

# Forest Analysis Techniques

## *Comparing fixed- and variable-width riparian buffers*

—by Glen Jordan

## Introduction

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### Problem

Does better protecting streams mean harvesting less timber?

Forest managers often delineate buffers around water features, such as streams, to protect aquatic organisms and preserve travel corridors for land-based animals. The riparian buffers commonly established in managed forests are of fixed widths between 30 and 50 meters (m). Some argue, however, that better protection could be achieved with variable-width buffers. With this approach, smaller buffers could adequately protect flat areas, while buffers of greater width could protect the steeply sloped areas that require them.

The question is, Will buffering streams as a function of slope exclude more timber from harvest compared to the status quo? How would you make the comparison to find the trade-off between maximizing timber harvest in the Woodlot and establishing better protection of streams?

### 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: riparian buffer; reclassifying forest features spatially; characterizing by a single number; selecting features by attribute; overlaying features (poly-on-poly, poly-on-line); buffering features (fixed and variable width)*

## Prerequisites

A basic working knowledge of ArcGIS® and geographic information system (GIS) data, including use of a geodatabase; familiarity with forest inventory data also 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
- Projection: New Brunswick Double Stereographic Grid (unless otherwise stated)

# Student activity

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Does better stream protection mean more timber value excluded from harvest? You will conduct an analysis that compares the relative "costs" of two buffering strategies in terms of timber values.

Riparian buffers define a zone around water where harvesting activities are limited to partial cuts or even excluded. Such buffers are intended to protect aquatic life, by moderating water temperatures and preventing soil erosion and sediment runoff, and to provide travel corridors for land-based animals as well.

Buffers of a fixed width between 30 and 50 m are most common, even though terrain relief varies. Buffers of variable width are thought to better accommodate such terrain variety in the landscape. With the variable-width buffering strategy, streams running through relatively flat areas could be adequately protected from soil erosion and sediment runoff with smaller buffers. Conversely, streams passing through steeply sloped areas would require buffers of greater width.

The concern is that variable-width buffers could exclude too much timber from harvest, but would this be the outcome in the Woodlot?

You can find the answer by buffering Woodlot streams to a fixed 50 m, and then to variable widths based on surrounding slope values. By overlaying the different buffers on Woodlot stands, you can tally the timber volumes included in them—in other words, the volume of trees that would be excluded from harvest. Then you can compare the two buffering strategies, fixed versus variable width, to see whether the latter would allow timber harvesting.

## Results expected

A tally of timber volume amounts within both fixed- and variable-width buffers

## Data available

- Cover types feature class: *cover*
- Permanent streams feature class: *streams*
- Elevation surface raster: *DEM\_Woodlot*
- Slope raster: *slope\_percent*

## Solution steps

1. Examine Woodlot terrain.
2. Assign slope values to individual features.
3. Buffer stream segments using variable and fixed widths.
4. Compare the costs of the two buffering strategies.

### EXAMINE WOODLOT TERRAIN

Are slope-sensitive buffers more costly than fixed-width buffers of 50 m? That depends very much on terrain. Are steep slopes common? If they are, a variable-width buffering strategy is likely to exclude more timber from harvest than a fixed buffer width of 50 m.

What's the situation in the Woodlot?

### RELATED CONCEPT: RECLASSIFY USING LOCATION ATTRIBUTES TO QUANTIFY

- 1 Start ArcScene™.
- 2 Add the *DEM\_Woodlot* raster as a layer.
- 3 Assign the scene a vertical exaggeration of 10 (right-click *Scene Layers* » *Scene Properties* » *General*). Use *DEM\_Woodlot* to provide base heights (right-click *DEM\_Woodlot* » *Properties* » *Base Heights*).
- 4 Symbolize *DEM\_Woodlot* with the *Elevation #1* stretched color scheme.

