

Forest Analysis Techniques

Evaluating economical timber amounts

—by Glen Jordan

Introduction

Problem

How do you calculate the operable timber yield of a forest by skidding distance (how far felled trees are from roadside)?

A common clearcut harvesting practice involves felling trees, by hand or machine, and skidding them to roadside for further processing and eventual transport to a mill. For a stand of trees to be "operable" (justifying operating costs), it must offer at least a minimum volume yield, and the felled trees must be accessible via road.

All things considered, the shorter the skidding distances to roadside, the more productive a harvest operation will be. Depending on the harvesting equipment, distances beyond a maximum would be uneconomical. How would you tally up operable timber amounts in a forest by skidding distance?

Location

A small, 1,400-hectare (ha) woodlot in the Acadian-New England forest region of North America

Time to complete the lab

Three hours

Keywords: timber forest product analysis; characterizing with a single number; numerical distribution; map; selecting features by attribute; using Python in the Field Calculator; summarizing an attribute; calculating a distance surface; calculating zonal statistics

Prerequisites

A basic working knowledge of ArcGIS® and geographic information system (GIS) data, including the geodatabase; familiarity with forest inventory data helpful but not essential

Data used in this lab

- Feature classes and rasters for a forest woodlot (personal geodatabase)
- Geographic coordinate system: NAD 1983 CSRS New Brunswick Stereographic
- Datum: NAD83 datum
- Projection: New Brunswick Double Stereographic Grid (unless otherwise stated)

Student activity

Sometimes after disturbances, such as fire, insects, and disease, that wipe out whole areas of trees, new trees of uniform height and age grow in their place. Such stands of trees lend themselves to clearcutting, a common harvesting technique in such forest regions, where cutting trees clears the way for skidding them to roadside for transportation.

Several operational constraints limit when and where stands can be scheduled for clearcutting. Two in particular are critical. First, stands must be operable—in other words, have a minimum volume yield sufficient to justify operating costs. Second, enough felled trees must be within skidding distance of the road.

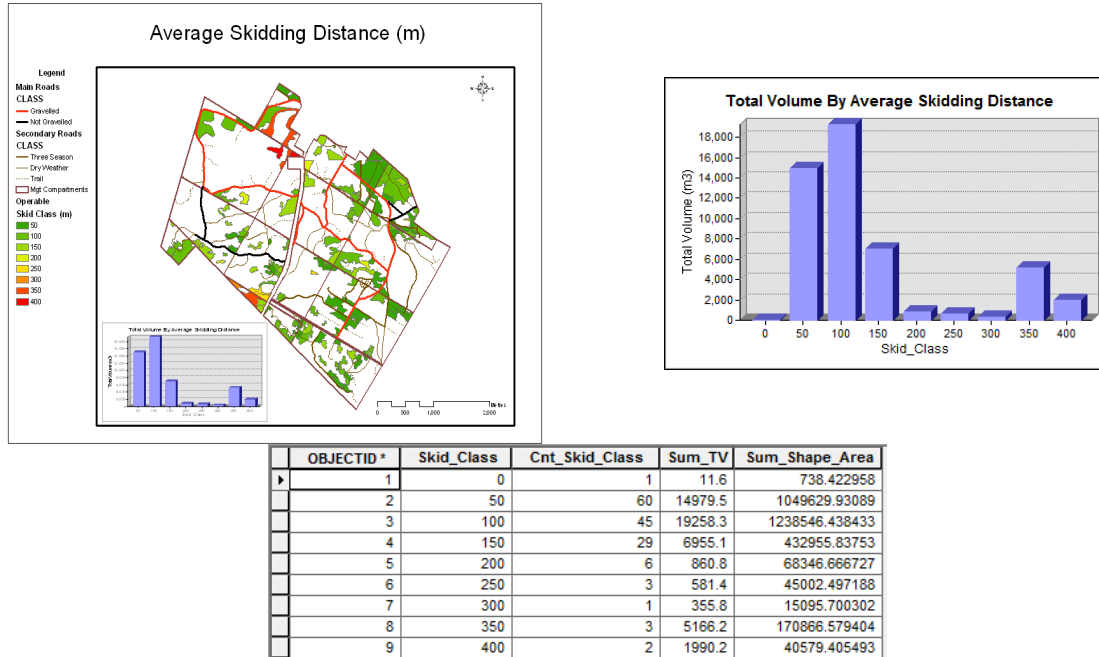
You'll evaluate economical timber amounts in the Woodlot with the following questions in mind:

- How much operable timber is there?
- How accessible are operable stands in the Woodlot?
- What range of skidding distances do you see in the Woodlot?
- What timber amounts are within economical skidding distances compared to those that are not?
- Is the existing Woodlot road network adequate?

You'll find answers by identifying operable timber in the Woodlot, assigning skidding distances to the nearest road, and computing areas and volumes of operable timber by 50-meter (m) distance classes.

Results expected

A map layout, summary table, and chart of operable timber amounts by 50 m skidding distance classes in the Woodlot



Data available

- Cover types feature class: *cover*
- Main road centerlines feature class: *clines*
- Secondary roads feature class: *roads*
- Stand volumes table: *volumes*
- Layer files for management compartments and main and secondary roads, located in the *Layer Files* folder

Solution steps

1. Identify operable stands.
2. Determine skidding distances.
3. Classify operable stands by average skidding distance.
4. Summarize operable stands by average skidding distance.
5. Map average skidding distances.

IDENTIFY OPERABLE STANDS

Your first task is to locate the forest stands that are practical to harvest—in other words, operable stands. In general, stand operability is determined by a minimum volume yield and species composition. In the case of the Woodlot, operable stands are those yielding a minimum of 75 m³/ha of any tree species, except stands with a significant tolerant hardwood content or stands situated on poorly drained sites, such as treed bogs.

RELATED CONCEPT: CHARACTERIZE USING A SINGLE NUMBER

- 1 Start ArcMap™, and if you haven't already, use *Environment Settings (Geoprocessing » Environments » Workspace)* to establish both your Current and Scratch Workspaces as your *Woodlot* geodatabase.
- 2 Add the cover types feature class (*cover*) from the *Woodlot* geodatabase as a layer.

Tolerant hardwoods are identifiable only via the *TH_* field in the stand volumes table. That means you must join *volumes* to the *Cover Types* attribute table to isolate operable stands.

- 3 Join the *volumes* table to *Cover Types* via their *Stand#* and *Stand_ID* fields.

Now, in the *Cover Types* attributes table, it's easy to identify stands with the minimum operable volume yield using the *VH* field, while bogs are easily identified where the *TYPE* field contains the BG code.

