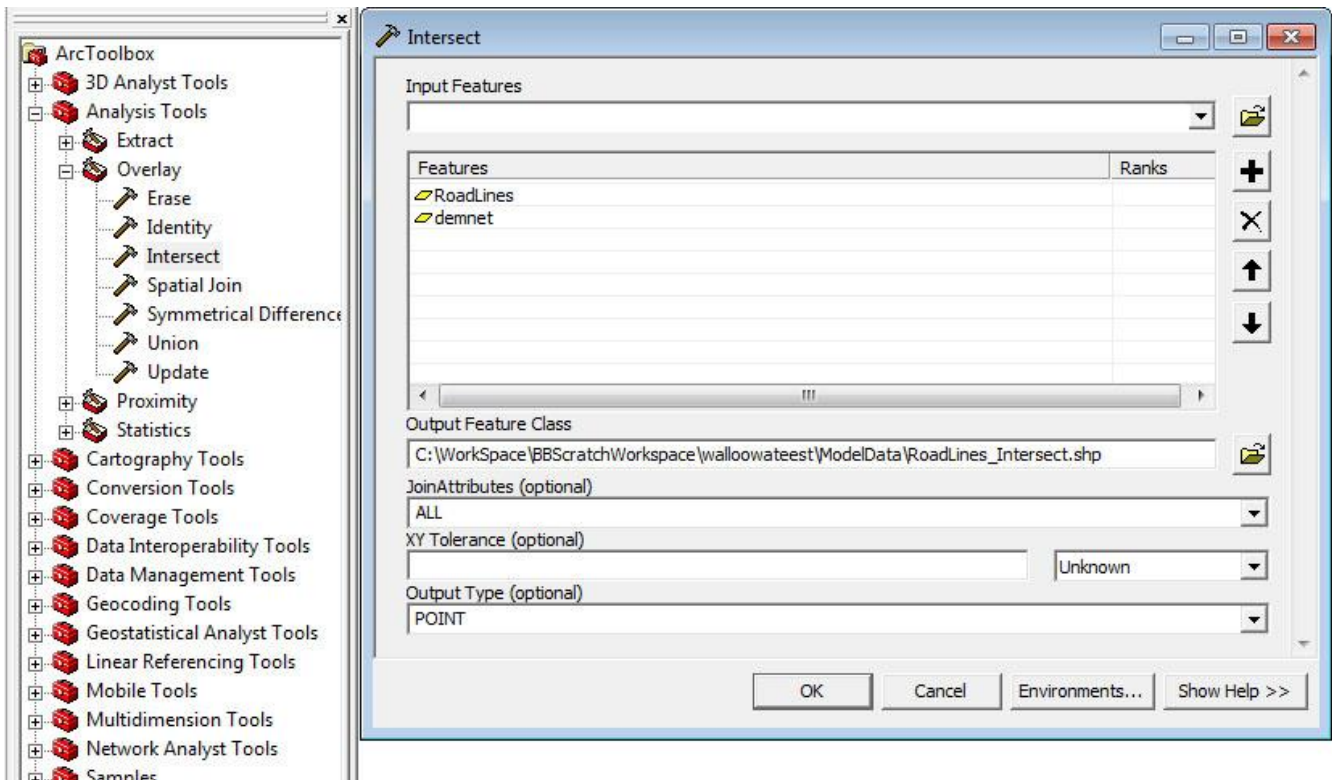
- a. Under the *Input feature layer* drop-downs, specify the RoadLines and demnet shapefiles.



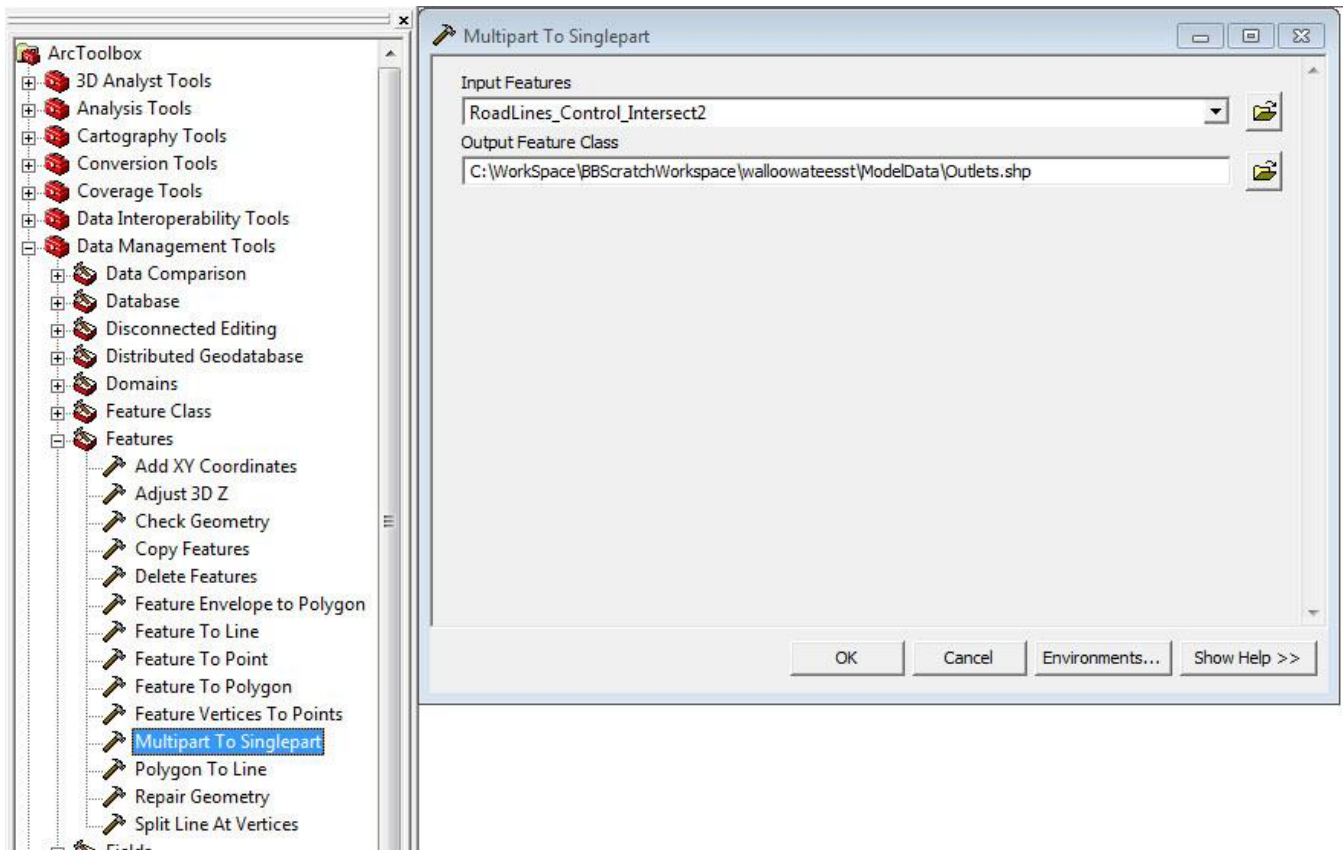
- b. Under the *Output storage* field, click the disk symbol and select where you want to save the outlets shapefile, and name it *Outlets.shp*.
- c. Leave everything else as the default.
- d. When the dialog box pops up to notify you that the function has completed, click *OK*.

Second, there are two steps in ArcToolbox that can be run consecutively. This method may be faster for large datasets.

1. In ArcToolbox, click *Analysis Tools-> Overlay -> Intersect*
 - a. Under the *Input Features* drop-down menu, select the RoadLines shapefile and then the demnet shapefile.
 - b. Ensure that the *Output Feature Class* is pointed at the correct workspace; you can leave this shapefile named as the default.
 - c. Under *Output Type (optional)*, select *POINT*.
 - d. Leave everything else as the default.
 - e. Click *OK*.



2. Still in ArcToolbox, navigate to *Data Management-> Features-> Multipart To Singlepart*



- a. Under *Input Features*, select the shapefile you created in step 1.
 - b. Under *Output Features*, ensure that the new shapefile will be saved to the correct workspace, and rename it *Outlets.shp*.
3. Click *OK*.
 4. You can delete the shapefile that was created during step 1.

The DEM that you use has an effect on the data outputs. The National Map website is currently the main easy source for DEMs for anywhere in the United States. DEMs downloaded from the National Map are in one degree blocks, projected into the GCS North American NAD83 coordinate system, and are in decimal degrees (as opposed to meters). For most locations, there are multiple options for the resolution of the DEM. One arc second corresponds to about 30 m, depending on latitude, and most DEMs were created as one arc second natively. This is the best resolution to use most of the time. If your watershed overlaps more than one of these one-degree blocks, you will need to mosaic those DEMs using the *Mosaic To New Raster* function under ArcToolbox-> *Data Management Tools*-> *Raster*-> *Raster Dataset*, using *32_BIT_FLOAT* in the *Pixel type (optional)* field. Once the DEM is mosaicked, it should be projected into the UTM coordinate system using the method in the manual (p. 33), with the exception of leaving the *Output cell size (optional)* field as whatever the default is (usually some number between 25 and 27 in the northern parts of the continental U.S.). In general, the more you change a DEM, the less accurate it will be. Though the DEM must be re-projected to UTM for GRAIP, changes to the cell size result in further, unnecessary, interpolation (essentially an educated guess by the computer). Once the DEM is projected, it can be extracted by the buffered HUC boundary as usual.

Changes to the Manual Text and Figures

The text of the manual has been superseded with new text on a sub-section by sub-section basis where the changes to procedures are significant (Section II of this Addendum). However, there may be occasional references throughout the manual text to outdated processes that did not warrant replacing the entire section. For example, the old *Combined Stability Index* function process that has been greatly simplified is referenced in a few places in the manual, and these and other references to outdated processes can be ignored. Windows 7 and GRAIP are compatible, but since GRAIP is a 32-bit program, the location in which GRAIP is installed is C:\Program Files (x86)\GRAIP. You may notice that the new figures look a little different than the old figures; the old figures were made with Windows XP, while the new figures were made with Windows 7. The content in the function menus and windows is the same, regardless.

Additionally, there were some changes to function menus in the *Road Surface Erosion Analysis* menu of the GRAIP toolbar that do not result in any change in procedures, shown and explained below.

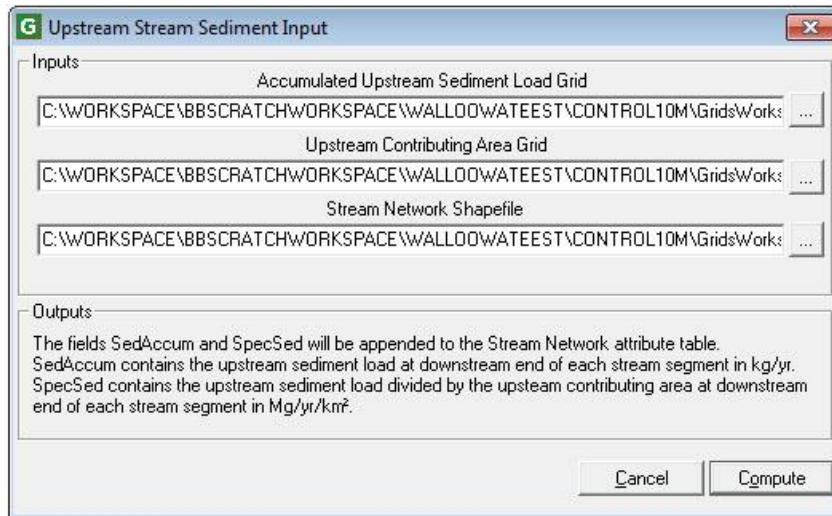


Figure 1. The updated menu for the Upstream Stream Sediment Input function. GRAIP 1.0.8 used the pit-filled DEM as one of the inputs for this function, but that is no longer necessary. The outputs are the same, and no changes to procedures are required.