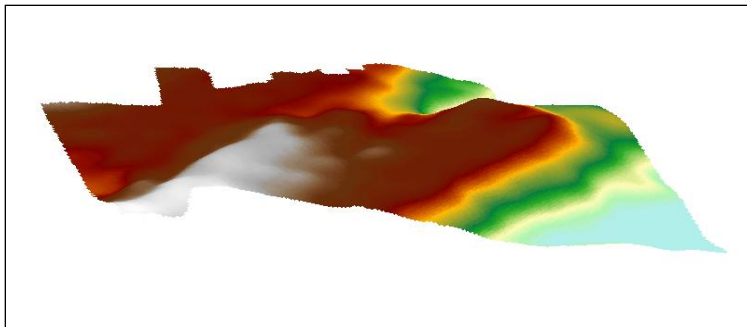


Figure 1. A 3D view of Woodlot terrain.

It looks as if some areas of steep slope exist here, and you would expect to see streams flowing over them. But how much steeply sloped area is there exactly?

- 5 Close ArcScene and start ArcMap™. Use *Environment Settings* (*Geoprocessing* » *Environments* » *Workspace*) to establish both your Current Workspace and Scratch Workspace as your *Woodlot* geodatabase.
- 6 Add the *slope\_percent* raster as a layer.

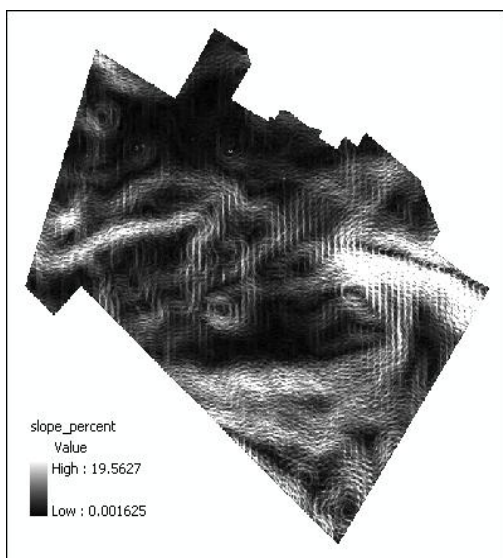


Figure 2. A 2D display of slope values (percent) across the Woodlot.

Slopes range from 0 to a maximum of just over 19 percent, with steeper slopes displayed in lighter shades. How can you calculate the areas that different slope values occupy? Start by classifying the data from its continuous scale into a few discrete classes, for example, 2 percent classes.

- 7 Using the *Reclassify* tool (*Spatial Analyst Tools* » *Reclass*), classify the *slope\_percent* raster into a new raster of 2 percent slope classes.

8 Name the raster *SlopeClasses*.

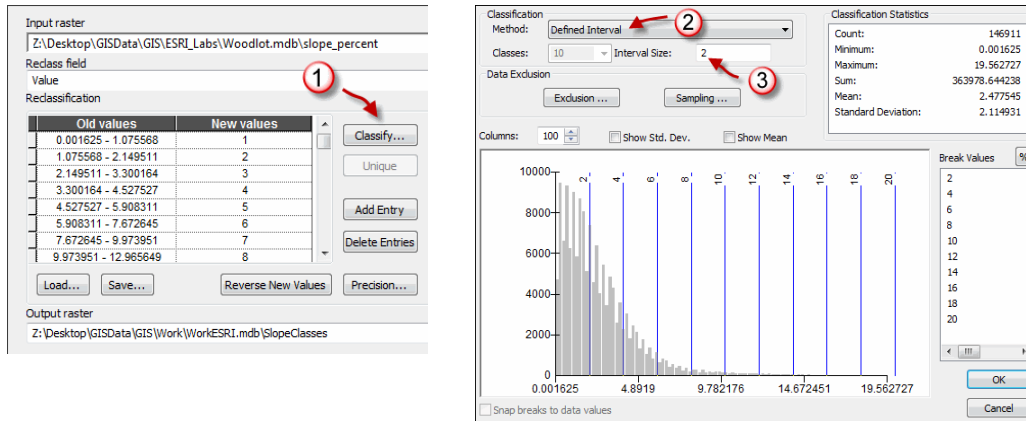


Figure 3. Reclassify the slope raster into a new raster of 2 percent slope classes.