- 4 Use *Definition Query (Layer Properties » Definition Query)* to isolate operable stands in the *Cover Types* layer with the following query expression:

```
[cover.TYPE] <> 'BG' AND [cover.VH] >= 75 AND [volumes.TH_] <= 25
```

- 5 Rename the layer *Operable*.

The *Operable* layer should now contain 150 stands scattered across the Woodlot.



Figure 1. Operable stands in the Woodlot.

How much area do they occupy? How much timber volume do they contain? Those questions are easy to answer.

- 6 Open the *Operable* attribute table.
- 7 In turn, right-click the *Total Volume* and *Shape_Area* fields and select *Statistics*.

Field	Field
Total Volume	Shape_Area
Statistics:	Statistics:
Count: 150	Count: 150
Minimum: 11.6	Minimum: 603.412702
Maximum: 4240.1	Maximum: 169898.556553
Sum: 50158.9	Sum: 3061761.478926
Mean: 334.392667	Mean: 20411.743193
Standard Deviation: 601.359727	Standard Deviation: 25444.561015

Figure 2. Summary statistics for the *Total Volume* (TV) and *Shape_Area* attribute fields.

Results reveal that operable stands total 50,158.9 m³ of harvestable timber volume and occupy 306 ha. These are significant amounts, but how are the amounts positioned relative to the Woodlot's existing road network? Does the Woodlot's road network provide adequate access? More to the point, is most operable timber within an economical skidding distance?

DETERMINE SKIDDING DISTANCES

The significance of skidding distance in harvest economics is easy to grasp. But how do you characterize an entire stand with a skidding distance, when every square meter in any given stand is at some unique distance from a road?

You could try buffering roads in small increments, 1 m perhaps, up to some maximum skidding distance, say 500 m, and overlay the buffers on operable stands to partition them into 1 m skidding distance zones. While that approach is possible, using the *Multiple Ring Buffer* tool (*Analysis Tools » Proximity*), it would not be practical since several hundred 1 m buffers would have to be generated and overlaid on operable stands.

Another, more practical, solution lacks the precision of the 1 m buffers yet provides sufficient accuracy in this case. It involves assigning an average skidding distance to each operable stand, as opposed to trying to partition them into 1 m zones. If operable stands are generally small, as they are in the Woodlot, assigning average skidding distances still allows an accurate summary of operable timber amounts by skidding distances.

RELATED CONCEPT: CHARACTERIZE USING A SINGLE NUMBER

- 1 Assemble the Woodlot's road network by merging (*Data Management Tools » General*) the *clines* and *roads* feature classes. Exclude sewer and transmission lines (*CLASS* field) found in *clines* using *Definition Query*.
- 2 Name the layer *RoadNetwork*.

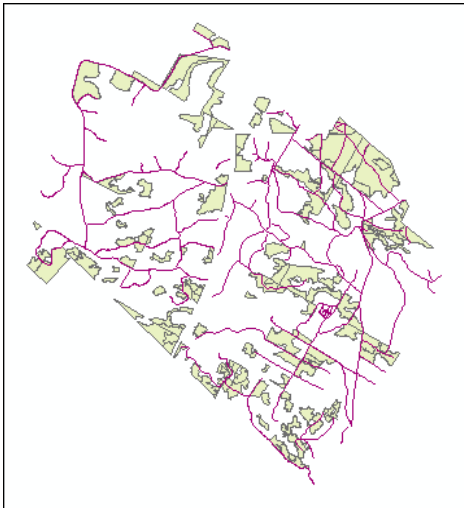


Figure 3. The Woodlot's road network (156 features) superimposed on operable stands.

It appears that the Woodlot has adequate roads overall and that most operable stands have a road adjacent or passing through. Yet many areas within stands appear quite distant from a road, which tells you that some stands may have a large average skidding distance.

You can find out by computing distances around the road network.

- 3 Use the *Euclidean Distance* tool (*Spatial Analyst Tools » Distance*) to compute a distance raster (10 x 10 m cell size) that records incremental distances around the entire Woodlot road network. Make sure to set the processing extent to the Woodlot property (the *compart* feature class in the *Woodlot* geodatabase) via the tool's *Environments* button.
- 4 Name the output *SkidDistance*.

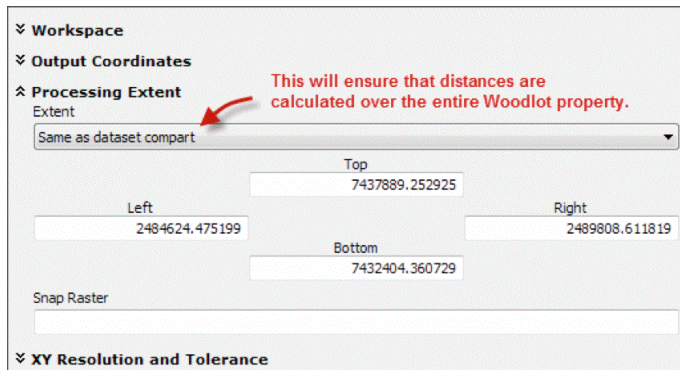
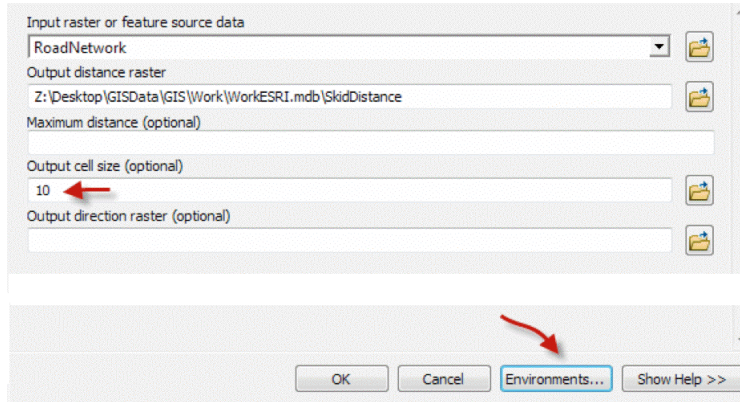


Figure 4. *Euclidean Distance* tool setup, with *Processing Extent* defined as the *compart* feature class.