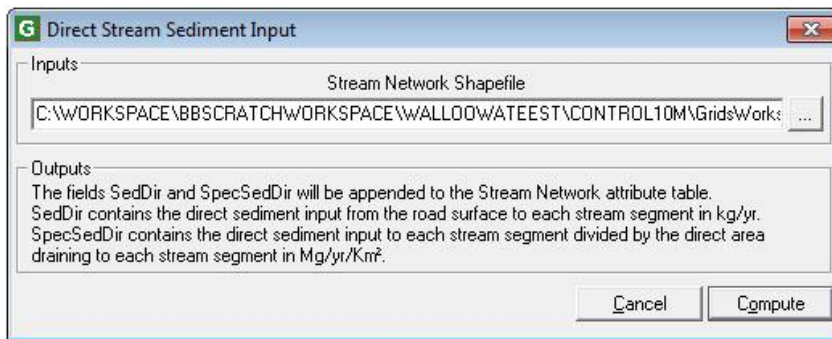


Figure 2. The updated menu for the Direct Stream Sediment Input function. GRAIP 1.0.8 used three additional grids for inputs to this function, and they are no longer necessary. The outputs are the same, and no changes to procedures are required.

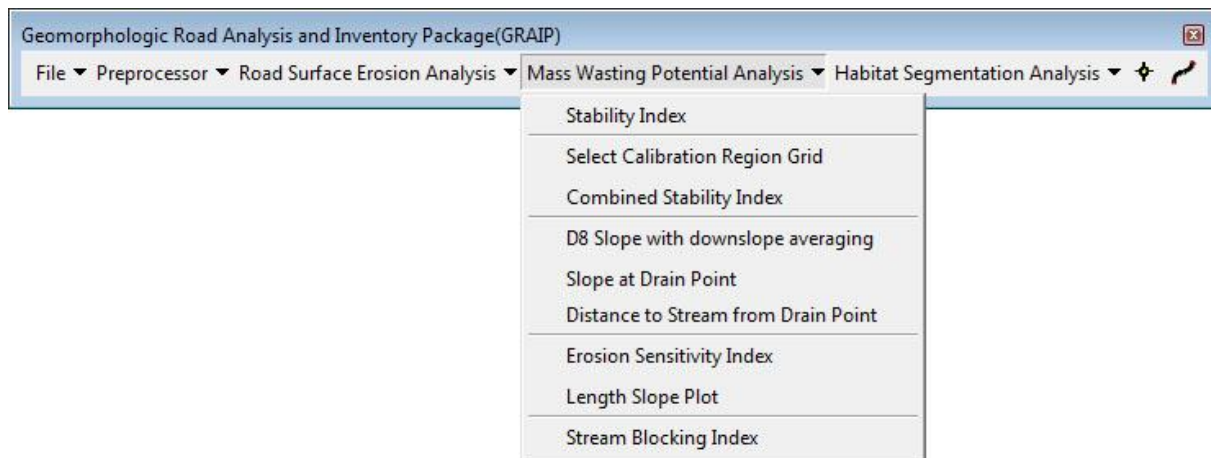


Figure 3. The updated menu for the Mass Wasting Potential Analysis functions. GRAIP 1.0.8 did not include the Distance from Stream to Drain Point function.

SECTION II: REPLACEMENT INSTRUCTIONS

The following sections are to be referred to in place of their corresponding sections in the original manual. The updates made with GRAIP 1.0.9 changed the information and procedures substantially in these sections.

- Preprocessing Shapefiles, pp. 40-46 in the original manual
- Running TauDEM, pp. 72-76 in the original manual
- Mass Wasting Potential Analysis, pp. 100-117 in the original manual
- Appendix D: Attribute Table Field Name Explanations, DrainPoints Attribute Table only, pp. 136-137 in the original manual

Preprocessing Shapefiles

This section replaces the *Preprocessing Shapefiles* section under Section II of the office manual, pp. 40-46.

The Preprocessor has two functions. It creates the GRAIP file structure, and it checks the incoming data for the most common errors. Preprocessing creates a single shapefile with all of the drain points, called DrainPoints, and one with all of the road segments, called RoadLines. It also creates a single database with all of the data, and relates the correct DEM, DrainPoints, RoadLines, the database, and, later, the stream network shapefile to each other under a new file with a .graip extension. This .graip can only be opened with the GRAIP toolbar in ArcMap. In total, eight files are created, not including the multiple files that make up one shapefile (FileName.graip, DrainPoints.shp, RoadLines.shp, FileNameDP.log, FileNameRD.log, FileName.mdb, FileNameshdp.txt, and FileNameshprd.txt; see Figure 14). The log files are created to identify RoadLines and DrainPoints that may have insufficient or erroneous data values.

SUMP.shp	1 KB	SHP File
SUMP.shp.xml	2 KB	XML Document
SUMP.shx	1 KB	SHX File
UmaGDec.graip	2 KB	GRAIP File
UmaGDec.mdb	10,936 KB	Microsoft Access Application
UmaGDecDP.log	1 KB	Text Document
UmaGDecRD.log	1 KB	Text Document
UmaGDecshdp.txt	1 KB	Text Document
UmaGDecshprd.txt	1 KB	Text Document
WATER_BA.dbf	3 KB	DBF File
WATER_BA.prj	1 KB	PRJ File
WATER_BA.sbn	1 KB	SBN File

Figure 14. The files created by the GRAIP Preprocessor, not including DrainPoints.shp and RoadLines.shp.

and FileNameshprd.txt; see Figure 14). The log files are created to identify RoadLines and DrainPoints that may have insufficient or erroneous data values.

When the Preprocessor builds the database for the input data, it references another database file called GRAIP.mdb (located in C:\Program Files (x86)\GRAIP\graip db), which has attributes that must match up with the attributes in the drain point and road lines shapefiles. The attributes in those shapefiles are originally input in the field GPS unit based on a particular data dictionary (see Volume 1: Data Collection Method).

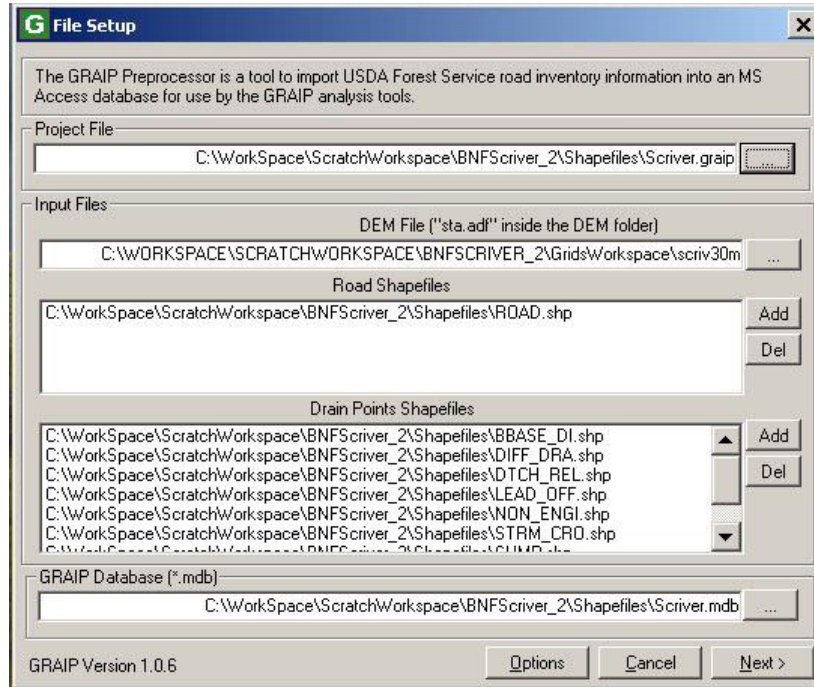
Essentially, in order for everything to match up correctly at this step, the data dictionary used for field collection and the GRAIP.mdb file must match. The current data dictionaries are INVENT5_0 and INVENT5_0_W, and are available on the GRAIP website (<http://www.fs.fed.us/GRAIP/downloads.shtml>). Use these when collecting new data.

GRAIP 1.0.9 has preserved the ability to use the previous version of the field data dictionary, INVENT4_2. However, the steps to use INVENT4_2 have changed from GRAIP 1.0.8. Previously, the GRAIP.mdb file would be copied into the working directory for GRAIP under Program Files on the hard drive. Due to changes in the way administrative permissions are granted on Forest Service computers, this process has changed, so that now the GRAIP.mdb file is copied by hand into the workspace in which you will create the .graip file, and then re-named to match the name you give to the .graip file. When you do this, make sure to not replace the MDB file when the GRAIP Preprocessor asks. GRAIP will automatically complete this step if you are using INVENT5_0 or INVENT5_0_W.

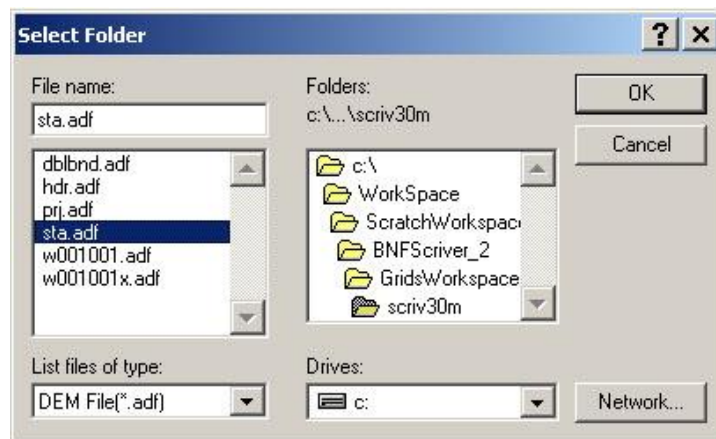
Data collected with INVENT5_0 and INVENT5_0_W are not compatible with INVENT4_2 data in the model. In other words, you cannot combine old data with new data in the same GRAIP modeling run.

1. If your data was not collected using the INVENT4_2 data dictionary, skip this step and proceed to step 2. The GRAIP Preprocessor copies the GRAIP.mdb database from C:\Program Files (x86)\GRAIP\graip db into the workspace in which you are creating the .graip file, and renames it as FileName.mdb (where “FileName” is the name you give your .graip file). The GRAIP.mdb database in Program Files (x86)\GRAIP\graip db is set up for INVENT5_0 and INVENT5_0_W, so if you have data in INVENT4_2, you must trick GRAIP into using the GRAIP.mdb file for INVENT4_2.
 - a. If you do not have a copy of the INVENT4_2 GRAIP.mdb database, look on the website or contact us.
 - b. In Windows (as opposed to Arc Catalog), copy and paste the GRAIP.mdb database that applies to INVENT4_2 into the workspace where you will create the .graip file.
 - c. Rename the GRAIP.mdb database to match the name you will give to your .graip file.
 - i. For example, if you are naming your .graip file “sasquatch.graip”, then you would name your copied MDB database as “sasquatch.mdb”.
2. Open the GRAIP Preprocessor

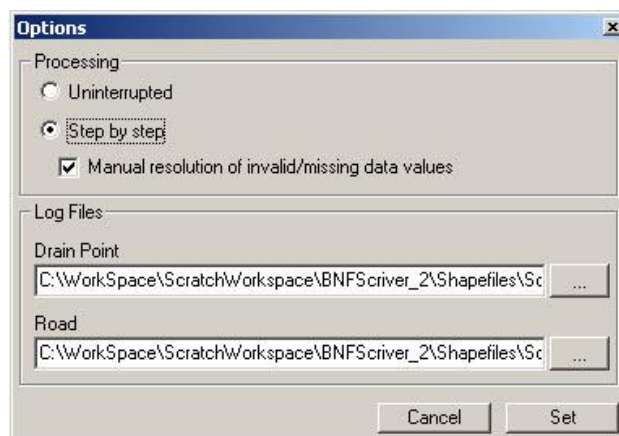
- a. This is a separate program, installed with the GRAIP Toolbar and found in the GRAIP folder under *Programs* in the *Start* menu.



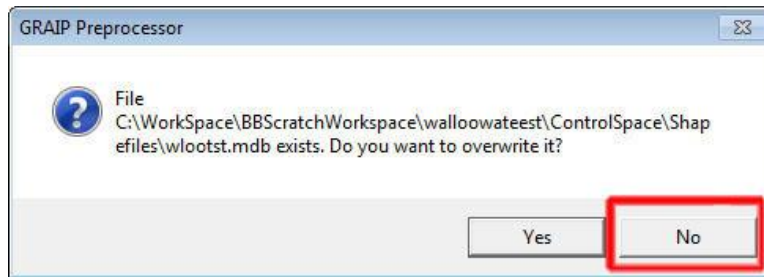
3. Create a new .graip file
 - a. Under *Project File*, click the {...} button, navigate to the folder with your shapefiles or wherever you want to save the .graip and other created files.
 - b. Name the file with something relevant. Do not use spaces. Click *OK*. FileName is used here to refer to the .graip, etc.
4. Select the DEM
 - a. Under *DEM File*, click {...}, navigate to the desired clipped DEM, referred to here as just “dem” (it should be in the same folder in which you intend to save the TauDEM-created files, discussed previously). Double-click dem, select sta.adf, and click *OK*.