As you can see in the *Reclass* tool histogram, most slopes in the Woodlot are less than 6 percent.

9 To determine the actual amounts in hectares, open the *SlopeClasses* attribute table.

	OID	VALUE	COUNT
▶	0	1	73176
	1	2	46467
	2	3	18330
	3	4	5224
	4	5	1898
	5	6	982
	6	7	523
	7	8	209
	8	9	90
	9	10	12

Figure 4. Value attribute table for the reclassified slope raster.

The *COUNT* values for the first three classes, 2 through 6 percent slope values, totals 137,973, or almost 1,380 ha.

Raster cell size in the Woodlot inventory is 10 x 10 m, or 100 m<sup>2</sup>. That means 100 cells—in other words, 10,000 m<sup>2</sup>—equal 1 ha.

It doesn't seem likely that slope-dependent stream buffering will exclude more timber volume from harvest than fixed-width buffering of 50 m. In fact, it may end up excluding less. To find out, in the next set of steps, you'll assign a slope value to forest stands and other features adjacent to streams, which allows you to buffer streams as a function of surrounding slope.

## ASSIGN SLOPE VALUES TO INDIVIDUAL FEATURES

Stands and other forest features, especially larger ones, often encompass a range of slope values. With such variety, how do you characterize the slope of these features?

When a feature encloses a mixture of slopes, you can arrive at a single value by summarizing in some way. For example, you could compute an average slope. Other possibilities include minimum, maximum, or most frequently occurring slope. Which ArcGIS tool(s) allows you to do this?

### RELATED CONCEPT: RECLASSIFY USING LOCATION ATTRIBUTES TO QUANTIFY

- 1 Add the *cover* feature class as a layer.
- 2 Use the *Zonal Statistics as Table* tool (*Spatial Analyst Tools » Zonal*) to compute a table of *slope\_percent* statistics for *Cover Types* features (zones).
- 3 Save the table in your *Woodlot* geodatabase with the name *SlopeStats*.

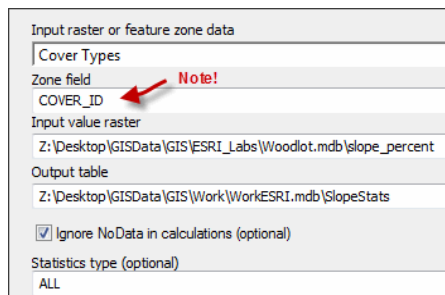


Figure 5. Compute slope statistics for each Woodlot *Cover Types* feature.

**Question 1:** *Why is it critical to use COVER\_ID as the Zone field?*

If you open the *SlopeStats* attribute table, you'll see what *Zonal Statistics as Table* has calculated.

OBJECTID *	COVER_ID	COUNT	AREA	MIN_	MAX_	RANGE	MEAN	STD	SUM_
1	101	225	22500	0.306333	2.424441	2.118108	1.226903	0.406352	276.05316
2	102	51	5100	0.69158	1.56798	0.8764	1.125282	0.217766	57.389351
3	103	184	18400	0.05914	4.479596	4.420456	1.348839	0.747079	248.18642
4	104	285	28500	0.610673	4.509928	3.899255	2.108867	0.649168	601.02722
5	105	366	36600	0.226135	2.048021	1.821887	1.036477	0.402026	379.35059
6	106	212	21200	0.372663	2.774869	2.402206	1.47881	0.450338	313.50763
7	107	1100	11000	0.008005	2.410008	2.402003	0.487929	0.398873	536.72217
8	108	691	69100	0.066277	2.703013	2.636736	1.109468	0.572332	766.64233
9	109	83	8300	0.36998	2.159032	1.789052	1.224842	0.400831	101.6619
10	110	1358	13580	0.013643	1.904828	1.891185	0.46756	0.306364	634.94659
11	111	117	11700	0.036327	0.753728	0.717401	0.343316	0.176046	40.167938
12	112	272	27200	0.020133	2.956703	2.936571	0.55111	0.506739	149.90182
13	113	196	19600	0.042682	1.46099	1.418308	0.561961	0.30058	110.14432
14	190	172	17200	0.257522	3.067819	2.810298	1.509592	0.526233	259.64975
15	199	93	9300	0.438786	3.962808	3.524043	1.804319	0.750118	167.80167
16	201	314	31400	0.041323	2.445968	2.404645	0.781576	0.409939	245.41484