Question 1: *What would happen if you didn't set a value for Processing Extent?*

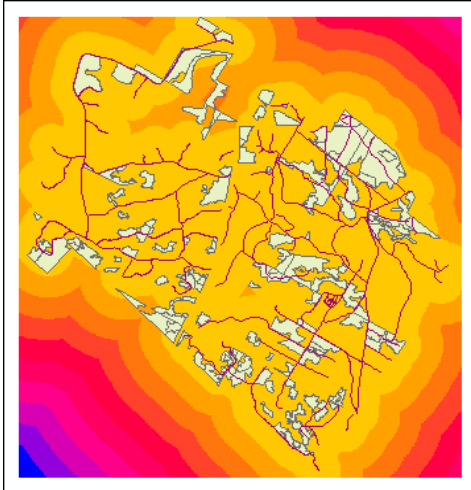


Figure 5. Continuous distance surface (10 m cell size) around the Woodlot's road network.

In the *SkidDistance* display, you can see bands of distance emanating out around the Woodlot's road network.

You can improve the display by confining the distance raster to Woodlot property boundaries and by remapping the distances into 50 m classes.

- 5 Use *Extract By Mask* (*Spatial Analyst Tools* » *Extraction*) to derive a distance raster confined to the Woodlot by clipping with the *compart* feature class.
- 6 Name it *WoodlotSkid*.

Input raster	SkidDistance
Input raster or feature mask data	Z:\Desktop\GISData\GIS\Work\WorkESRI.mdb\compart
Output raster	Z:\Desktop\GISData\GIS\Work\WorkESRI.mdb\WoodlotSkid

Figure 6. Clipping the distance surface to the boundaries of the Woodlot.

- 7 Remove *SkidDistance*, and you can see the new distance raster confined to the Woodlot.

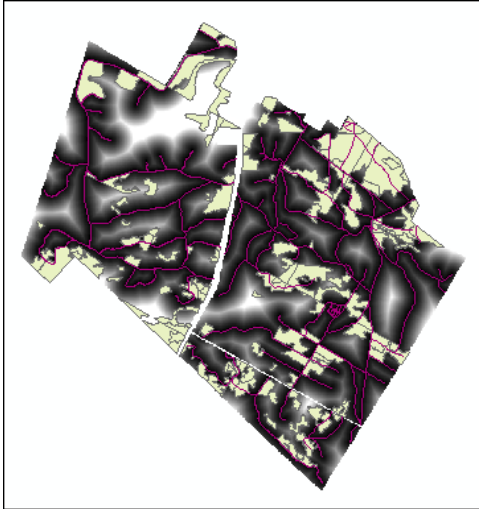


Figure 7. Distance surface confined to the Woodlot property.

Note that the maximum distance is about 613 m. So, no area in the Woodlot is farther than 613 m from a road.

How can you use this distance raster to assign an average distance to each *Operable* stand, and with that done, compile a summary of operable timber amounts by skidding distance?

CLASSIFY OPERABLE STANDS BY AVERAGE SKIDDING DISTANCE

Within each operable stand, you want to examine skidding distance values in *WoodlotSkid*, compute an average, and assign the average to the stand. What ArcGIS tool allows you to do this?

RELATED CONCEPT: RECLASSIFY SPATIALLY

- 1 Use the *Zonal Statistics as Table* tool (*Spatial Analyst Tools » Zonal*) to compute a summary table of *WoodlotSkid* values within each operable stand (zone).
- 2 Name the output table *SkiddingStats*.

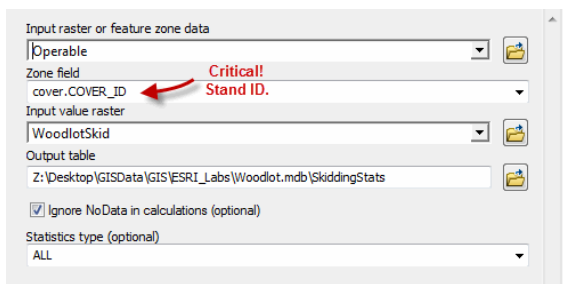


Figure 8. Calculating skidding distance statistics for each Woodlot feature (*COVER_ID* field).

If you open and examine the result table *SkiddingStats* (figure 9), you'll see that a variety of skidding distance statistics—*MIN*, *MAX*, *RANGE*, *MEAN*, and so forth—are shown for each of the 150 operable stands (*COVER_ID* field). For example, the average skidding distance for Woodlot stand 101 is 50 m.

OBJECTID*	COVER_ID	COUNT_	AREA	MIN_	MAX_	RANGE	MEAN	STD	SUM
1	101	225	22500	0	98.488579	98.488579	49.972233	28.104927	11243
2	103	184	18400	0	110	110	41.640053	27.540827	766
3	107	1100	11000	90.553848	612.94373	522.38989	314.37732	163.05795	34581
4	108	691	69100	0	158.11388	158.11388	63.691181	37.551941	44010
5	109	83	8300	0	30	30	12.324463	5.48045	1022.1
6	201	314	31400	0	106.30146	106.30146	24.982231	23.737476	7844.4
7	202	1584	15840	0	130	130	49.52269	34.400944	78443
8	206	200	20000	22.36068	192.35384	169.99316	118.89143	39.652576	23778
9	208	16	1600	0	40	40	21.078279	10.580934	337.2
10	211	209	20900	0	84.852814	84.852814	36.336235	20.838028	7594.1
11	217	143	14300	50.990196	192.35384	141.36365	133.61002	29.567532	19106
12	218	316	31600	0	172.62677	172.62677	110.69624	38.320938	34980
13	220	85	8500	0	72.111023	72.111023	28.266035	17.719267	2402
14	224	173	17300	0	58.309521	58.309521	19.094414	13.456154	3303.1

Figure 9. Summary skidding distance statistics for each operable stand in the Woodlot.

That's all well and good, but how do you actually assign *MEAN* values to stands in the *Operable* feature class? Why should you care?

Ultimately, you want to know how operable stand amounts, area and volume, are distributed across skidding distances. To compute a summary table of this information, you need the *MEAN* skidding distance values found in *SkiddingStats* present in the *Operable* feature class.

How do you copy *MEAN* values from *SkiddingStats* into the *Operable* attribute table?

- 3 Join *SkiddingStats* to the *Operable* attribute table via their shared stand identifiers, *COVER_ID* and *Stand#*, respectively.

Doing this provides access to information in both tables. It's now easy to copy skidding distances into the *Operable* feature class.

- 4 Open the *Operable* attribute table.
- 5 Add a new float field named *Skid_Distance* (*Table Options* » *Add Field*).

6 Use *Field Calculator* to calculate $Skid_Distance = MEAN$.

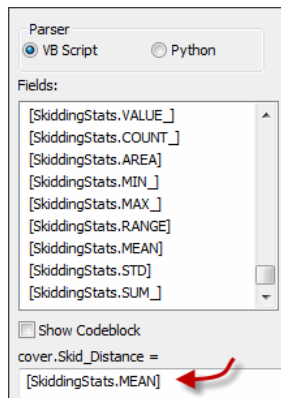


Figure 10. Assigning mean skidding distances to operable stands.