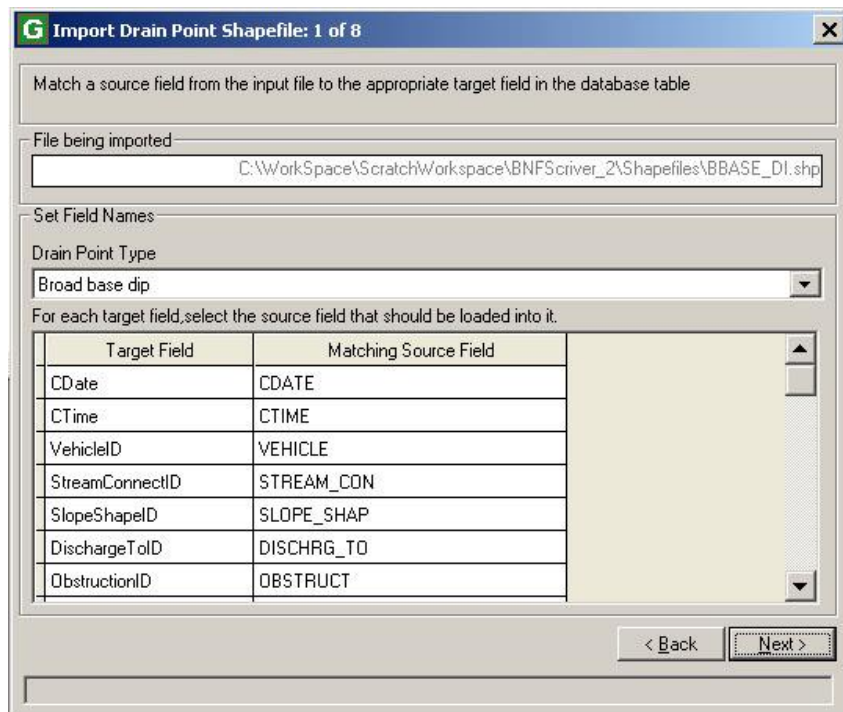
- b. If you don't have the DEM, you can still correct errors. For this step, use a dummy DEM (any DEM). You will have to re-preprocess the data with the correct DEM before running GRAIP.
5. Add the road shapefile(s), and the drain point shapefiles.
 - a. Under *Road Shapefiles*, click *Add*. Navigate to the location of the ROAD shapefile(s), select them, and click *OK*.
 - b. Under *Drain Points Shapefiles*, click *Add*, Navigate to the location of the drain point shapefiles, select all of the drain point shapefiles, and click *OK*. There are nine possible drain point shapefiles, but not every study will have them all. They are BBASE_DI, DIFF_DRA, DTCH_REL, EXCAV_ST, LEAD_OFF, NON_ENGI, STRM_CRO, SUMP, and WATER_BA.
 - c. You can add more than one shapefile with the same name, as if you imported, corrected, and exported the shapefiles in two batches. In this case, the second (or even third or fourth) set of shapefiles should be in a separate sub-workspace in the same workspace as the rest of the shapefiles.
 6. Click *Options*, ensure *Step by step* and *Manual resolution of invalid/missing data values* are selected in the *Processing* field, and click *OK*. These options ensure that you will catch any errors in the next step. You may also change the location of the error log files in this step, but that is not generally necessary.
 - a. If you choose *Uninterrupted* in the *Processing* field, all defaults will be used, and you will have no opportunity to specify what actions to take, where appropriate. This is rarely a good idea.



7. Click *Next*. At this point, all of the files that are created by the preprocessor have been created, except *DrainPoints.shp* and *RoadLines.shp*. The next steps import the drain points and road shapefiles.
 - a. If your data was not collected using *INVENT4_2*, move to step 8 now. If your data was collected using *INVENT4_2*, and you have completed step 1 correctly, then you will see a dialog box pop up that asks if you want to overwrite the *FileName.mdb* that you previously copied into the *.graip* folder. Click *No*.

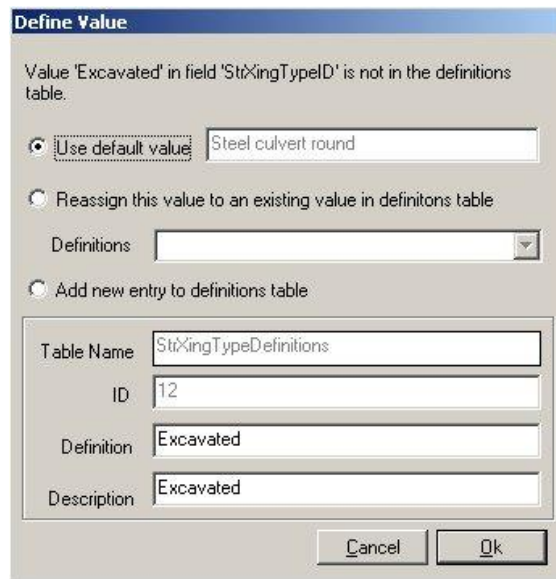


8. A screen appears with the heading *Import Drain Point Shapefile: 1 of X* (*X* is the total number of drain point shapefiles that you are importing). You can see the *File being imported*, which *Drain Point Type* the preprocessor thinks it is, and the *Target* and *Source* fields that go with that drain point type. Generally, these are all correct, and no input is needed. However, it is a good idea to check to make sure all of the target and source fields match up properly. If they don't, you can select a match from the



drop-down menu that appears under the *Matching Source Field* when you click on a property. If you have the latest version of GRAIP and the latest data dictionary in the field, this should not occur. If the data dictionary has been modified, the incoming data may have unexpected values, and the Preprocessor will not be able to automatically import the data into the GRAIP geodatabase structure. When you are sure everything matches, click *Next*. Repeat this process for all drain points and road lines (the road lines import process is similar).

- a. If there is an undefined value in a drain point or road line, such as if a property exists in the data dictionary in the field, but not in GRAIP, the *Define Value* dialog appears. For example, before the last update, in the STRM_CRO shapefile, the ChannelAngleID > 75 degrees did not match that in the GRAIP data dictionary, because the GRAIP data dictionary did not have a space (so it is >75 degrees), and this produced an error. If you are using the wrong version of GRAIP.mdb, this dialog box will appear a lot.



- i. You have three options, *Use default value*, *Reassign this value to an existing value in definitions table*, and *Add new entry to definitions table*. Select the appropriate choice and click *Ok*.
 - *Use default value* assigns the default value for that attribute to the errant point(s) or line(s).
 - *Reassign this value in definitions table* allows you to assign an attribute value of an existing attribute to the errant point(s) or line (s). This is best

to use when there is a misspelled word or similar error, as described above.

- *Add new entry to the definitions table* adds an entry for the errant value to the GRAIP MDB definitions table for the .graip. Use this if the value that is in error is a new value. If this attribute affects a calculation in the model, the default calculation value will be used.

- b.** If there are CTime fields in the ROAD shapefile that have anything entered in them that is not a valid 24-hour time with four digits (e.g. 0745, 0959, 1919, etc.) or 999, then the Preprocessor will freeze during the *Import Road Lines Shapefile* step. Examples of invalid CTime entries include: 9999, 6130, 930, 34, blank cell.
 - i.** If this happens, you must find the errant CTimes and edit them so that they are valid. Add the ROAD shapefile in which the error occurs to ArcMap, and use the layer's attribute table to find and edit the errors. See the instructions for *Editing Data Errors* for more information.
- 9.** Preprocessing is now complete. The FileNameDP.log and FileNameRD.log files, located in the same folder as FileName.graip, contain the errors that the preprocessor found, used in the next step.

```

GRAIP Project File:C:\workspace\Scratchworkspace\BNFScrver_2\Shapefiles\Scriver.graip"
"GRAIP Database File:C:\workspace\Scratchworkspace\BNFScrver_2\Shapefiles\Scriver.mdb"
"03-21-2011", "16:06:10"
"GRAIPDID", "Drain Type", "Error Message", "Action Taken"
1232, "Ditch relief", "value 'Ditch out' in field 'DitchReliefTypeID' is not in the
definitions table. ", "Added to definition table as ID 6"
1847, "Stream Crossing", "value 'Excavated' in field 'strXingTypeID' is not in the
definitions table. ", "Added to definition table as ID 12"
1854, "Stream Crossing", "value '>75 degrees' in field 'ChannelAngleID' is not in the
definitions table. ", "Reassigned value as > 75 degrees"
0, "Broad base dip", "Orphan Drain Point", "Nothing"
1, "Broad base dip", "Orphan Drain Point", "Nothing"
2, "Broad base dip", "Orphan Drain Point", "Nothing"
11, "Broad base dip", "Orphan Drain Point", "Nothing"
13, "Broad base dip", "Orphan Drain Point", "Nothing"
15, "Broad base dip", "Orphan Drain Point", "Nothing"
21, "Broad base dip", "Orphan Drain Point", "Nothing"
53, "Broad base dip", "Orphan Drain Point", "Nothing"
80, "Broad base dip", "Orphan Drain Point", "Nothing"
108, "Broad base dip", "Orphan Drain Point", "Nothing"
138, "Broad base dip", "Orphan Drain Point", "Nothing"
156, "Broad base dip", "Orphan Drain Point", "Nothing"
158, "Broad base dip", "Orphan Drain Point", "Nothing"
160, "Broad base dip", "Orphan Drain Point", "Nothing"
167, "Broad base dip", "Orphan Drain Point", "Nothing"
170, "Broad base dip", "Orphan Drain Point", "Nothing"
179, "Broad base dip", "Orphan Drain Point", "Nothing"
182, "Broad base dip", "Orphan Drain Point", "Nothing"
191, "Broad base dip", "Orphan Drain Point", "Nothing"
192, "Broad base dip", "Orphan Drain Point", "Nothing"
205, "Broad base dip", "Orphan Drain Point", "Nothing"
286, "Broad base dip", "Orphan Drain Point", "Nothing"
426, "Broad base dip", "Orphan Drain Point", "Nothing"
    
```

- 10.** In the next step, you will locate and fix any errors. When you re-preprocess the data, after the errors are corrected, and any time the DEM used does not change (including if you change which shapefiles are used, so long as the DEM remains the same), you can just select the already created *Project File* (FileName.graip) on the first screen, and click *Next*. Click *OK* when asked if you want to delete the DrainPoints, RoadLines, and FileName.mdb files. Proceed as before. You will have to go through any *Define Value* dialogs again. If you change the DEM, you must use a new .graip (e.g. FileName2.graip). Again, click *OK* when asked if you want to delete the DrainPoints, RoadLines, and FileName.mdb files. If no points have been added or deleted from the original shapefiles, the preprocessor assigns the same GRAIPDID/GRAIPRID number to each point as it did the first time.

 - a.** If you have data that was collected using INVENT4_2, you will need to delete the FileName.mdb database, copy a fresh version of the INVENT4_2 GRAIP.mdb database into the workspace, and rename it as before. Then, when it asks if you want to delete FileName.mdb, as before, click *No*. You still want to click *Yes* when it asks if you want to delete the DrainPoints and RoadLines files.

Running TauDEM

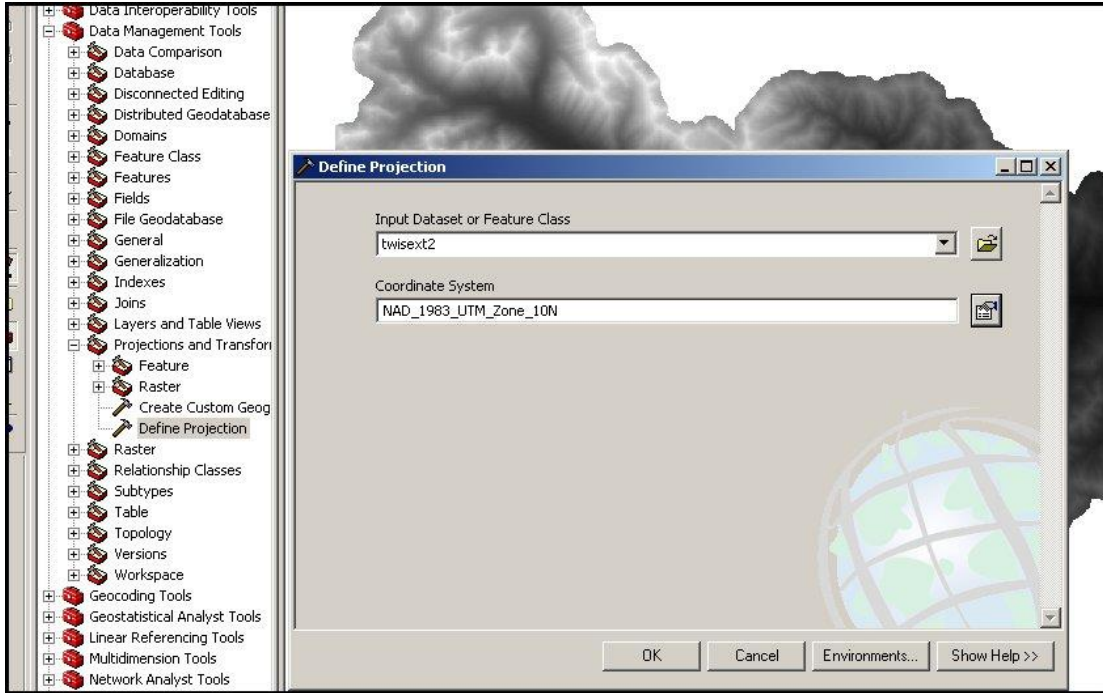
This section replaces the *Running TauDEM* section under Section III of the office manual, pp. 72-76.