Figure 6. Slope (percent) statistics for each Woodlot feature.

The table provides an array of slope statistics for each polygon in the *cover* feature class as identified by the *COVER\_ID* field. For example, stand 101 has an average slope of 1.2 percent.

The *COVER\_ID* field now makes it possible to join the *SlopeStats* table to *cover* via their shared ID values, giving you access to slope statistics for each feature in *cover*. With such access, you can assign stream-buffering widths to *cover* features based on their slope statistics; it's simply a question of which slope statistic to use. In this case, use the mean to characterize *cover* features.

- 4 Join *SlopeStats* to *cover* via their shared *COVER\_ID* and *Stand#* fields, respectively.

If you open the *Cover Types* attribute table, you can see that the join has provided access to the slope statistics for each feature, as expected.

With this information in place, you're one step closer to buffering Woodlot streams according to the average slope of surrounding features: wide buffers where neighboring areas are on steep slopes and narrower buffers for shallow slopes.

## BUFFER STREAM SEGMENTS USING VARIABLE AND FIXED WIDTHS

Buffering streams to a fixed width of 50 m is easy, but before you can buffer streams according to surrounding slope, you have to associate them with surrounding features and their average slopes. How might you accomplish this?

Streams pass through stands and other cover-type features. But what segments pass through what features? Determining this allows you to classify each segment with its surrounding slope and then buffer accordingly.

### RELATED CONCEPT: RECLASSIFY USING LOCATION ATTRIBUTES TO QUANTIFY

- 1 Add the *streams* feature class as a layer.

The stream network in the Woodlot is extensive. Any type of riparian buffering will exclude significant amounts of timber from harvest.

Will variable-width buffering exclude more or less timber than fixed-width buffers of 50 m? To determine that, you'll have to associate streams with features they pass through, and thus their assigned slope value. A polygon-on-line overlay accomplishes that.

- 2 Using the *Intersect* tool (*Analysis Tools* » *Overlay*), overlay *Cover Types* on *Permanent Streams*.
- 3 Name the output feature class *streams\_aveslopes*.

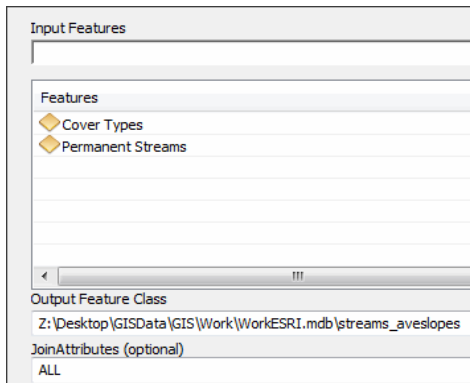


Figure 7. Intersecting Woodlot streams with *Cover Types* features.

This polygon-on-line overlay produces a new feature class that appears no different from the original *Permanent Streams*. Take a closer look, though, and you'll see otherwise.

- 4 Remove *Permanent Streams*.
- 5 In *streams\_aveslopes*, select `Cover_ID = 523` using *Select By Attributes*.
- 6 Zoom in on it and identify one of the topmost selected line segments.