Average skidding distances are now assigned to each operable stand. By sorting the *Skid_Distance* field in descending order, you can see that average skidding distances range from almost 400 m down to 10 m. Computing your summary table is next.

SUMMARIZE OPERABLE STANDS BY AVERAGE SKIDDING DISTANCE

Here, you want to determine how operable volume amounts (*TV* field) and stand areas (*Shape_Area*) are distributed across the array of skidding distances (*Skid_Distance*). Are most at the greater distances, or are they evenly distributed across all distances or in some other pattern?

First, decide on skidding distance classes that are meaningful for use as the basis of the summary. What makes sense—25 m, 50 m, 75 m, 100 m, or some other class interval? Given the nature of harvesting operations and the typical harvesting equipment used in the Woodlot, 50 m or 75 m are resolutions that would be meaningful. Go with the finer resolution, 50 m.

RELATED CONCEPT: CHARACTERIZE USING A NUMERIC DISTRIBUTION

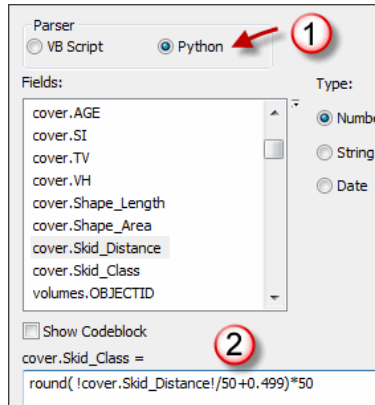
- 1 Remove the joined table *SkiddingStats* from the *Operable* layer.

Removing the joined table will improve the efficiency of subsequent processing operations but is optional.

- 2 Open the *Operable* attribute table.
- 3 Add a short integer field named *Skid_Class*.

- 4 Use the following Python formula in *Field Calculator* to populate *Skid_Class* with 50 m distance classes:

```
Skid_Class = round(Skid_Distance / 50 + 0.499) * 50.
```



You could use Visual Basic (VB) here instead of Python. The problem with VB is that it does not deal well with Null field values. In this case, there are none.

Figure 11. Calculating 50 m skid distance classes using the *Python Round* function.

Efficient calculation method

The formula is a very efficient way to calculate defined interval classes when compared with the alternative—a series of *Select By Attributes* and *Field Calculator* operations. The general form of the formula is `round(infield / interval + 0.49) * interval`. To correctly handle input values that lie on interval boundaries, though, you will have to change `0.49` to `0.499` or `0.4999`, and so forth, depending on how many decimal places are involved in the input field. **Warning:** If the inputs are whole numbers, add a decimal to `interval` to avoid truncating when dividing.

Now you're ready to summarize the skidding distance classes by operable volume and area totals.

- 5 Summarize *Skid_Class* (right-click *Skid_Class* and click *Summarize*) by *TV* and *Shape_Area* sum in a table named *Skid_Summary* in your geodatabase.

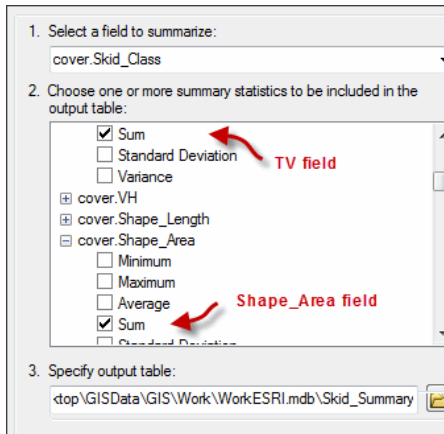


Figure 12. Calculating volume (TV) and area (Shape_Area) totals by 50 m skidding classes (Skid_Class).

By opening the *Skid_Summary* table (figure 12), you can see that most of the currently operable timber in the Woodlot (more than 270 ha) has an average skidding distance of 150 m or less. However, more than 7,000 m³ lie 350 m and beyond, which would probably require additional road building to make economical harvesting possible.

	OBJECTID *	Skid_Class	Cnt_Skid_Class	Sum_TV	Sum_Shape_Area
▶	1	0	1	11.6	738.422958
	2	50	60	14979.5	1049629.93089
	3	100	45	19258.3	1238546.438433
	4	150	29	6955.1	432955.83753
	5	200	6	860.8	68346.666727
	6	250	3	581.4	45002.497188
	7	300	1	355.8	15095.700302
	8	350	3	5166.2	170866.579404
	9	400	2	1990.2	40579.405493

Figure 13. Volume (m³) and area (m²) totals by 50 m average skidding distance for operable stands in the Woodlot.

A histogram is always a powerful way to capture the pattern in tabular summaries, such as *Skid_Summary*.

- 6 Create a vertical bar histogram of *Sum_TV* by *Skid_Class* (Table Options » Create Graph) similar to the following:

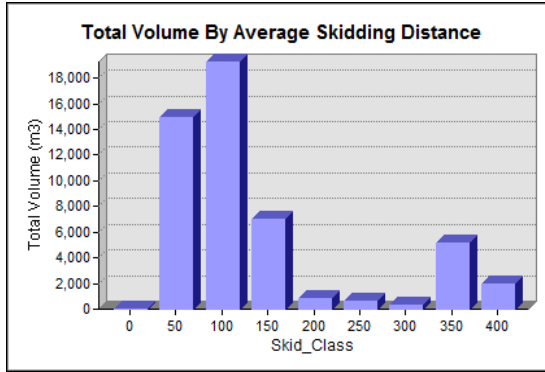


Figure 14. Histogram of total volume (m^3) by average skidding distance (m) for operable stands in the Woodlot.

The bimodal distribution of volume amounts is now very obvious. What does the area distribution look like? Chart that and find out if you wish.

How are operable timber volumes distributed spatially—in other words, what's their spatial pattern? For example, are the amounts beyond 300 m dispersed or clustered? A map of average skidding distances (*Skid_Class*) will help you answer that.

MAP AVERAGE SKIDDING DISTANCES

A map that symbolizes 50 m skidding distance classes with a unique color scheme helps you visualize the spatial distribution of operable stands relative to their average skidding distances.

RELATED CONCEPT: CHARACTERIZE USING A MAP (GEOGRAPHIC DISTRIBUTION)

- 1 Map the *Skid_Class* field in *Operable* uniquely, with a *Slope* color ramp.