TauDEM is used to generate a set of grids and shapefiles that are used by GRAIP, including the stream network shapefile (18 files in total). There are 14 grid files created by TauDEM (dem stands for the name of the DEM used): demfel, demsd8, demp, demang, demslp, demad8, demsca, demgord, demplen, demtlen, demsrc, demord, demw, and demdist. There are two shapefiles created by TauDEM: demnet, demw. The stream network shapefile (demnet) is associated with FileName.graip, and is added when the .graip is opened. The last two files are demtree.dat and demcoord.dat. See Appendix F: TauDEM Inputs and Outputs for more information.

TauDEM may take a long time to run, depending on the size of the DEM (the maximum grid size is about 7000 x 7000 cells). The folder in which the DEM that is used is placed will be the folder in which all of the TauDEM-generated files are saved to. Later, this is the same folder in which SINMAP will create its folder. As such, it is a good idea to start with a fresh ArcInfo Workspace with only the DEM that you plan to use in it. TauDEM requires that the DEM name not be any longer than seven characters. The DEM should be projected to a rectangular coordinate system, such as UTM, rather than a geographic coordinate system, and should be about 30 m resolution (generally 25-27 m resolution in the northern two-thirds of the continental U.S.).

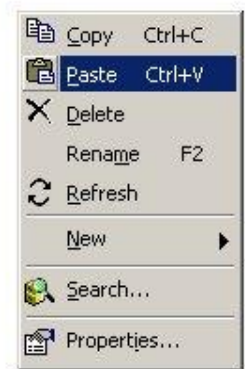
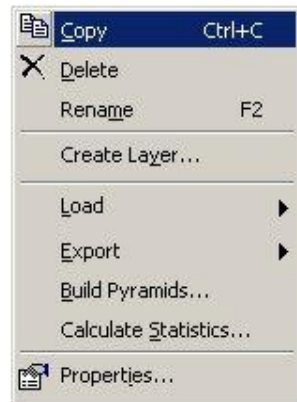
1. The projection for the DEM must be defined if it is not already. If it is defined, skip to step 2.
 - a. Open ArcMap, add the DEM.
 - b. Open ArcToolbox.
 - i. ArcMap Main Menu-> *Window*-> *ArcToolbox*, or the button in the Standard toolbar.
 - c. In ArcToolbox, go to *Data Management*-> *Projections and Transformations*-> *Define Projection*.
 - i. Under the *Input Dataset or Feature Class*, use the drop down menu to select the DEM.

- ii. Click the box to the left of the *Coordinate System* field-> *Select*-> navigate to the projection that that the DEM is in, click *Add*, then *Apply* and *OK*.
- iii. Click *OK*. The projection is now defined. This works for any GIS file.

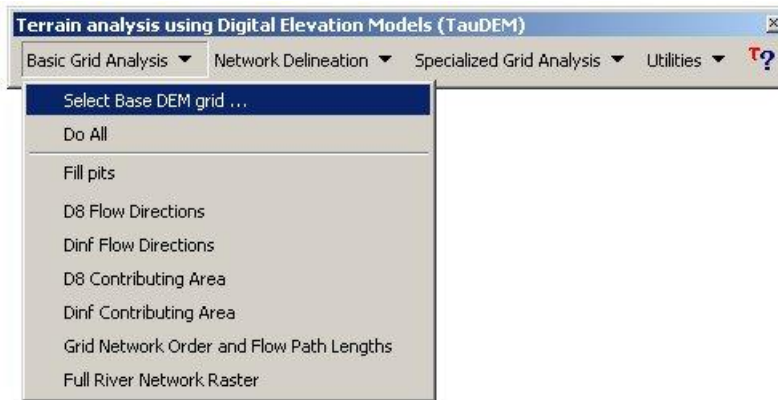


- d. Close ArcMap or open a new map file. You don't have to save the map file because the changes are saved automatically. This will set the ArcMap viewer with the correct projection information before TauDEM is run.
2. If you don't have one already, create an ArcInfo workspace for the TauDEM (and later SINMAP) files. This should be done for every data set, even if multiple data sets share the same DEM. If you have done this, skip to step 4.

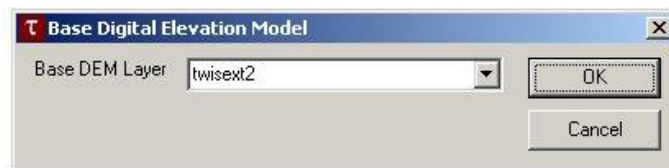
- a. Open ArcCatalog, and navigate to your working folder (see Appendix A: An Example File Management System for an example of a file system for GRAIP).
- b. Right-click-> *New*-> *ArcInfo Workspace*. Rename the new workspace with something obvious (see Section I, Figure 8).
- c. Navigate to the location of the clipped DEM. Copy it.
 - i. Right-click the DEM-> *Copy*



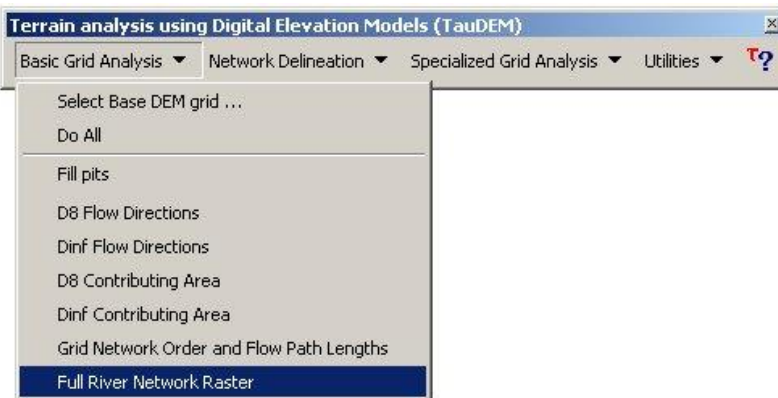
- d. Navigate back to the new workspace and paste the DEM into it.
 - i. Open the workspace folder.
 - ii. Right-click anywhere in the folder-> *Paste*.
- e. Close ArcCatalog or navigate away from the new workspace. TauDEM and ArcGIS might get confused if the workspace they are modifying is active (currently being viewed) in ArcCatalog at the same time.
3. Open ArcMap and add the clipped DEM with the projection defined from the TauDEM workspace to the viewer.
4. It is best to do the rest of these steps one immediately after another. From the TauDEM toolbar-> *Basic Grid Analysis*-> *Select Base DEM grid...*



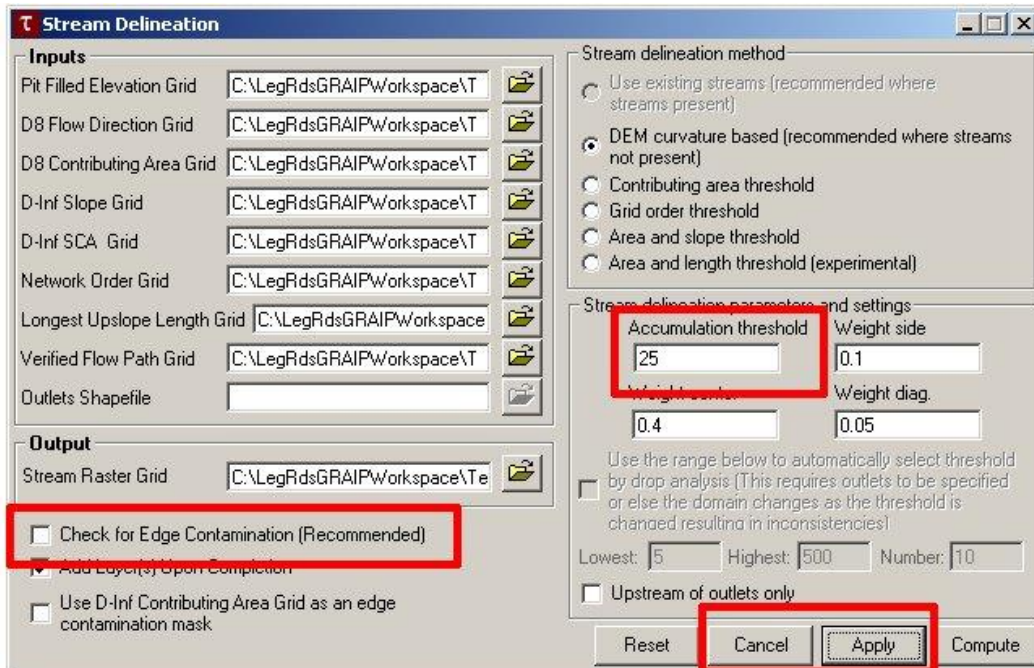
- a. Use the drop-down menu to select the DEM and click *OK*.



5. Go to *Basic Grid Analysis*-> *Full River Network Raster*. You don't want to run this step now, just adjust its parameters.



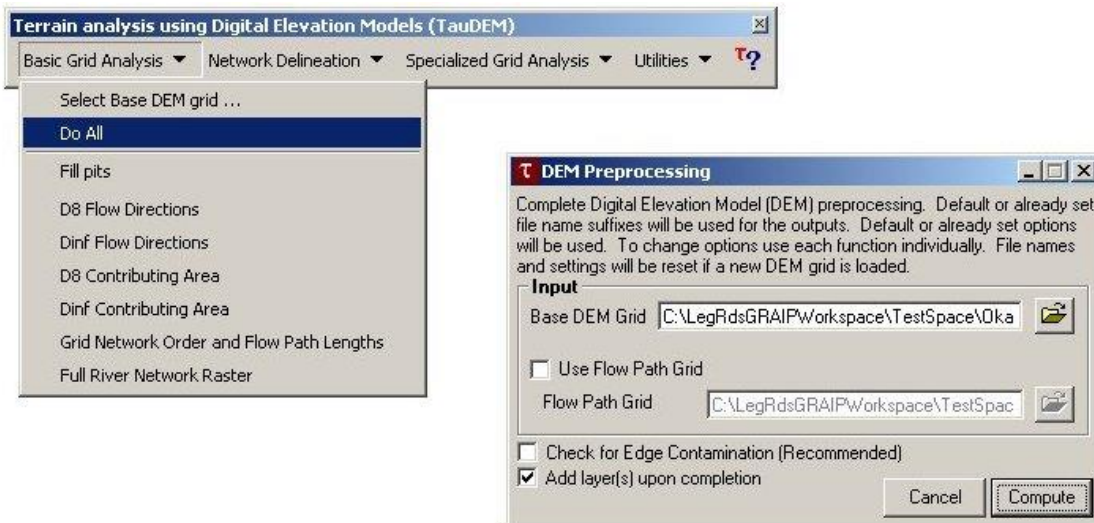
- a. Uncheck *Check for Edge Contamination*.
 - i. This will automatically uncheck *Use D-Inf Contributing Area Grid as an edge contamination mask*.
- b. Change the *Threshold* to 25.
- c. Click *Apply* twice (to ensure it registers), then *Cancel*.



- d. We use the *DEM curvature based* method for determining channel locations. This is the default, but other approaches may also be suitable. See the TauDEM website and manual for more information.