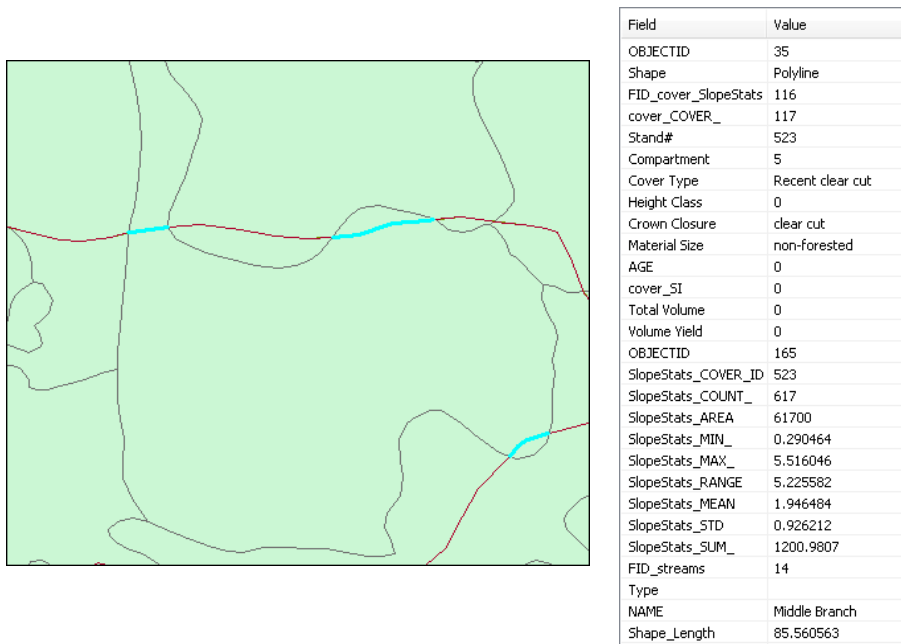


Figure 8. Woodlot stand 523 intersects two stream features as highlighted.

Stand 523 cuts two stream features into three pieces, but as two multipart features, one with a single part (lower) and the other with two (upper).



In this case, multipart features are not an issue; in others, it could be. When in doubt about multipart features, use the *Multipart To Singlepart* tool (*Data Management Tools » Features*) to "explode" multipart features into their constituent pieces.

The *MEAN* value tells you that the topmost multipart feature has inherited, among other things, the average slope (1.95 percent) of stand 523.

Buffering stream segments according to slope should now be straightforward. The only question is, What buffer distances do you use for the various average slope values?

It's a matter of reclassifying features in *streams\_aveslopes* by buffer width according to their average slopes, so that wide buffer widths are assigned stream segments associated with stands on steep average slopes and narrower ones with shallow slopes. The following table outlines one possibility:

Average slope (%)	Buffer width (m)
0–3	25
>3–6	50
> 6	75

Table 1. Suggested buffer width (m) assignments for slope values

- In *streams\_aveslopes*, add a short integer field named *Buffer\_Width*.

It's now a matter of populating *Buffer\_Width* with buffer widths using the *Select By Attributes* and *Field Calculator* process.

- Calculate *Buffer\_Width* values using the *MEAN* field and the following table as your guide:

Condition	Number of features	Buffer_Width
MEAN >= 0 AND MEAN <= 3	120	25
MEAN > 3 AND MEAN <= 6	45	50
MEAN > 6	15	75

Table 2. Executing buffer-width assignments

Now you're all set to buffer stream segments to varying widths.

- Clear selected features.

- 10 Use the *Buffer* tool (*Analysis Tools » Proximity*) to buffer *streams\_aveslopes* features using the *Buffer\_Width* field.
- 11 Use the *ALL Dissolve Type* option to blend overlapping buffers.