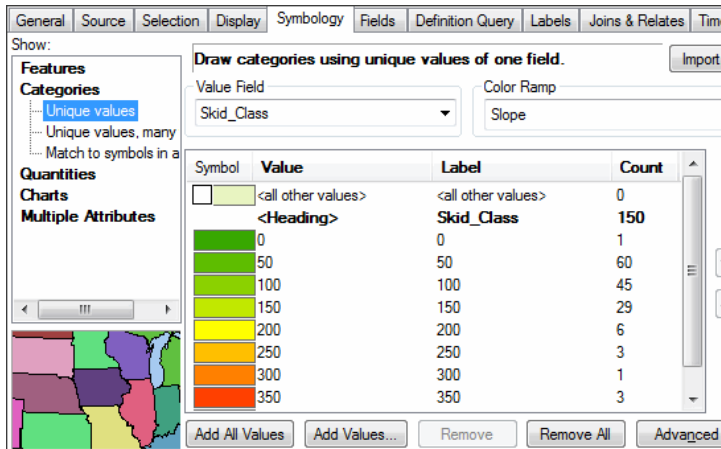


Figure 15. Mapping average skidding distance classes (*Skid_Class*) using the slope color ramp.

Comparing green shaded areas to orange and red areas, note that operable stands beyond 300 m are clustered in just two areas of the Woodlot. Building roads to access these should be relatively inexpensive.

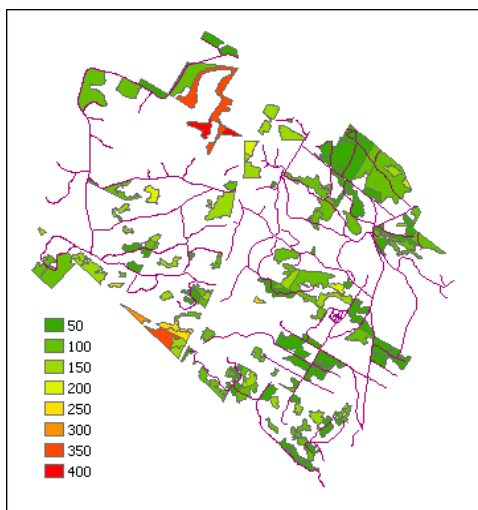


Figure 16. Geographic distribution of operable stands by their average skidding distance.

To present your analysis results to a larger audience, a map layout that includes the histogram, as well as the map, would be ideal. Try that.

- 2 First, though, from the *Layer Files* folder, add layer files *Main Roads*, *Secondary Roads*, and *Mgt Compartments*.

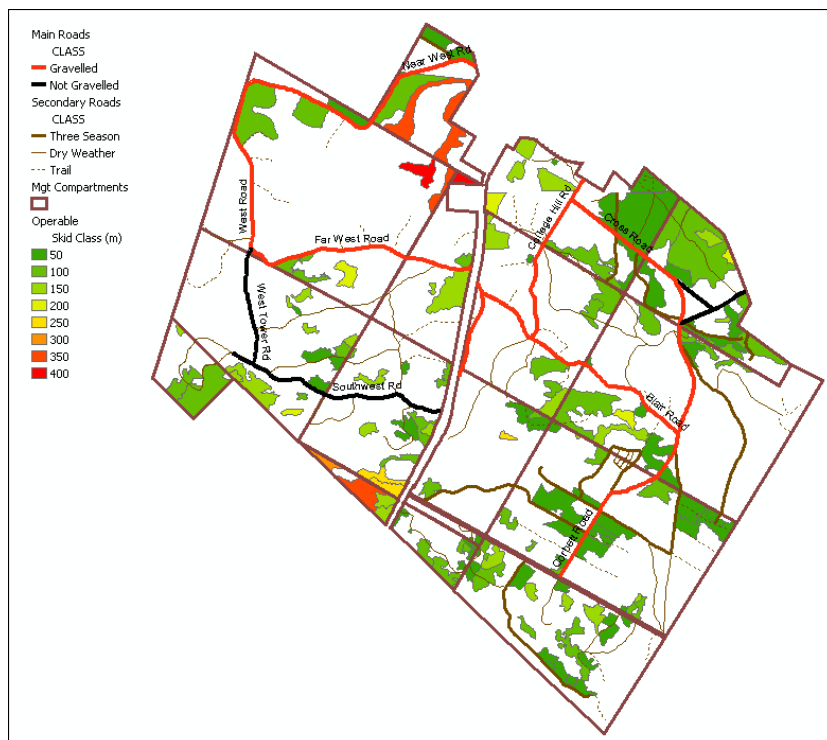


Figure 17. Map of average skidding distances for operable stands in the Woodlot, with main and secondary roads and management compartment layer files added.

This provides spatial context for the skidding classes theme. Now, on to the layout.

3 Enter *Layout* view.

4 Use one of the built-in landscape layout templates (*Layout » Change Layout*) to assemble a map layout, zoomed out fully on the Woodlot.

That presents your map in a pretty wrapper. While the layout provides visual clues about average skidding distances and operable timber, it's only half the story.

5 Right-click the title bar of your histogram window (*View » Graphs* if the chart is closed) and select *Add to Layout*.