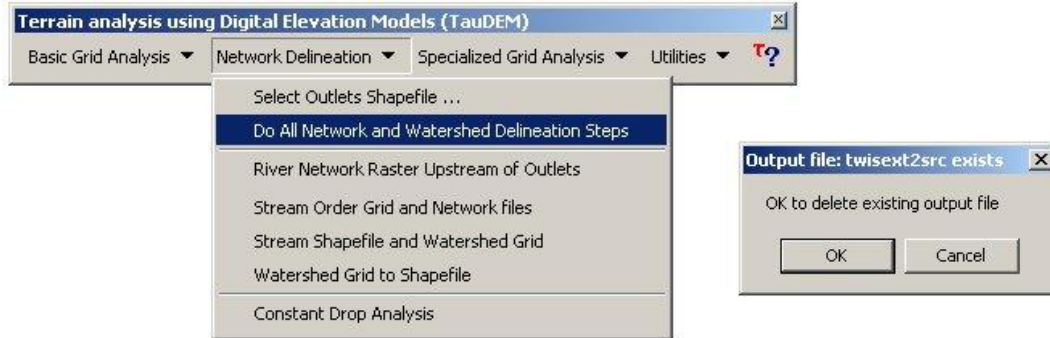
6. Go to *Basic Grid Analysis*-> *Do All*.

- a. Double-check the default parameters and click *Compute*.



- b. This step produces 11 grids (demfel, demsd8, demp, demang, demslp, demad8, demsca, demgord, demplen, demlen, demsrc).

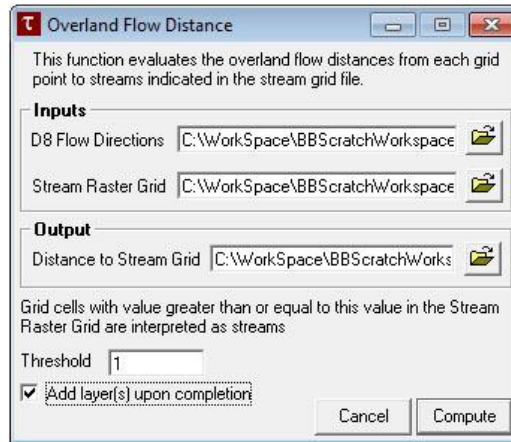
7. Go to *Network Delineation*-> *Do All Network and Watershed Delineation Steps*.



- a. Click *OK* when asked if it's OK to delete the existing src output file.
- b. This step creates the last four grids and shapefiles (demord, demw, demnet.shp, demw.shp), recreates demsrc (which is why you are asked if the original demsrc can be deleted), and the last two files (.dat extension).

- c. Do not use an outlet point.

8. Go to *Specialized Grid Analysis*-> *Flow Distance to Streams*.



- a. Ensure that the correct grids are specified for each of the inputs and that the output will be saved to the correct location.
 - i. Generally, if this function is run in order with the rest, the defaults are correct.
- b. Click *Compute*.
- c. This function creates a grid with values representing the distance a drop of water that was dropped on each cell would cover before it hits a TauDEM modeled stream (demdist).

9. Before proceeding, close ArcMap or open a new map file. This will allow for a fresh start for the next section. You don't have to save the map file because grids and shapefiles are already saved on the hard drive.

Mass Wasting Potential Analysis

This section replaces the *Mass Wasting Potential Analysis* section under Section III of the office manual, pp. 99-117.

The functions in the *Mass Wasting Potential Analysis* menu produce data that indicate the likelihood of mass wasting events caused by concentrated road drainage discharging onto the hillslope below a road. The default parameters can often be adjusted to provide more accurate results. The risk predictions can be compared to the data produced by SINMAP for a road vs. no road comparison.

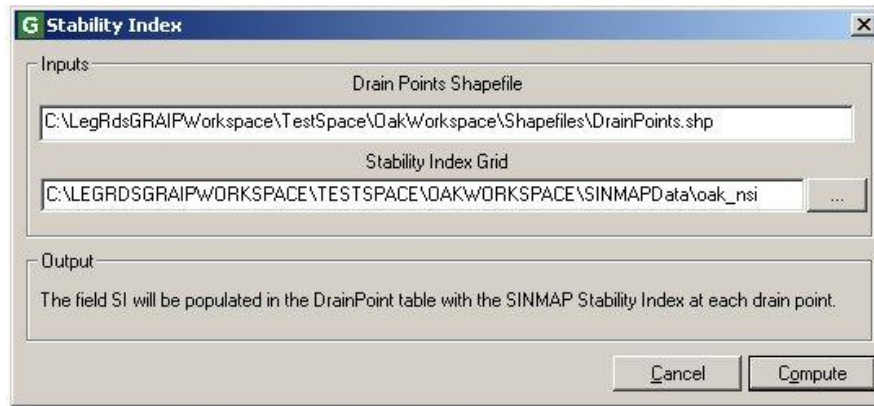
There are nine tools under the *Mass Wasting Potential Analysis* menu heading. These steps can be undertaken only after SINMAP has been run. The first step finds the stability index at each drain point from the demsi grid that SINMAP created, and populates the *SI* column in the DrainPoints table. The second and third tools create the combined stability index grid and four other intermediary grids (demsic, demrmin, demrmax, demrdmin, and demrdmax, respectively), and one text file (demcalp.csv) that take the road water into account for landslide risk. The *SIR* column is also populated in the DrainPoints table. The combined stability index grid (demsic) can be compared to the stability index grid (demsic, from above) to see the affect the road has on the terrain stability.

The fourth and fifth steps create a slope grid (demslpd) and populate the *Slope* column of the DrainPoints table, which is the slope of the hillslope below each drain point. The sixth step uses the demdist grid created by TauDEM to populate the *DistToStre* column in the DrainPoints table. The next step addresses gully initiation risk with the Erosion Sensitivity Index, and so populates the *ESI* column of the DrainPoints table. The eighth step creates a road length vs. hillslope plot called *L-S Plot* (note that the Y-axis is logarithmic) that can be used to calibrate the ESI threshold for increased gully risk (ESI_{crit}). The final step calculates the Stream Blocking Index (SBI) for each stream crossing, and so populates the *PipeDiaToChanWidthRatio*, *PipeDiaToChanWidthScore*, *SkewAngle*, *SkewAngleScore*, and *SBI* columns in the DrainPoints table.

The combined stability index grid adds water from the road at each drain point to the hillslope, based on the contributing length of road and a predetermined additional road runoff rate (effectively increasing the contributing area at the cells in which the drain points lie). The overall effect is to decrease slope stability at the location of each drain point that receives road water. Slope stability will not increase from possible interception of shallow groundwater by a ditch, as GRAIP only accounts for the added surface runoff.

1. If not already open, open ArcMap or a new map window and open the GRAIP file (the .graip).

2. GRAIP toolbar-> *Mass Wasting Potential Analysis-> Stability Index*



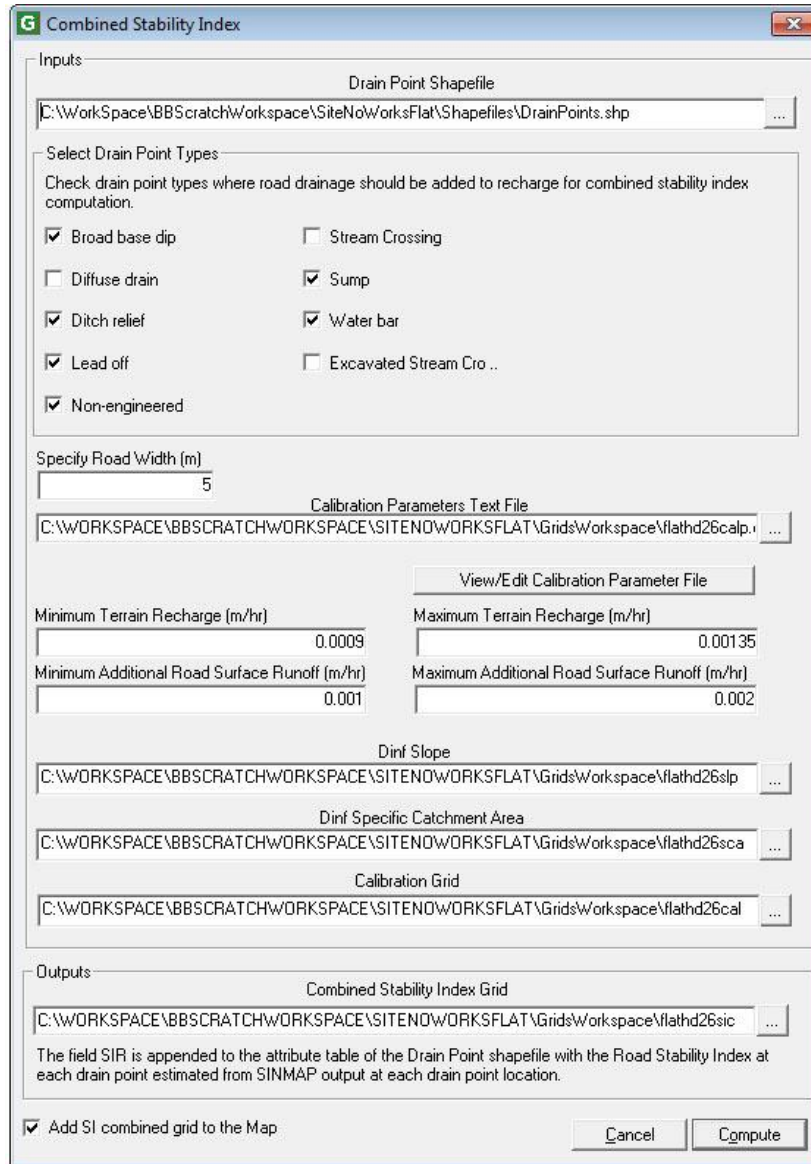
- a. Ensure that the DrainPoints shapefile and each of the grids are correctly located, and click *Compute*.
- b. Check that the *SI* column has been populated in the DrainPoints Attribute Table. There should not be any zero values.

DrainPoints.ELength	DrainPoints.UnitSed	DrainPoints.SedDel	DrainPoints.SI	DrainPoints.SIR	DrainPoints.Slope	DrainPoints.SI
27.323491	0.481893		2.258418	0	0	
34.829077	1.394905		2.143331	0	0	
40.669834	8.510792		1.967258	0	0	
118.685738	3.95808		8.753125	0	0	
101.668264	5.110711		4.059776	0	0	
68.494068	5.059151	346.52185	2.791034	0	0	
83.327707	6.236918		2.665183	0	0	
60.282024	5.521542		2.83087	0	0	
70.686006	3.134929		2.486201	0	0	
86.366567	4.547994		1.952626	0	0	
101.779191	6.394881		3.124053	0	0	
91.237964	5.897792		0.930503	0	0	
35.187989	4.972836		0.887064	0	0	
27.935776	8.318025		1.091479	0	0	
25.704862	3.418384		0.999979	0	0	

- 3. *Mass Wasting Potential Analysis-> Select Calibration Region Grid->* navigate to the SINMAPData folder created previously-> select the calibration grid (demcal)-> click *Add*. The calibration region grid is added to ArcMap.