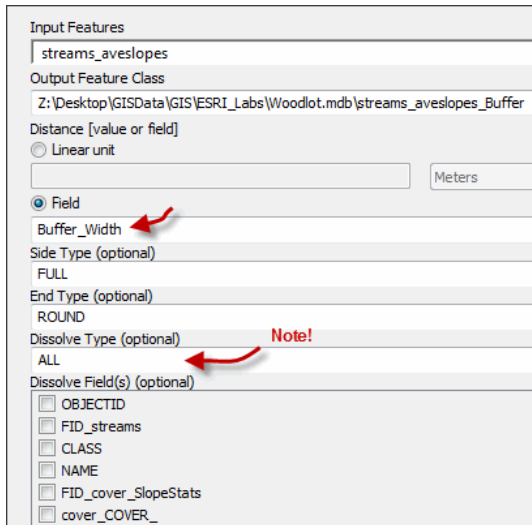


Figure 9. Buffering Woodlot streams to variable widths (*Buffer\_Width* field).

**Question 2:** *What would happen if you didn't set Dissolve Type to All when buffering features?*

- 12 Zoom out to about 1:15,000 and turn off *Cover Types*.

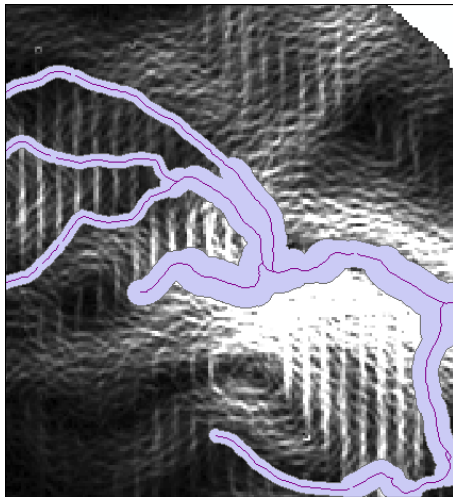


Figure 10. Zoomed in on variable-width buffers in the northeast portion of the Woodlot.

It's pretty obvious that buffer widths are greater in areas of steep slope (white shading), particularly around Corbett Brook in the northeast corner of the Woodlot.

You are close to answering the original question about timber exclusions. How do they compare using erosion-sensitive buffers versus the more common fixed-width buffers?

Buffering Woodlot streams to a fixed distance of 50 m is straightforward.

- 13 Use the *Buffer* tool again to buffer *streams\_aveslopes* features using a fixed width of 50 m.
- 14 Name the new feature class *streams\_aveslopes\_50*.
- 15 Using the *ALL Dissolve Type* option, blend overlapping buffers.

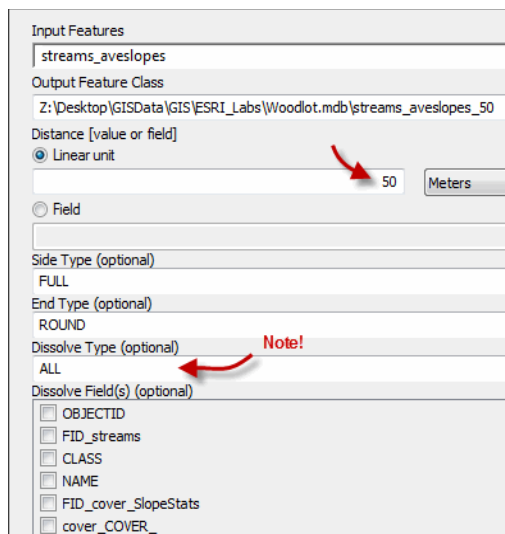


Figure 11. Buffering Woodlot streams to a fixed width of 50 m.

By positioning the fixed-width buffers beneath the variable-width buffers, it will be easy to see where the slope-sensitive buffers are narrower than the 50 m ones.