6 Position and resize the chart in the layout.

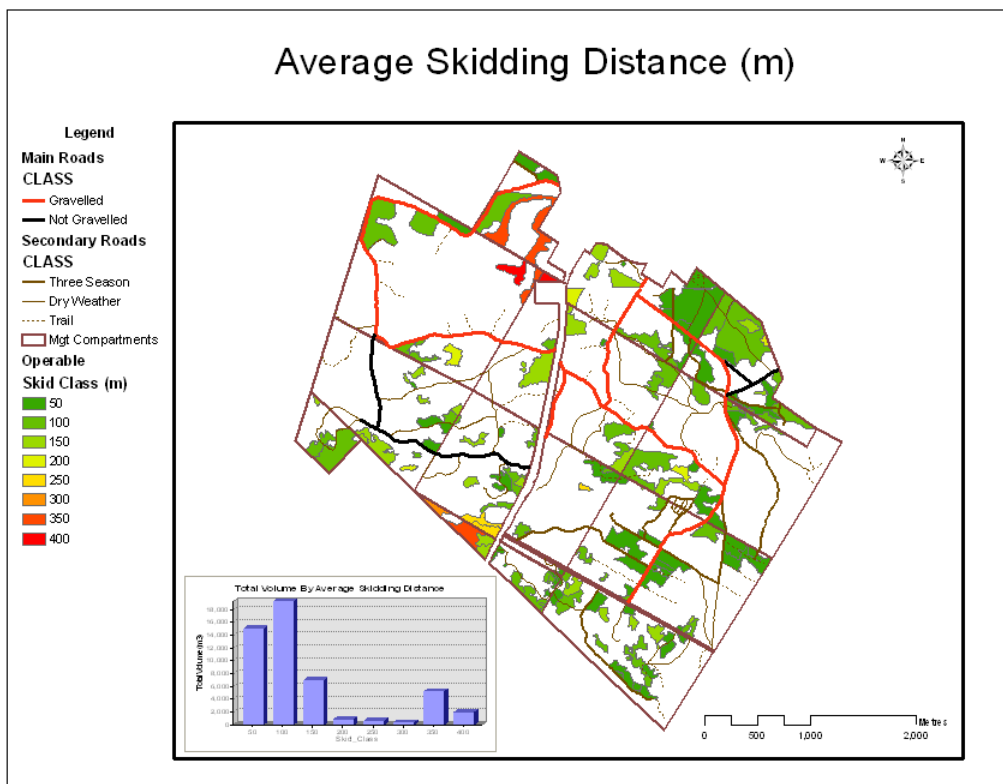


Figure 18. Map layout of average skidding distances for operable stands in the Woodlot, with main and secondary roads and management compartment layer files and histogram added.

This gives you both numbers and a map to inform your audience. They're a powerful combination.

Conclusion

Your analysis reveals that very little of the Woodlot's operable timber is beyond an economical skidding distance. What is beyond is clustered in a couple of patches that could easily be served by a minimum of all-season or dry-weather road building.

You might want to explore changing some parameters such as operable timber criteria or the selection criteria for identifying the road network. Do Woodlot trails really provide adequate harvest access? Are results sensitive to changes in these inputs?

You might also consider taking a different approach for assigning operable stands a skidding distance. What if, unlike the Woodlot, your forest consisted of mainly larger stands? In that case, assigning average skidding distances might not be reasonable. As an alternative, you could use the *Multiple Ring Buffer* tool to create concentric buffers of some width, say 50 m, around the road network, and overlay those on operable stands to partition them into distance zones. Or, why not simply use the *Reclassify* tool to classify the skidding distance raster into 50 m classes? Then, using the *Zonal Statistics as Table* tool, compute total volume amounts of operable stands in each 50 m class (zone).

Submit your work

- Summary table, chart, and map layout of operable stands by average skidding distance
- A summary of the exercise, indicating where and how the related reclassify and characterize concepts and analysis techniques are used (Your summary could take the form of a table that checks off each of these elements.)
- Explanation of why, when using the formula $\text{round}(\text{invalue}/\text{interval} + 0.49) * \text{interval}$, it's important to add a decimal place to `interval` when `invalue` is a whole number
- Answer to the question posed in the exercise:
 1. What would happen if you didn't set a value for Processing Extent when using the Euclidean Distance tool?
- Results gathered using the suggested alternative solutions:
 - Use the *Multiple Ring Buffer* tool to create concentric buffers of some width, say 50 m, around the road network and overlay those on operable stands to partition them into distance zones.
 - Use the *Reclassify* tool to build a raster of 50 m skidding classes. Then, using the *Zonal Statistics as Table* tool, compute operable stand volume totals (*TV* field) for each class (zone). Hint: You'll need to create a *TV* raster where each 10 m cell contains a volume amount (*VH* values - $\text{m}^3/\text{ha} * 0.01 \text{ ha}$).

Credits

Sources of supplied data

Course Data

Data\cover, courtesy of University of New Brunswick Faculty of Forestry and Environmental Management

Data\highway, courtesy of University of New Brunswick Faculty of Forestry and Environmental Management

Data\newprop, courtesy of University of New Brunswick Faculty of Forestry and Environmental Management

Data\tin, courtesy of University of New Brunswick Faculty of Forestry and Environmental Management

Data\Woodlot.mdb, courtesy of University of New Brunswick Faculty of Forestry and Environmental Management

Data\Codes\Woodlot_Codes.xls, courtesy of University of New Brunswick UNB Faculty of Forestry and Environmental Management

Data\Coordinate Systems\ATS 1977 New Brunswick Stereographic.prj, courtesy of ESRI
Data\Coordinate Systems\NAD 1983 CSRS New Brunswick Stereographic.prj, courtesy of ESRI

Data\GPS\Knowledge.shp, courtesy of University of New Brunswick
Data\GPS\towers.xls, courtesy of University of New Brunswick Faculty of Forestry and Environmental Management

Data\Layer Files\Age Classes.lyr, courtesy of Glen Jordan
Data\Layer Files\Air Photo Centre Points.lyr, courtesy of Glen Jordan
Data\Layer Files\Main Roads.lyr, courtesy of Glen Jordan
Data\Layer Files\Mgt Compartments.lyr, courtesy of Glen Jordan
Data\Layer Files\Non-forested.lyr, courtesy of Glen Jordan
Data\Layer Files\Secondary Roads.lyr, courtesy of Glen Jordan
Data\Layer Files\Streams.lyr, courtesy of Glen Jordan

Data\Mass Points\DTM.txt, courtesy of Service New Brunswick

Data\Models\Clearcutting.tbx, courtesy of Glen Jordan
Data\Models\Forest Analysis.tbx, courtesy of Glen Jordan
Data\Models\Forest Values.tbx, courtesy of Glen Jordan

Data\Orthophotos\Z45856650.tif, courtesy of Service New Brunswick
Data\Orthophotos\Z45856660.tif, courtesy of Service New Brunswick
Data\Orthophotos\Z45856670.tif, courtesy of Service New Brunswick
Data\Orthophotos\Z45906650.tif, courtesy of Service New Brunswick
Data\Orthophotos\Z45906660.tif, courtesy of Service New Brunswick
Data\Orthophotos\Z45906670.tif, courtesy of Service New Brunswick
Data\Orthophotos\Z45956650.tif, courtesy of Service New Brunswick
Data\Orthophotos\Z45956660.tif, courtesy of Service New Brunswick
Data\Orthophotos\Z45956670.tif, courtesy of Service New Brunswick

Data\Photos\118_178.TIFF, courtesy of University of New Brunswick Faculty of Forestry and Environmental Management

Data\Photos\118_178.tiffw, courtesy of University of New Brunswick Faculty of Forestry and Environmental Management

Data\Photos\118_178r.tif, courtesy of University of New Brunswick Faculty of Forestry and Environmental Management

Data\Photos\118_180.TIFF, courtesy of University of New Brunswick Faculty of Forestry and Environmental Management

Data\Photos\118_180.tiffw, courtesy of University of New Brunswick Faculty of Forestry and Environmental Management

Data\Photos\118_180r.tif, courtesy of University of New Brunswick Faculty of Forestry and Environmental Management