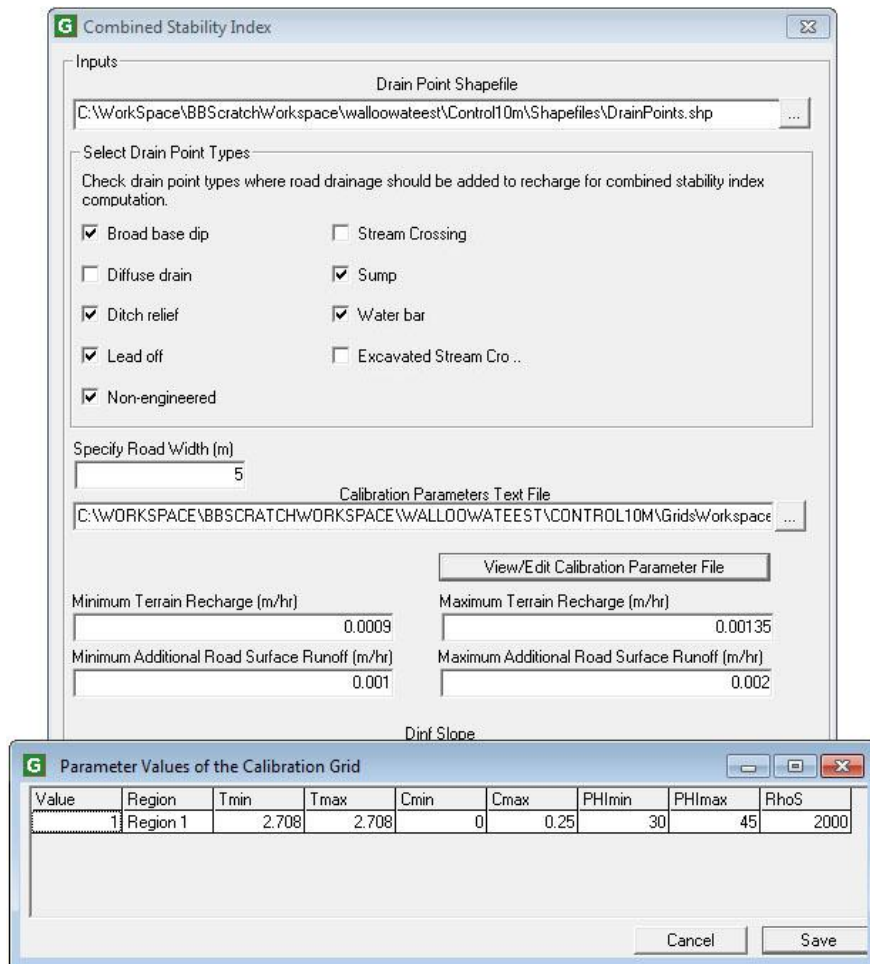
4. *Mass Wasting Potential Analysis-> Combined Stability Index*



- a. Under *Select Drain Point Types*, ensure that each of the listed drain point types have a check in their box except *Diffuse drain*, *Stream Crossing*, and *Excavated Stream Cro...*
 - i. These three drain point types do not behave in the same way as the others with regard to landslide risks, and so they must be excluded from this step.
 - ii. If you are using an INVENT4_2 dataset, the excavated stream crossing automatically does not show up.
- b. Ensure that the DrainPoints and RoadLines shapefiles are correctly located from the SICShapefiles workspace. Ensure that the fields *Calibration Parameters Text*

File, *Dinf Slope*, *Dinf Specific Catchment Area*, and *Calibration Grid* are correctly populated and located (demcalp.csv, demslp, and demsca from the TauDEM folder, and demcal from the SINMAPData folder, respectively).

- c. The following are default parameters:
 - i. *Specify Road Width (m)* is 5.
 - ii. *Minimum Terrain Recharge (m/hr)* is 0.0009.
 - iii. *Maximum Terrain Recharge (m/hr)* is 0.00135.
 - iv. *Minimum Additional Road Surface Runoff (m/hr)* is 0.001.
 - v. *Maximum Additional Road Surface Runoff (m/hr)* is 0.002.
- d. You can edit additional parameters by clicking on the *View/Edit Calibration Parameter File* button. If you have calibrated SINMAP to a landslides point layer, you will change the parameters in this step to match those from SINMAP. To do this, click the *View/Edit Calibration Parameter File* button.



- i. In the *Parameter Values of the Calibration Grid* window that pops up, enter the calibrated values from SINMAP for each property in the appropriate column.
 - Do not edit the columns labeled *Value* and *Region*. If you have more than one calibration region, there will be one row for each region.
 - The next two columns, *Tmin* and *Tmax* stand for the transmissivity of the soil, which corresponds to the *T* in the *T/R (Lower/Upper Bound)* parameters in SINMAP. The *R* stands for terrain recharge, the value of which can be viewed and adjusted in the main *Combined Stability Index* screen (see above) in the *Minimum/Maximum Terrain Recharge (m/hr)* fields. For each of the *T* columns, calculate the value to enter, based on the appropriate value (*Minimum* or *Maximum*) already given for *R*, such that,

$$\frac{T}{R} = X$$

where X is the desired value for the *T/R (Lower/Upper Bound)* parameters in SINMAP. For example, if the SINMAP calibration parameter for *T/R (Lower Bound)* is 1850, and the value for *Minimum Terrain Recharge (m/hr)* is 0.0009 (default), then solve for *T*,

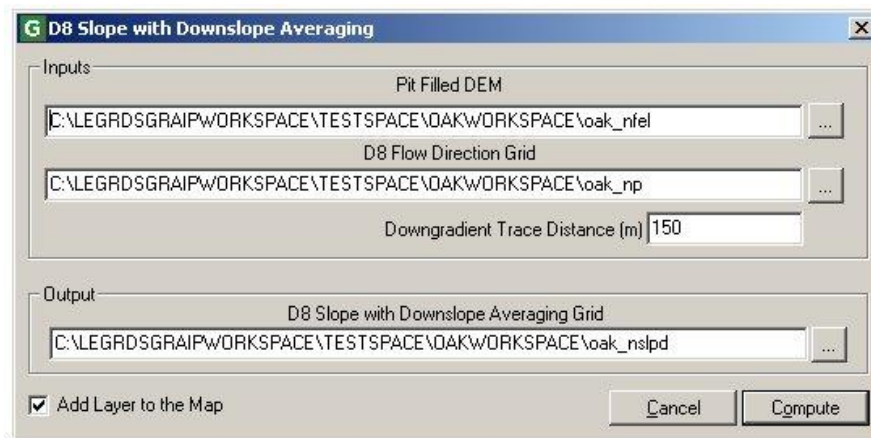
$$\frac{T}{0.0009} = 1850$$

$$T = 1.665$$

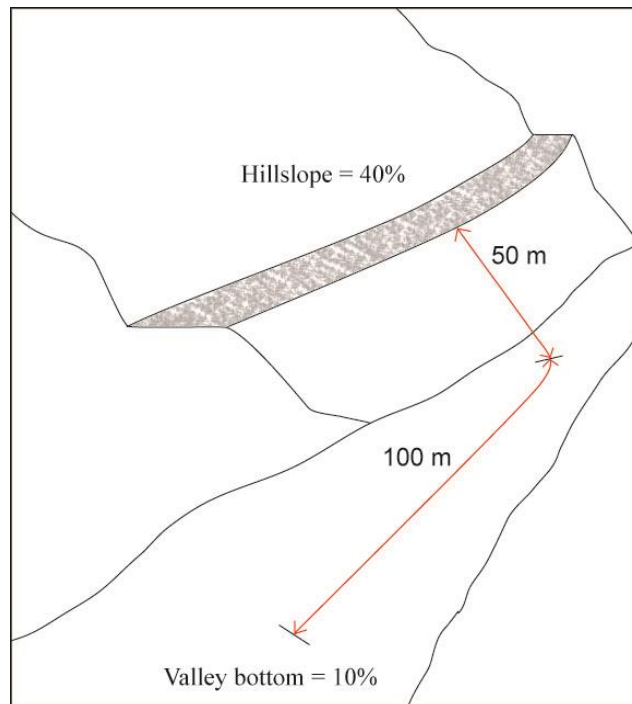
Enter this value in the *Tmin* column and then do a similar calculation to find *Tmax* (using the *Maximum Terrain Recharge (m/hr)*, which is 0.00135 by default).

- *Cmin* and *Cmax* correspond to the respective *Cohesion (Lower/Upper Bound)* parameters in SINMAP.
- *PHImin* and *PHImax* correspond to the respective *Phi(degrees) (Lower/Upper Bound)* parameters in SINMAP.
- *RhoS* corresponds to the *Soil Density (kg / m³)* parameter in SINMAP.

- ii. Click *Save*. The previously defined (in SINMAP) calibration parameters will be used to generate the Combined Stability Index grid.
 - e. Ensure that the *Combined Stability Index Grid* will be saved to the correct place. Do not change its name.
 - f. Check *Add SI combined grid to map* and click *Compute*.
 - g. Five grids and one text file (calibration parameters; demcalp.csv) are created:
 - i. The combined stability index grid (demsic) is added to ArcMap and saved wherever you specified.
 - ii. The minimum and maximum depth of terrain runoff grids (demrmin and demrmax) are not added to ArcMap and are saved to the same place as the TauDEM files. These files are intermediary (i.e. they are used by the *Combined Stability Index* function and nothing else)
 - iii. The specific discharge due to minimum and maximum runoff grids (demrdmin and demrdmax) are not added to ArcMap. These files are intermediary.
 - h. Sometimes, GRAIP and SINMAP may round certain values slightly differently, which results in an SI grid (demsic) that does not match up perfectly with the SIC (demsic), even where there are no roads. You may want to use the *Combined Stability Index* function to create a matching SI grid. To do this, run this function again, setting both the *Minimum Additional Road Surface Runoff (m/hr)* and *Maximum Additional Road Surface Runoff (m/hr)* to 0. This removes the road water from the equation, resulting in an equivalent to the SI grid.
5. *Mass Wasting Potential Analysis-> D8 Slope with downslope averaging*



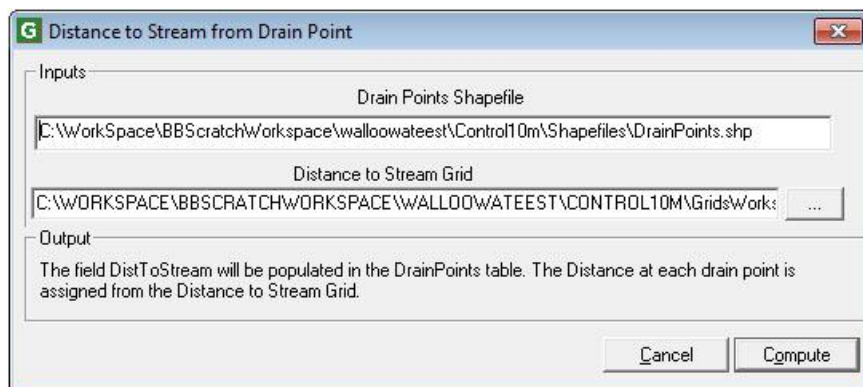
- a. The purpose of this function is to generate a grid of slopes at each cell that will be used to determine the slope at each drain point, which is used to help determine the Erosion Sensitivity Index (see below). The method used estimates the slope at each cell by averaging the slope from that cell to a cell that is located a specified trace distance downhill.
- b. Ensure that the *Pit Filled DEM* (demfel) and *D8 Flow Direction Grid* (demp) are correctly located.
- c. The default value for the *Downgradient Trace Distance (m)* field is 150.
 - i. This parameter defines the trace distance that the function will use. In some locations, the slope of the hill can be underestimated, because the stream valley bottom, which has a shallower slope than the actual hillslope, is included in the downgradient trace distance. It is important that the grid's values reflect the actual hillslope at each drain point. If there are drain points in the study that are within 150 m of a stream, the *Downgradient Trace Distance (m)* may be changed to a smaller number.



- ii. First, verify that there are drain points within 150 m of a stream. If there are, find an average point-to-stream distance in meters for only those drain points that are less than 150 m from the stream.

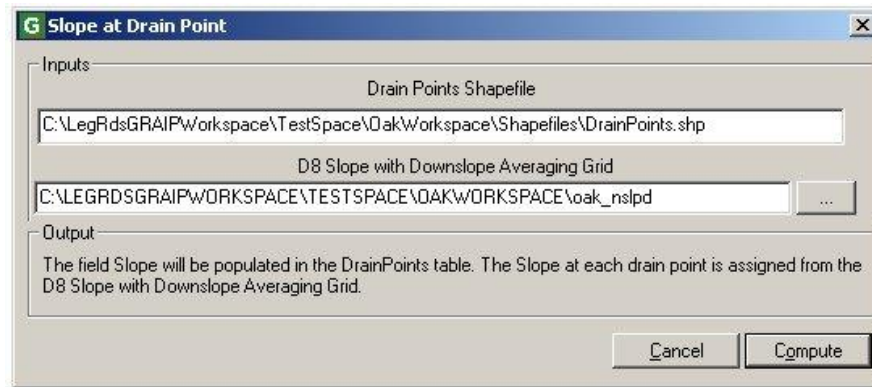
- iii. Since the DEM has a resolution of about 30 m, and you need two grid cell values to determine slope, you need an absolute minimum of 45 m of downslope trace distance (the length of the diagonal across a 30 m square is about 42 m). The simplest way to determine what the *Downgradient Trace Distance* should be is to take the greater of either the average point-to-stream distance or 45 m. However, the longer the specified trace distance, the more accurate the average (assuming a relatively constant slope on the hillslope). A slope calculated using only two grid cells will probably not be very accurate, due to imprecision in the 30 m DEM grid values. While 45 m might be a good distance to use for those points which are very close to the stream, it will not produce accurate results for points further away.
 - It is highly recommended that you use a number higher than 90 m. This would include three grid cells at a diagonal.
 - If most of the drain points that are within 150 m of the stream are within the same grid cell as the stream, then there is no way to take an accurate average hillslope, anyway, so these point-to-stream distances should be removed from consideration.
 - If there is only a small percentage of points within 150 m of the stream, then you may also consider using the default 150 m. This will result in inaccurate slope values for those points within 150 m, but the majority of points will have more accurate values.
- d. Ensure that the *D8 Slope with Downslope Averaging Grid* will be saved to the correct place. Do not change the name.
- e. Click *Compute*. The layer will be added to the map, but can be turned off to save drawing time.