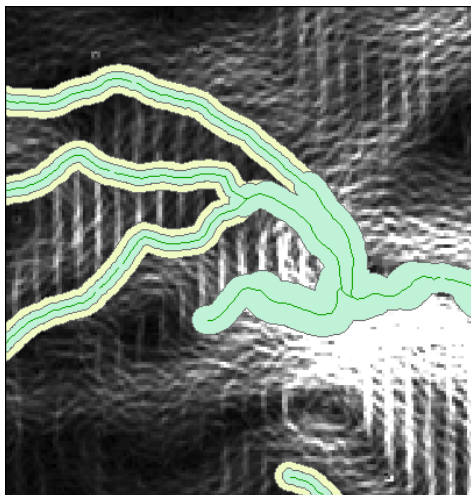


Figure 12. Variable-width buffers superimposed on fixed-width buffers in the Woodlot's northeast portion.

Does using a more erosion-sensitive buffering strategy exclude more timber from harvest than a conventional fixed-width buffering approach?

## COMPARE THE COSTS OF THE TWO BUFFERING STRATEGIES

Comparing differences in timber volumes included in the different buffering strategies requires another overlay. By overlaying each of your buffer layers, in turn, on *Cover Types*, you'll be able to determine the total volume of timber within each buffer.

Start with the fixed-width buffers. Either an intersect or union overlay will work, but since you need to retain only geographic areas within 50 m buffers, an intersect makes the most sense.

### RELATED CONCEPT: CHARACTERIZING BY A SINGLE NUMBER

- 1 Intersect *Cover Types* with *streams\_aveslopes\_50* and name the new feature class *Fixed*.

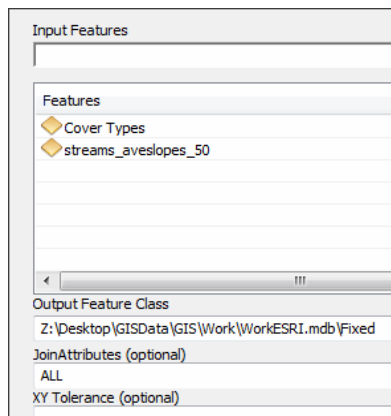


Figure 13. Intersecting 50 m buffers with Woodlot *Cover Types* features.

In identifying some polygons within *Fixed*, you can observe that each has the attributes of *Cover Types*, including *Total Volume* (VH field) and *streams\_aveslopes\_50*.

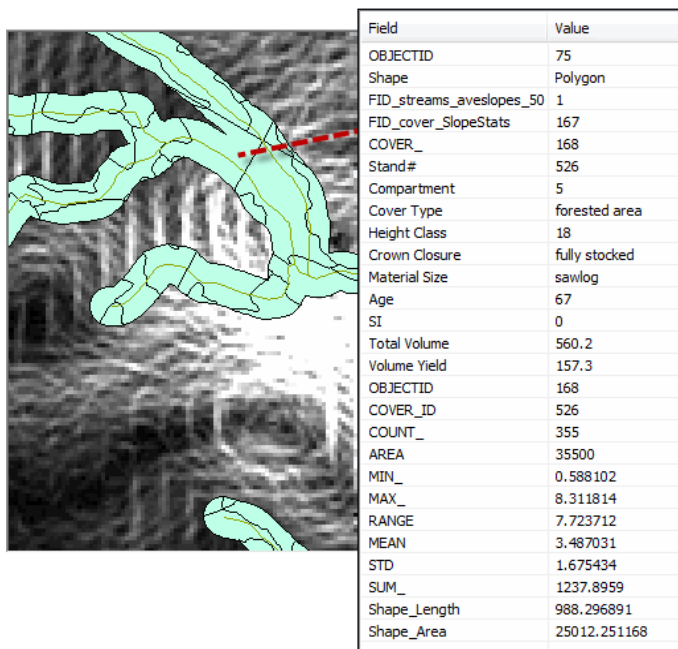


Figure 14. The portion of stand 526 and its attributes that fall inside the 50 m buffer.

The portion of stand 526 that falls within the fixed 50 m buffer is identified in figure 14. It indicates that the stand carries a timber volume of 560.2 m<sup>3</sup>. However, this amount is misleading. Do you know why?