Data\Photos\118_182.TIFF, courtesy of University of New Brunswick Faculty of Forestry and Environmental Management

Data\Photos\118_182.tiffw, courtesy of University of New Brunswick Faculty of Forestry and Environmental Management

Data\Photos\118_182r.tif, courtesy of University of New Brunswick Faculty of Forestry and Environmental Management

Data\Photos\118_184.TIFF, courtesy of University of New Brunswick Faculty of Forestry and Environmental Management

Data\Photos\118_184.tiffw, courtesy of University of New Brunswick Faculty of Forestry and Environmental Management

Data\Photos\118_184r.tif, courtesy of University of New Brunswick Faculty of Forestry and Environmental Management

Data\Photos\119_61.TIFF, courtesy of University of New Brunswick Faculty of Forestry and Environmental Management

Data\Photos\119_61.tiffw, courtesy of University of New Brunswick Faculty of Forestry and Environmental Management

Data\Photos\119_61r.tif, courtesy of University of New Brunswick Faculty of Forestry and Environmental Management

Data\Photos\119_65.TIFF, courtesy of University of New Brunswick Faculty of Forestry and Environmental Management

Data\Photos\119_65.tiffw, courtesy of University of New Brunswick Faculty of Forestry and Environmental Management

Data\Photos\119_65r.tif, courtesy of University of New Brunswick Faculty of Forestry and Environmental Management

Data\Photos\119_67.TIFF, courtesy of University of New Brunswick Faculty of Forestry and Environmental Management

Data\Photos\119_67.tiffw, courtesy of University of New Brunswick Faculty of Forestry and Environmental Management

Data\Photos\119_67r.tif, courtesy of University of New Brunswick Faculty of Forestry and Environmental Management

Data\Photos\119_69.TIFF, courtesy of University of New Brunswick Faculty of Forestry and Environmental Management

Data\Photos\119_69.tiffw, courtesy of University of New Brunswick Faculty of Forestry and Environmental Management

Data\Photos\119_69r.tif, courtesy of University of New Brunswick Faculty of Forestry and Environmental Management

Data\Photos\120_112.TIFF, courtesy of University of New Brunswick Faculty of Forestry and Environmental Management

Data\Photos\120_112.tiffw, courtesy of University of New Brunswick Faculty of Forestry and Environmental Management

Data\Photos\l20_112r.tif, courtesy of University of New Brunswick Faculty of Forestry and Environmental Management
Data\Photos\l20_114r.tif, courtesy of University of New Brunswick Faculty of Forestry and Environmental Management
Data\Photos\l21_30.TIFF, courtesy of University of New Brunswick Faculty of Forestry and Environmental Management
Data\Photos\l21_30.tiffw, courtesy of University of New Brunswick Faculty of Forestry and Environmental Management
Data\Photos\l21_30r.tif, courtesy of University of New Brunswick Faculty of Forestry and Environmental Management
Data\Photos\l21_32.TIFF, courtesy of University of New Brunswick Faculty of Forestry and Environmental Management
Data\Photos\l21_32.tiffw, courtesy of University of New Brunswick Faculty of Forestry and Environmental Management
Data\Photos\l21_32r.tif, courtesy of University of New Brunswick Faculty of Forestry and Environmental Management
Data\Photos\l21_34.TIFF, courtesy of University of New Brunswick Faculty of Forestry and Environmental Management
Data\Photos\l21_34.tiffw, courtesy of University of New Brunswick Faculty of Forestry and Environmental Management
Data\Photos\l21_34r.tif, courtesy of University of New Brunswick Faculty of Forestry and Environmental Management
Data\Photos\l21_36.TIFF, courtesy of University of New Brunswick Faculty of Forestry and Environmental Management
Data\Photos\l21_36.tiffw, courtesy of University of New Brunswick Faculty of Forestry and Environmental Management
Data\Photos\l21_36r.tif, courtesy of University of New Brunswick Faculty of Forestry and Environmental Management
Data\Photos\l21_38.TIFF, courtesy of University of New Brunswick Faculty of Forestry and Environmental Management
Data\Photos\l21_38.tiffw, courtesy of University of New Brunswick Faculty of Forestry and Environmental Management
Data\Photos\l21_38r.tif, courtesy of University of New Brunswick Faculty of Forestry and Environmental Management
Data\Photos\l22_77.TIFF, courtesy of University of New Brunswick Faculty of Forestry and Environmental Management
Data\Photos\l22_77.tiffw, courtesy of University of New Brunswick Faculty of Forestry and Environmental Management
Data\Photos\l22_77r.tif, courtesy of University of New Brunswick Faculty of Forestry and Environmental Management
Data\Photos\l23_16.TIFF, courtesy of University of New Brunswick Faculty of Forestry and Environmental Management
Data\Photos\l23_16.tiffw, courtesy of University of New Brunswick Faculty of Forestry and Environmental Management
Data\Photos\l23_16r.tif, courtesy of University of New Brunswick Faculty of Forestry and Environmental Management

Data\Photos\l23_18.TIFF, courtesy of University of New Brunswick Faculty of Forestry and Environmental Management
Data\Photos\l23_18.tiffw, courtesy of University of New Brunswick Faculty of Forestry and Environmental Management
Data\Photos\l23_18r.tif, courtesy of University of New Brunswick Faculty of Forestry and Environmental Management
Data\Photos\l23_20.TIFF, courtesy of University of New Brunswick Faculty of Forestry and Environmental Management
Data\Photos\l23_20.tiffw, courtesy of University of New Brunswick Faculty of Forestry and Environmental Management
Data\Photos\l23_20r.tif, courtesy of University of New Brunswick Faculty of Forestry and Environmental Management
Data\Photos\l23_22.TIFF, courtesy of University of New Brunswick Faculty of Forestry and Environmental Management
Data\Photos\l23_22.tiffw, courtesy of University of New Brunswick Faculty of Forestry and Environmental Management
Data\Photos\l23_22r.tif, courtesy of University of New Brunswick Faculty of Forestry and Environmental Management
Data\Photos\l24_129.TIFF, courtesy of University of New Brunswick Faculty of Forestry and Environmental Management
Data\Photos\l24_129.tiffw, courtesy of University of New Brunswick Faculty of Forestry and Environmental Management
Data\Photos\l24_129r.tif, courtesy of University of New Brunswick Faculty of Forestry and Environmental Management
Data\Photos\l24_131.TIFF, courtesy of University of New Brunswick Faculty of Forestry and Environmental Management
Data\Photos\l24_131.tiffw, courtesy of University of New Brunswick Faculty of Forestry and Environmental Management
Data\Photos\l24_131r.tif, courtesy of University of New Brunswick Faculty of Forestry and Environmental Management
Data\Photos\l26_175.TIFF, courtesy of University of New Brunswick Faculty of Forestry and Environmental Management
Data\Photos\l26_175.tiffw, courtesy of University of New Brunswick Faculty of Forestry and Environmental Management
Data\Photos\l26_175r.tif, courtesy of University of New Brunswick Faculty of Forestry and Environmental Management
Data\Photos\image2345, courtesy of University of New Brunswick Faculty of Forestry and Environmental Management
Data\Photos\image2345c1, courtesy of University of New Brunswick Faculty of Forestry and Environmental Management
Data\Photos\image2345c2, courtesy of University of New Brunswick Faculty of Forestry and Environmental Management
Data\Photos\image2345c3, courtesy of University of New Brunswick Faculty of Forestry and Environmental Management