6. *Mass Wasting Potential Analysis-> Distance to Stream from Drain Point*



- a. Ensure that the *Drain Points Shapefile* (DrainPoints) and the *Distance to Stream Grid* (demdist) are correctly located.
- b. Click *Compute*.
- c. Check to make sure that the *DistToStream* field is populated in the DrainPoints Attribute Table. There should not be any zero values, unless a drain point is located exactly on a stream.

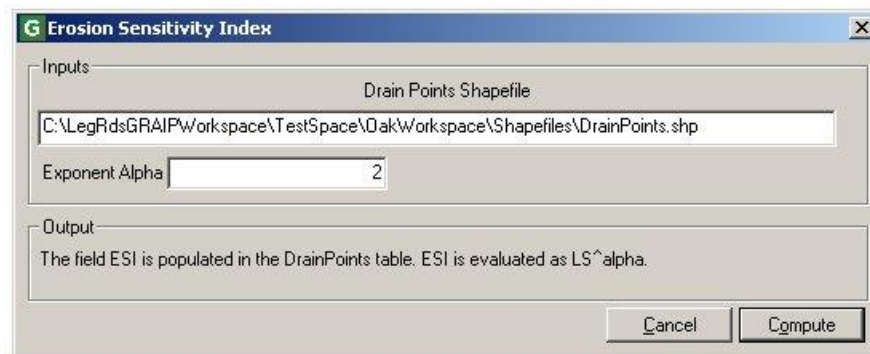
7. *Mass Wasting Potential Analysis-> Slope at Drain Point*



- a. Ensure that the *Drain Points Shapefile* (DrainPoints) and the *D8 Slope with Downslope Averaging Grid* (demslpd) are correctly located.
- b. Click *Compute*.
- c. Check to make sure the *Slope* column is populated in the DrainPoints Attribute Table. There should not be any zero values (unless the slope below a drain point is actually totally flat).

DrainPoints.UnitSed	DrainPoints.SedDel	DrainPoints.SI	DrainPoints.SIR	DrainPoints.Slope	DrainPoints.ESI	DrainPo
0.481893	0	2.258418	2.25909	0.171723	0	
1.394905	0	2.143331	1.45778	0.276508	0	
8.510792	0	1.967258	1.34407	0.28882	0	
3.95808	0	8.753125	8.75312	0.029256	0	
5.110711	0	4.059776	2.76986	0.07025	0	
5.059151	346.521851	2.791034	2.79103	0.119288	0	
6.236918	0	2.665183	2.66518	0.11122	0	
5.521542	0	2.83087	2.8308	0.090581	0	
3.134929	0	2.486201	1.65919	0.123635	0	
4.547994	0	1.952626	1.06815	0.130883	0	
6.394881	0	3.124053	1.8186	0.091871	0	
5.897792	0	0.930503	0.65053	0.190128	0	
4.972836	0	0.887064	0.79535	0.177141	0	
8.318025	0	1.091479	0.99946	0.186579	0	
3.418384	0	0.999979	0.99063	0.171399	0	

8. Mass Wasting Potential Analysis-> Erosion Sensitivity Index

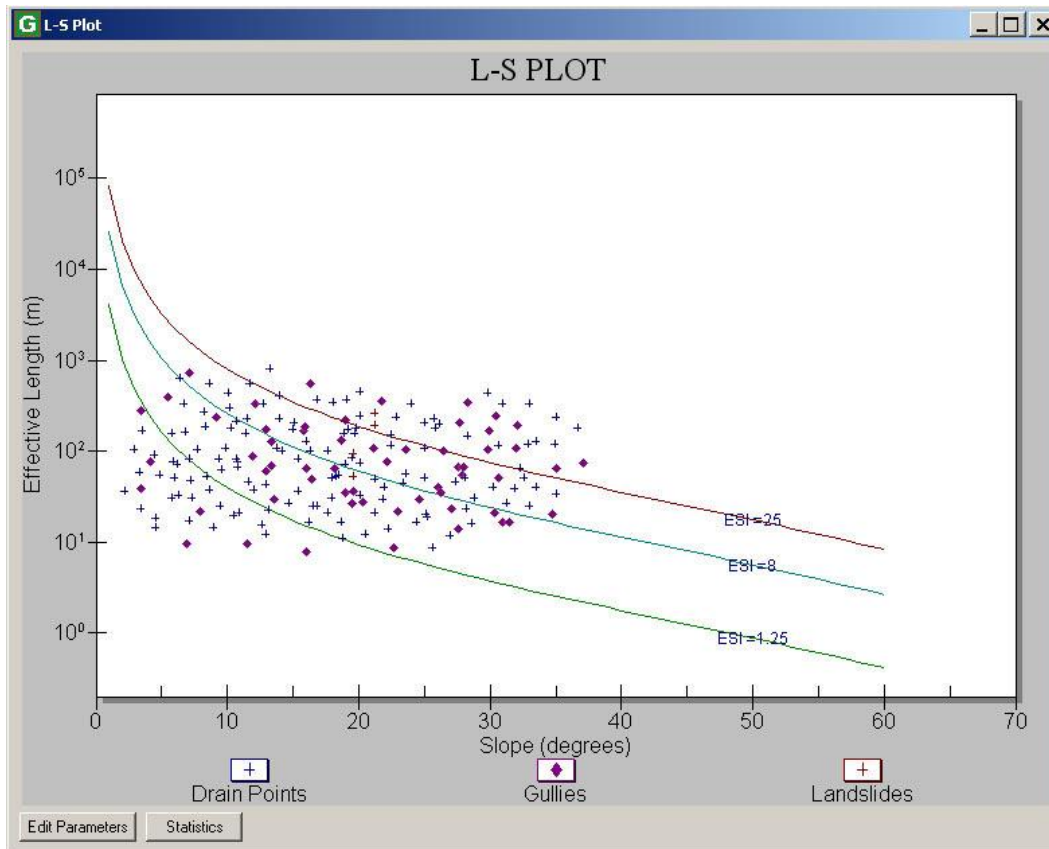


- a. The Erosion Sensitivity Index (ESI) assigns a value to each drain point that corresponds to the relative risk of a gully forming below that drain point.
- b. Ensure that the *Drain Points Shapefile* is correctly located.
- c. The default for the *Exponent Alpha* field is 2.
- d. Click *Compute*.
- e. Check to make sure the *ESI* column in the DrainPoints Attribute Table is populated. There may be some zero values, which are orphan drain points. This function sometimes takes a few moments to populate the table.

DrainPoints.SI	DrainPoints.SIR	DrainPoints.Slope	DrainPoints.ESI	DrainPoints.PipeDiaToChanWidthRatio	DrainPoints.P
2.258418	2.259095	0.171723	0.805741	0	
2.143331	1.457785	0.276503	2.662921	0	
1.967258	1.344074	0.28882	3.392562	0	
8.753125	8.753125	0.029245	0.101586	0	
4.059776	2.769869	0.07025	0.50174	0	
2.791034	2.791034	0.119263	0.974645	0	
2.665183	2.665183	0.11122	1.030762	0	
2.83087	2.83087	0.090561	0.494605	0	
2.486201	1.659195	0.123635	1.080483	0	
1.952626	1.068156	0.130863	1.479488	0	
3.124053	1.81866	0.091871	0.859044	0	
0.930503	0.650536	0.190123	3.298121	0	
0.887064	0.795353	0.177141	1.104155	0	
1.091479	0.999467	0.186529	0.972498	0	
0.999979	0.990637	0.171399	0.75515	0	

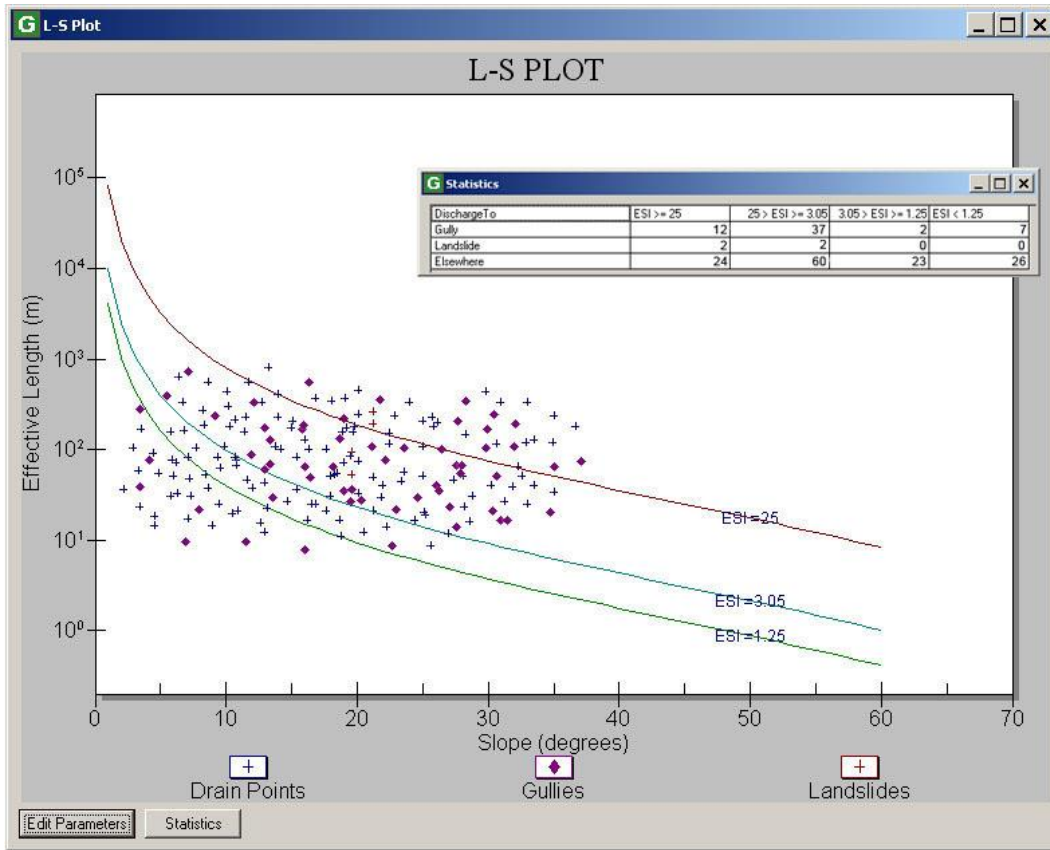
9. Mass Wasting Potential Analysis-> Length Slope Plot

- a. This generates a graph of effective length (m) vs. hillslope (degrees) of the drain points, including those drain points with gullies, with ESI isolines superimposed. Note that the Y-axis is logarithmic.
 - i. Effective length (or ELength) is the length of road that drains to each drain point.



- ii. The ESI isolines are plotted so that a point that lies on a particular line will have the ESI value of that line.
 - iii. The drain points that drain to gullies are represented as diamonds, those that drain to landslides as triangles, and the other drain points, which do not drain to gullies or landslides, as plus signs.
 - b. This figure can be used to pick a threshold value of ESI, above which, the risk of gully erosion increases significantly. This threshold may be referred to as ESI_{crit} .
 - i. Disregard or turn off the landslide points, as landslide risks may be unrelated to gully risks, and are addressed elsewhere in the model.
 - To turn off the landslide points, double-click anywhere in the chart area-> *Style* tab-> select *Landslides* from the options at right-> under *Point Type*, use the drop-down menu to select *Plus*-> click *OK*.
 - ii. This process only works if ELength and hillslope are the primary gully-forming factors. If other influences are more dominant, such as groundwater interception, variable soils and geology, or recent fire, then it may not be possible to determine reasonable ESI_{crit} thresholds.