Keep in mind, the *Total Volume* amounts refer to the timber value of entire stands. In the case of stand 526, only a portion falls within the 50 m buffer. How do you determine a correct volume amount for the buffer portion? Simple: you recalculate

$$\text{Total Volume (m}^3\text{)} = \text{Volume Yield (m}^3\text{/ha)} * \text{Area (ha)}.$$

**2** Use *Field Calculator* to calculate the following:

$$\text{Total Volume (TV)} = \text{Volume Yield (VH)} * \text{Shape\_Area} / 10000.$$

The *Total Volume* values should now be correct. You'll see that the amount for the portion of stand 526 that falls within the 50 m buffer has been reduced to 393.44 m<sup>3</sup>.

In the next three steps, you'll calculate the total amount of timber within the 50 m buffer.

**3** Open the *Fixed* attribute table.

**4** Right-click *Total Volume*.

**5** Select *Statistics*.

```

Count: 228
Minimum: 0
Maximum: 962.124393
Sum: 12979.730642
Mean: 56.928643
Standard Deviation: 108.550662

```

Figure 15. Total volume (m<sup>3</sup>) falling within the 50 m buffer around Woodlot streams.

This tells you that the cost of establishing 50 m buffers around streams in the Woodlot would be almost 13,000 m<sup>3</sup> in timber volume unavailable for harvest.

How about the cost of your variable-width buffers? Is the relative cost of these buffers higher or lower? You can answer that by using the same procedure you used to analyze the costs of the 50 m buffers.

6 Intersect *Cover Types* with *streams\_aveslopes\_50*.

7 Name the new feature class *Variable*.

The variable-width buffer, of course, carves stands into different portions in many places. How much timber volume is affected? Keep in mind that, as before, the *Total Volume* amounts are not correct.

8 Calculate new *Total Volume* values as  $\text{Total Volume} = \text{Volume Yield} * \text{Shape\_Area} / 10000$ .

This corrects *Total Volume* amounts to reflect the parts of stands inside the buffers.

9 Calculate the total volume of timber within the variable-width buffer.

```

Count: 209
Minimum: 0
Maximum: 559.812387
Sum: 9727.038473
Mean: 46.540854
Standard Deviation: 86.573305

```

Figure 16. Total volume (m<sup>3</sup>) falling within the variable-width buffers around Woodlot streams.

The cost of establishing variable-width buffers around streams in the Woodlot would be just over 9,700 m<sup>3</sup>. That's 3,300 m<sup>3</sup> less than the 13,000 m<sup>3</sup> cost of 50 m buffers.

## Conclusion

It looks like a win-win situation for variable-width buffers: better erosion protection and less timber value excluded from harvest. Keep in mind, though, that this conclusion is specific to the Woodlot where the terrain is relatively flat. In forests occupying rugged terrain, the opposite conclusion could well be the case.

You might want to explore changing parameters, such as buffer-width settings or the slope statistic you use to characterize features. Are results sensitive to changes in these inputs?

Can you think of a way to characterize forest features with their most frequently occurring slope as opposed to the mean? The *Zonal Statistics as Table* tool doesn't compute this. *Hint*: Investigate the *Tabulate Area* tool.

## Submit your work

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- A tally and comparison of timber volume excluded from harvest using variable-width versus fixed-width buffers
- A summary of the exercise, indicating where and how related reclassification and characterization concepts and analysis techniques are used (Your summary could take the form of a table that checks off each of these elements.)
- A discussion and explanation of multipart features (Why do they exist? Why might they be a problem?)
- Answers to the questions posed in the exercise:
  1. Why is it critical to use *COVER\_ID* as the *Zone* field in the *Zonal Statistics as Table* tool?
  2. What would happen if you didn't set *Dissolve Type* to *All* when buffering features?
- Results using the suggested alternative solution:
  - Characterize cover type features using their most frequently occurring slope (by area) rather than mean slope
- Lab procedure for a forest situated on terrain more rugged than that of the Woodlot.

# Credits

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## 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  
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## **Lesson 2: Analysis data**

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