Data\Rasters\accessibility, courtesy of University of New Brunswick Faculty of Forestry and Environmental Management

Data\Rasters\dollarvalue, courtesy of University of New Brunswick Faculty of Forestry and Environmental Management

Data\Rasters\elevation, courtesy of University of New Brunswick Faculty of Forestry and Environmental Management

Data\Shapes\basemap.shp, courtesy of University of New Brunswick Faculty of Forestry and Environmental Management

Data\Shapes\clines.shp, courtesy of University of New Brunswick Faculty of Forestry and Environmental Management

Data\Shapes\compart.shp, courtesy of University of New Brunswick Faculty of Forestry and Environmental Management

Data\Shapes\cover.shp, courtesy of University of New Brunswick Faculty of Forestry and Environmental Management

Data\Shapes\cpoints.shp, courtesy of University of New Brunswick Faculty of Forestry and Environmental Management

Data\Shapes\outline.shp, courtesy of University of New Brunswick Faculty of Forestry and Environmental Management

Data\Shapes\proads.shp, courtesy of University of New Brunswick Faculty of Forestry and Environmental Management

Data\Shapes\publicrow.shp, courtesy of University of New Brunswick Faculty of Forestry and Environmental Management

Data\Shapes\roads.shp, courtesy of University of New Brunswick Faculty of Forestry and Environmental Management

Data\Shapes\s4551.shp, courtesy of University of New Brunswick Faculty of Forestry and Environmental Management

Data\Shapes\s4552.shp, courtesy of University of New Brunswick Faculty of Forestry and Environmental Management

Data\Shapes\streams.shp, courtesy of University of New Brunswick Faculty of Forestry and Environmental Management

Data\Shapes\towers.shp, courtesy of University of New Brunswick Faculty of Forestry and Environmental Management

Data\Shapes\volumes.dbf, courtesy of University of New Brunswick Faculty of Forestry and Environmental Management

Data\Updates\l20_112u.tif, courtesy of University of New Brunswick Faculty of Forestry and Environmental Management

Data\Updates\l20_114u.tif, courtesy of University of New Brunswick Faculty of Forestry and Environmental Management

Data\Updates\l23_16u.tif, courtesy of University of New Brunswick Faculty of Forestry and Environmental Management

Data\Updates\l23_18u.tif, courtesy of University of New Brunswick Faculty of Forestry and Environmental Management

Data\Updates\l24_129u.tif, courtesy of University of New Brunswick Faculty of Forestry and Environmental Management

Data\WatershedDelineation\Watershed Delineation Tools.tbx – ESRI

Lesson 2: Analysis data

Data\Budworm\DiagStep1a.gif, courtesy of Glen Jordan
Data\Budworm\DiagStep2a.gif, courtesy of Glen Jordan
Data\Budworm\DiagStep3a.gif, courtesy of Glen Jordan
Data\Budworm\DiagStep4a.gif, courtesy of Glen Jordan
Data\Budworm\DiagStep4b.gif, courtesy of Glen Jordan
Data\Budworm\DiagStep6a.gif, courtesy of Glen Jordan
Data\Budworm\DiagStep7a.gif, courtesy of Glen Jordan
Data\Budworm\ResStep3a.gif, courtesy of Glen Jordan
Data\Budworm\ResStep6a.gif, courtesy of Glen Jordan
Data\Budworm\ResStep6b.gif, courtesy of Glen Jordan
Data\Budworm\ResStep7a.gif, courtesy of Glen Jordan

Data\Erosion\DiagStep1a1.gif, courtesy of Glen Jordan
Data\Erosion\DiagStep1a2.gif, courtesy of Glen Jordan
Data\Erosion\DiagStep2a.gif, courtesy of Glen Jordan
Data\Erosion\DiagStep3a.gif, courtesy of Glen Jordan
Data\Erosion\DiagStep3b.gif, courtesy of Glen Jordan
Data\Erosion\DiagStep3c.gif, courtesy of Glen Jordan
Data\Erosion\DiagStep4a.gif, courtesy of Glen Jordan
Data\Erosion\ResStep1d.gif, courtesy of Glen Jordan
Data\Erosion\ResStep2a.gif, courtesy of Glen Jordan
Data\Erosion\ResStep3a.gif, courtesy of Glen Jordan
Data\Erosion\ResStep3b.gif, courtesy of Glen Jordan
Data\Erosion\ResStep4a.gif, courtesy of Glen Jordan
Data\Erosion\ResStep4b.gif, courtesy of Glen Jordan
Data\Erosion\ResStep4c.gif, courtesy of Glen Jordan

Data\Skid\DiagStep2a1.gif, courtesy of Glen Jordan
Data\Skid\DiagStep2a2.gif, courtesy of Glen Jordan
Data\Skid\DiagStep2b.gif, courtesy of Glen Jordan
Data\Skid\DiagStep3a.gif, courtesy of Glen Jordan
Data\Skid\DiagStep3b.gif, courtesy of Glen Jordan
Data\Skid\DiagStep4a.gif, courtesy of Glen Jordan
Data\Skid\DiagStep4b.gif, courtesy of Glen Jordan
Data\Skid\DiagStep4c.gif, courtesy of Glen Jordan
Data\Skid\DiagStep5a.gif, courtesy of Glen Jordan
Data\Skid\ResStep1b1.gif, courtesy of Glen Jordan
Data\Skid\ResStep1b2.gif, courtesy of Glen Jordan

Data\Skid\ResStep3a.gif, courtesy of Glen Jordan

Data\Skid\ResStep4b.gif, courtesy of Glen Jordan

Data\Skid\ResStep4c.gif, courtesy of Glen Jordan

Data\Tipping\DiagStep2a.gif, courtesy of Glen Jordan

Data\Tipping\DiagStep2b.gif, courtesy of Glen Jordan