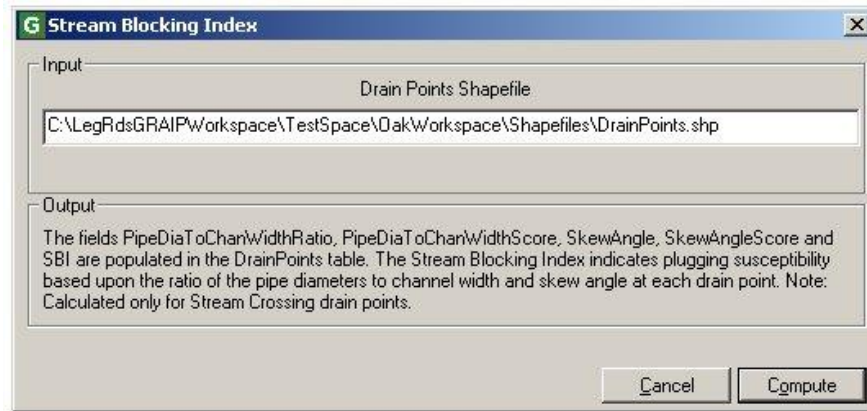
- iii. Generally, if there are not many gullies observed at drain points in your area, then gullying may not be of enough concern to complete this calibration process. For example, if you have a watershed with 5000 drain points, and only 25 of them have small gullies (0.5%), then the risks of further gully forming are probably not very high. However, if you have only 100 drain points, and only 5 gullies (5%), then sufficient risk probably exists to justify this calibration process. Note that, assuming your gullies fit the ELength-hillslope model, the more gullies you have, the easier and more accurate your calibration will be.
- iv. Notice that the distribution of drain points with gullies is weighted to the regions of the graph with higher ESI (further right and up; longer ELength and steeper slope). Therefore, the higher the ESI of a drain point, the higher the risk of gullying.
 - If this distribution trend is not present, then it is likely that the gullies recorded in your data have other contributors. If this is the case, you may have success if you can determine which points are affected by external factors and remove them from consideration.
- v. The goal is to find the ESI isoline that most closely bounds the lower part of the cluster of drain points with gullies. This process is similar to the process used in the calibration of SINMAP. You will move the middle ESI isoline (default value of 8) until you are satisfied with its location.
 - In the *L-S Plot* window, click *Edit Parameters*. From here, you can change the value of each ESI isoline, as well as the value of alpha (which you first encountered above in the *Erosion Sensitivity Index* function; generally, there is no need to change this value).
 - Change the value of the *Medium ESI* field to change the location of the middle ESI isoline. Larger values move the line up and right; smaller values move it down and left. Press *Ok*.
 - You can view information about the distribution of drain points with gullies among the ESI regions (i.e. the area between the ESI isolines) by clicking the *Statistics* button in the *L-S Plot* window.



- vi. The value of the middle ESI isoline when the line most closely bounds the cluster of drain points with gullies is the value of ESI_{crit} .
- c. If you have more GRAIP data for the same area, you may want to incorporate it into one L-S Plot that you can use to more accurately find the ESI_{crit} . This involves exporting the DrainPoints Attribute Table into a spreadsheet program, such as Microsoft Excel, and further combining and manipulating it there.
- d. If you desire a more rigorous analysis, you can export the relevant data into a statistical computing program, such as R, where you can apply regression techniques, such as the local fit regression, in order to find the ESI_{crit} threshold. Using this technique allows you to more easily see the point at which gully probabilities begin to significantly increase.
- e. ESI_{crit} can be used to determine the distribution of drain points that have a high risk of gullying but do not yet have a gully.

f. Nothing is added to any table, created, or saved in this step.

10. Mass Wasting Potential Analysis-> Stream Blocking Index



- a. Ensure that the *Drain Points Shapefile* is correctly located.
- b. Click *Compute*.
- c. Ensure that the *PipeDiaToChanWidthRatio*, *PipeDiaToChanWidthScore*, *SkewAngle*, *SkewAngleScore*, and *SBI* columns in the *DrainPoints* table are populated at stream crossings. Most of the values will likely be zeros, because most drain points are not stream crossings. The range of values is 1-4, with 4 being the highest risk.

DrainPoints.EID	DrainPoints.PipeDiaToChanWidthRatio	DrainPoints.PipeDiaToChanWidthScore	DrainPoints.SkewAngle	DrainPoints.SkewAngleScore	DrainPoints.SBI
0.21118	1	1	< 25 degrees	0	1
0.06124	0.75	2	45-75 degrees	1	3
0.38524	1	1	25-45 degrees	0	1
0.45266	1	1	45-75 degrees	1	2
1.01858	0.75	2	25-45 degrees	0	2
1.02456	1	1	25-45 degrees	0	1
1.44311	0	3	< 25 degrees	0	3
0.77298	2	1	< 25 degrees	0	1
4.00631	1.5	1	25-45 degrees	0	1
6.53786	1.5	1	<Null>	1	2
5.28683	1.5	1	25-45 degrees	0	1
13.98194	2	1	< 25 degrees	0	1
3.84392	1	1	< 25 degrees	0	1
2.143	2	1	< 25 degrees	0	1
	1.5	1	< 25 degrees	0	1

- i. Bridges and fords get an SBI value of 0, because SBI requires a culvert to be present to be applicable.

Appendix D: Attribute Table Field Name Explanations

The below Attribute Table for the DrainPoints shapefile replaces that found in *Appendix D: Attribute Field Name Explanations*, on pp. 136-137 of the original manual. The other Attribute Tables (RoadLines and the stream network shapefile) did not have any changes from GRAIP 1.0.8 to 1.0.9.

DrainPoints Attribute Table																			
<i>Field Name</i>	<i>Description</i>																		
FID	Feature ID number																		
Shape	Point; type of shapefile																		
GRAIPDID	GRAIP ID number																		
GRAIPDID	GRAIP ID number																		
DrainTypeID	Drain Point Type ID																		
	<table border="0"> <tr><td>1</td><td><i>Broad Based Dip</i></td></tr> <tr><td>2</td><td><i>Diffuse Drain</i></td></tr> <tr><td>3</td><td><i>Ditch Relief</i></td></tr> <tr><td>4</td><td><i>Lead Off Ditch</i></td></tr> <tr><td>5</td><td><i>Non-Engineered</i></td></tr> <tr><td>6</td><td><i>Stream Crossing</i></td></tr> <tr><td>7</td><td><i>Sump</i></td></tr> <tr><td>8</td><td><i>Water Bar</i></td></tr> <tr><td>9</td><td><i>Excavated Stream Crossing</i></td></tr> </table>	1	<i>Broad Based Dip</i>	2	<i>Diffuse Drain</i>	3	<i>Ditch Relief</i>	4	<i>Lead Off Ditch</i>	5	<i>Non-Engineered</i>	6	<i>Stream Crossing</i>	7	<i>Sump</i>	8	<i>Water Bar</i>	9	<i>Excavated Stream Crossing</i>
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6	<i>Stream Crossing</i>																		
7	<i>Sump</i>																		
8	<i>Water Bar</i>																		
9	<i>Excavated Stream Crossing</i>																		
Cdate	Collection Date																		
Ctime	Collection Time																		
VehicleID	Crew Identifier Number																		
DrainID	Drain point ID																		
StreamConnectID	Stream Connection																		
	<table border="0"> <tr><td>1</td><td><i>No</i></td></tr> <tr><td>2</td><td><i>Yes</i></td></tr> </table>	1	<i>No</i>	2	<i>Yes</i>														
1	<i>No</i>																		
2	<i>Yes</i>																		
OrphanID	Drain point orphan																		
	<table border="0"> <tr><td>0</td><td><i>Not applicable for drain type</i></td></tr> <tr><td>1</td><td><i>No</i></td></tr> <tr><td>2</td><td><i>Yes</i></td></tr> </table>	0	<i>Not applicable for drain type</i>	1	<i>No</i>	2	<i>Yes</i>												
0	<i>Not applicable for drain type</i>																		
1	<i>No</i>																		
2	<i>Yes</i>																		
Comments	Comments from field crew																		
SedProd	Produced sediment routed to drain point (kg/yr)																		
Elength	Effective length of flowpath to drain point (m)																		
UnitSed	Produced sediment per meter of road draining to drain point (kg/m/yr)																		
SedDel	Sediment delivered to the stream (kg/yr)																		

SI	Stability Index												
SIR	Combined Stability Index												
Slope	D8 Slope (L/L)												
ESI	Erosion Sensitivity Index												
PipeDiaToChanWidthRatio	Ratio of pipe diameter to channel width												
PipeDiaToChanWidthScore	Score for PipeDiaToChanWidthRatio												
SkewAngle	Angle between pipe and channel												
SkewAngleScore	Score for SkewAngle												
SBI	Stream Blocking Index												
Barrier	Fish passage barrier score												
	<table border="0"> <tr> <td style="padding-right: 10px;">0</td> <td><i>Blocked to all species</i></td> </tr> <tr> <td>1</td> <td><i>Unknown passage</i></td> </tr> <tr> <td>2</td> <td><i>Open to all species</i></td> </tr> </table>	0	<i>Blocked to all species</i>	1	<i>Unknown passage</i>	2	<i>Open to all species</i>						
0	<i>Blocked to all species</i>												
1	<i>Unknown passage</i>												
2	<i>Open to all species</i>												
DischargeT	Location on the hillslope where the drain point discharges												
	<table border="0"> <tr> <td style="padding-right: 10px;">1</td> <td><i>Forest floor</i></td> </tr> <tr> <td>2</td> <td><i>Gully</i></td> </tr> <tr> <td>3</td> <td><i>Ditch</i></td> </tr> <tr> <td>4</td> <td><i>Landslide</i></td> </tr> <tr> <td>5</td> <td><i>Wetland</i></td> </tr> <tr> <td>6</td> <td><i>Stream</i></td> </tr> </table>	1	<i>Forest floor</i>	2	<i>Gully</i>	3	<i>Ditch</i>	4	<i>Landslide</i>	5	<i>Wetland</i>	6	<i>Stream</i>
1	<i>Forest floor</i>												
2	<i>Gully</i>												
3	<i>Ditch</i>												
4	<i>Landslide</i>												
5	<i>Wetland</i>												
6	<i>Stream</i>												
DistToStre	Overland flow distance from the drain point to the nearest stream channel (m)												

Release Notes

Version Number	Release Date	Notes
1.0.0	5/24/07	
1.0.1	6/4/07	
1.0.2	7/6/07	
1.0.3	7/10/07	
1.0.4	8/14/07	<ul style="list-style-type: none"> - Link between Roadlines and Drainpoints created from CDate, CTime and Vehicle fields
1.0.5	9/14/07	<ul style="list-style-type: none"> - If near match is found for Add Value, reassign now initially selected - Added alpha and beta parameters to the Filter Stream Crossing function. - Added Slope to the Roadlines table - Added alpha parameter to the LS Plot function. - Clarified the meaning of Possible Passage.
1.0.6	2/29/08	<ul style="list-style-type: none"> - Added ability to have multiple input shapefiles of the same type - Expanded the length of several text fields in the database. - Fixed the preprocessor so that the file info is saved when an additional file is added to an existing project. - Delete DrainPoints and Roadlines index files when the shapefiles are deleted in the preprocessor so that expired index fields don't cause drain points and road line segments to disappear in ArcGIS.
1.0.7	3/9/09	<ul style="list-style-type: none"> - Fixed ELength calculation. - Fixed RemoveGrid function to only scan for GRID files rather than all raster dataset files. This prevents errors when there is another file with a raster dataset extension in the workspace.
1.0.8	3/20/10	<ul style="list-style-type: none"> - Fixed bug in the writing of parameters file for combined stability index function. The program should no longer overwrite parameters with the default parameters after they have been edited.
1.0.9	2/2014	<ul style="list-style-type: none"> - Fixed minor errors in <i>SedDir</i>, <i>SedAccum</i>, and <i>SpecSed</i>. - Modified the RoadLines range function for road slope. - Added <i>DischargeTo</i> field to DrainPoints shapefile to make it easier to export ESI data to external programs. - Added <i>DistToStre</i> field to DrainPoints shapefile. - Added flow path distance to streams to drain points. - Eliminated extra steps related to stream crossings and diffuse drains for <i>Combined Stability Index</i>. - <i>SBI</i> no longer applies to bridges and fords. - DEM resampling changed to a better method.

Updates are available through the GRAIP website: <http://www.fs.fed.us/GRAIP/index.shtml>

References

Cissel, Richard M., Black, Thomas A., Schreuders, Kimberly A. T., Prasad, Ajay, Luce, Charles H., Tarboton, David G., Nelson, Nathan A. 2012. *The Geomorphic Road Analysis and Inventory Package (GRAIP) Volume 2: Office Procedures*. Gen. Tech. Rep. RMRS-GTR-281. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 160 p.